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Impact of Nursing Management Measures by Pediatric Head Nurses on Nursing Quality

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Abstract: *Objective:* To investigate the impact of nursing management measures implemented by pediatric head nurses on nursing quality in pediatric wards. *Methods:* A total of 150 hospitalized children with common respiratory, digestive, and neurological diseases in pediatrics were selected as study subjects. According to the threshold of nursing quality scores in their respective wards, they were divided into two groups. Univariate analysis was first used to compare differences in observation variables between the two groups, and multivariate logistic regression analysis was then used to screen independent influencing factors of nursing quality. *Results:* The average nursing quality score of the wards where the 150 children were hospitalized was 86.24 points. Those with scores ≥ 85 were assigned to the high nursing quality group, and those with scores < 85 to the low nursing quality group, with 92 cases in the high-score group and 58 cases in the low-score group. Statistically significant differences were found between the two groups in head nurse management duration, hierarchical training coverage rate, perfection of the risk early warning mechanism, frequency of nurse-patient communication, emergency response time, nurses' seniority, and ward bed-to-nursing ratio ($p < 0.05$). No statistically significant differences were found in age, sex, or disease type ($p > 0.05$). Multivariate logistic regression analysis showed that hierarchical training coverage rate, perfection of the risk early warning mechanism, frequency requirement of nurse-patient communication, emergency response time regulation, and ward bed-to-nursing ratio configuration were independent influencing factors of nursing quality, with statistically significant differences ($p < 0.05$). *Conclusion:* Multiple measures related to pediatric head nurse nursing management are major influencing factors of nursing quality. Clinically, head nurse management protocols can be adjusted according to the above factors, and nursing resource allocation can be optimized, thereby improving the overall nursing service level in pediatric wards and providing better nursing services for hospitalized children.

Keywords: Pediatric nursing quality; Head nurse nursing management; Influencing factors; Pediatric ward nursing

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1. Introduction

As a special clinical unit serving minors, pediatrics directly links nursing service quality with disease outcomes, medical safety, and family medical experience, and it is a core indicator for measuring the

comprehensive capacity of pediatric medical services. Currently, the incidence of nursing adverse events in pediatric wards in China is 3.2–5.7%. Third-party medical service satisfaction surveys show that the average nursing satisfaction of family members of hospitalized children in pediatrics is only 78.3%, far lower than the average level of 91.2% in adult internal medicine wards. The shortcomings in pediatric nursing quality have become a core bottleneck restricting the high-quality development of the pediatric medical service system, making quality optimization urgent.

Existing studies on improving pediatric nursing quality mostly focus on interventions at the individual nurse level, such as strengthening nursing operational standards and optimizing service attitudes, and rarely explore the core driving factors for quality improvement from the top-level design dimension of nursing management. Most studies only use univariate descriptive statistical analysis to analyze associated variables, without adjusting for confounding factors such as demographics and disease characteristics, resulting in high heterogeneity in reported influencing factors and an inability to provide a homogeneous reference for pediatric nursing management in medical institutions at different levels.

Based on Robbins' nursing management theory, the quality management efficacy of a nursing unit is directly related to the control strategies and resource allocation plans of nursing managers. As the first responsible person for nursing management in pediatric wards, the regulatory effect of head nurses' management measures on nursing quality has been preliminarily recognized by the academic community. However, existing studies have not yet systematically clarified the independent effects of various variables under the head nurse management dimension on pediatric nursing quality, nor have they completed the weighting of related influencing factors, failing to provide evidence-based support for optimizing head nurse management protocols [1].

Through a systematic analysis of factors related to nursing quality in pediatric wards, this study screens independent influencing factors, which can provide empirical evidence for the refined adjustment of the pediatric nursing management system. It has important clinical guiding value for reducing the incidence of pediatric nursing adverse events, enhancing the medical safety of children, and optimizing the medical experience of family members.

2. Materials and methods

2.1. General information

This was a retrospective study involving 150 hospitalized children admitted to the pediatric department as study subjects. The cases covered common diseases of the respiratory, digestive, and nervous systems. This study conformed to the relevant principles of the Declaration of Helsinki.

2.1.1. Inclusion criteria

(1) Meeting the diagnostic criteria for common pediatric diseases of the respiratory, digestive, and nervous systems, with a definite diagnosis.
(2) Complete clinical diagnosis and treatment data.
(3) Completion of the entire hospitalization and treatment process.
(4) Complete records related to the nursing process, with conditions sufficient for determining nursing quality outcomes.

2.1.2. Exclusion criteria

(1) Complicated with severe congenital underlying diseases.
(2) Complicated with malignant tumors or immune system diseases.
(3) Complicated with abnormal mental development or mental disorders.
(4) Missing hospitalization nursing records, making outcome determination impossible.
(5) Transfer to another hospital or loss to follow-up during hospitalization.

2.2. Methods

2.2.1. Data collection

Two categories of research data were collected through the hospital information system, pediatric ward nursing management archives, inpatient nursing documents, and monthly nursing quality audit records. The first category was baseline data of the children, including age, sex, disease type, and length of hospitalization. The second category was data related to ward nursing operations and management, including the head nurse's tenure in the ward, registered seniority of nurses on duty, actual number of open beds in the ward, number of nurses on duty, records of hierarchical training, archived documents of the nursing risk early warning mechanism, nurse-patient communication registration records, and emergency response time registration books [2]. All data were independently extracted by two nursing researchers with intermediate professional titles who had received unified training. After double-checking for accuracy, the data were entered into a standardized research database. Cases with data completeness of less than 90% were excluded.

2.2.2. Survey instruments

The Pediatric Ward Nursing Quality Evaluation Scale issued by the China Nursing Quality Control Center in 2022 was adopted. The scale contains four dimensions—implementation of basic nursing, specialized nursing procedures, nursing safety management, and nursing service satisfaction—with a total of 32 items. Each item was scored using a Likert 5-point scale, with a total score ranging from 0 to 100. A higher score indicated better comprehensive nursing quality in the ward. This scale has been promoted and applied in pediatric nursing quality control work in multiple tertiary hospitals in China. In this study, the Cronbach's α coefficient was 0.921, and the content validity index was 0.946, demonstrating good reliability and validity.

A self-designed questionnaire on management measures of pediatric head nurses was also used. The researchers systematically reviewed the Robbins nursing management theoretical framework and high-level research findings related to pediatric nursing management both domestically and internationally, and completed the questionnaire design in combination with the actual operations of the pediatric ward in the medical institution where the study was conducted. The questionnaire included four survey dimensions: coverage rate of hierarchical training, completeness of the risk early warning mechanism, requirements for nurse-patient communication frequency, and regulations on emergency response time, with a total of 16 items. A percentage scoring system was adopted. The pre-survey results showed that the Cronbach's α coefficient of the questionnaire was 0.876, and the content validity index was 0.913, meeting the reliability and validity requirements for research instruments.

2.2.3. Quality control

Before data extraction, all researchers received unified training to clarify the definitions and extraction standards of each variable. After data entry was completed, 15% of the samples were randomly selected for

re-verification to ensure a data entry accuracy rate of 100%. The administration of all survey instruments strictly followed standardized procedures to avoid result bias caused by human factors [3].

2.3. Statistical methods

SPSS 26.0 software was used for data analysis in this study. Continuous data were expressed as mean ± standard deviation, and between-group comparisons were performed using independent-samples *t*-tests. Categorical data were expressed as case numbers and percentages, and between-group comparisons were performed using the χ^2 test. Univariate analysis was used to compare differences among groups with different characteristics or scale thresholds, with $p < 0.05$ considered statistically significant. Variables that showed statistically significant differences in the univariate analysis were included in multivariate logistic regression analysis to screen for independent influencing factors of the study outcomes [4].

3. Results

3.1. Occurrence of outcome events and group description

The nursing quality scores of the wards where the 150 hospitalized children in this study were located ranged from 72 to 96 points, with a mean score of (86.24 ± 5.17) points. Based on the nursing quality score threshold, the patients were divided into two groups. Those with scores ≥ 85 points were assigned to the high nursing quality group, totaling 92 cases, accounting for 61.33% of the total sample. Those with scores < 85 points were assigned to the low nursing quality group, totaling 58 cases, accounting for 38.67% of the total sample.

3.2. Univariate analysis results

The univariate analysis results showed that head nurse management duration, coverage rate of hierarchical training, completeness of the risk early warning mechanism, frequency of nurse-patient communication, emergency response time, nurse seniority, and ward bed-to-nurse ratio were associated with pediatric ward nursing quality, whereas age, sex, and disease type of the children were not associated with pediatric ward nursing quality. See **Table 1**.

Table 1. Univariate analysis results of the two study groups [n (%)]

Item	Category	High nursing quality group (n = 92)	Low nursing quality group (n = 58)	χ^2 value	*p* value
Gender	Male	51 (55.43)	32 (55.17)	0.001	0.974
	Female	41 (44.57)	26 (44.83)		
Age	< 3 years	47 (51.09)	31 (53.45)	0.079	0.779
	≥ 3 years	45 (48.91)	27 (46.55)		
Disease type	Respiratory system	42 (45.65)	26 (44.83)	0.050	0.975
	Digestive system	33 (35.87)	21 (36.21)		
	Nervous system	17 (18.48)	11 (18.97)		
Head nurse management duration	≥ 5 years	62 (67.39)	25 (43.10)	8.712	0.003
	< 5 years	30 (32.61)	33 (56.90)		
Hierarchical training coverage rate	≥ 80%	71 (77.17)	24 (41.38)	19.488	< 0.001
	< 80%	21 (22.83)	34 (58.62)		

Item	Category	High nursing quality group (n = 92)	Low nursing quality group (n = 58)	χ^2 value	*p* value
Completeness of risk early warning mechanism	≥ 90 points	68 (73.91)	20 (34.48)	22.441	< 0.001
	< 90 points	24 (26.09)	38 (65.52)		
Frequency of nurse-patient communication	≥ 2 times/day	76 (82.61)	27 (46.55)	20.766	< 0.001
	< 2 times/day	16 (17.39)	31 (53.45)		
Emergency response time	≤ 5 min	65 (70.65)	23 (39.66)	13.850	< 0.001
	> 5 min	27 (29.35)	35 (60.34)		
Average seniority of nurses	≥ 3 years	59 (64.13)	24 (41.38)	7.495	0.006
	< 3 years	33 (35.87)	34 (58.62)		
Ward bed-to-nurse ratio	≥ 0.4	63 (68.48)	22 (37.93)	13.379	< 0.001
	< 0.4	29 (31.52)	36 (62.07)		

3.3. Explanation of variable assignment

The pediatric ward nursing quality grouping was taken as the dependent variable, and variables with statistically significant differences in the univariate analysis were taken as independent variables for assignment. The specific assignment scheme is shown in **Table 2**.

Table 2. Variable assignment

Variable	Assignment
Nursing quality group	Low nursing quality group = 0; High nursing quality group = 1
Head nurse management duration	< 5 years = 0; ≥ 5 years = 1
Hierarchical training coverage rate	< 80% = 0; ≥ 80% = 1
Completeness of risk early warning mechanism	< 90 points = 0; ≥ 90 points = 1
Frequency of nurse-patient communication	< 2 times/day = 0; ≥ 2 times/day = 1
Emergency response time	> 5 min = 0; ≤ 5 min = 1
Average nursing seniority	< 3 years = 0; ≥ 3 years = 1
Ward bed-to-nurse ratio	< 0.4 = 0; ≥ 0.4 = 1

3.4. Results of multivariate analysis

Variables with statistically significant differences in the univariate analysis were included in a multivariable logistic regression analysis. The results showed that hierarchical training coverage rate, degree of refinement of the risk early-warning mechanism, frequency requirements for nurse–patient communication, stipulated emergency response time, and ward bed-to-nurse ratio allocation were independent influencing factors for nursing quality in pediatric wards. See **Table 3**.

Table 3. Results of multivariable Logistic regression analysis of factors influencing nursing quality in pediatric wards

Influencing factor	Regression coefficient	Standard error	Wald χ^2 value	*p*	OR value	95% CI
Hierarchical training coverage rate ≥ 80%	1.178	0.416	8.013	0.005	3.248	1.439–7.331
Completeness of risk early warning mechanism ≥ 90 points	1.325	0.452	8.594	0.003	3.762	1.552–9.118

Influencing factor	Regression coefficient	Standard error	Wald χ^2 value	*p*	OR value	95% CI
Frequency of nurse-patient communication ≥ 2 times/day	0.987	0.394	6.273	0.012	2.683	1.241–5.802
Emergency response time ≤ 5 min	0.864	0.372	5.392	0.020	2.373	1.144–4.922
Ward bed-to-nurse ratio ≥ 0.4	1.241	0.437	8.068	0.004	3.459	1.469–8.143

4. Discussion

Pediatrics is a special clinical unit serving minors. The quality of nursing services directly affects disease outcomes, medical safety, and family members' healthcare experience of hospitalized children, and it serves as a core indicator for measuring the comprehensive capacity of pediatric medical services. With the continuous rise in public demand for children's health services, the homogenization and refinement of pediatric nursing quality have become core tasks in the high-quality development of the pediatric medical system [5]. As the primary person responsible for nursing management in pediatric wards, the head nurse's management strategies directly determine the efficiency of nursing resource allocation and the service effectiveness of the nursing team. Clarifying the core influencing factors under the head nurse's management dimension is of great practical significance for precisely optimizing pediatric nursing management rules. By analyzing the nursing quality and related management factors in wards where hospitalized children were treated, and after adjusting for confounding factors, this study identified five independent influencing factors related to pediatric nursing quality, providing empirical evidence for the refined adjustment of pediatric nursing management [6].

The coverage rate of tiered training is one of the primary management factors affecting pediatric nursing quality. Pediatric nursing is characterized by strong specialty orientation, refined operational requirements, and numerous risk points. Nurses with different years of experience and at different levels differ considerably in specialty nursing competence and emergency response capability. Insufficient coverage of tiered training can easily lead to stratification of the nursing team's service capacity. Problems such as non-standardized operations and inadequate risk identification among junior nurses directly reduce the overall nursing quality of the ward. A well-established tiered training system can match training content to nurses' competency levels: junior nurses focus on basic nursing operations, specialty nursing routines, and nurse-patient communication skills, while senior nurses focus on complex case nursing, emergency response, and nursing quality control. When training coverage reaches a high level, the competence of the entire nursing team can be homogenized, effectively compensating for quality shortcomings caused by individual differences. In clinical management, head nurses can incorporate the coverage rate of tiered training into core management assessment indicators, formulate individualized training plans based on the competency structure of the ward nursing team, and establish a closed-loop management mechanism of training-assessment-practice to ensure that training content is actionable and can be translated into actual nursing competence, avoiding formalistic training [7].

The degree of completeness of the risk early warning mechanism is the core management support for ensuring pediatric nursing safety. Pediatric patients are generally young, unable to accurately express their discomfort, and their conditions progress rapidly and insidiously, making risk identification far more difficult than in adult wards. A well-developed nursing risk early warning mechanism can standardize the

identification points, handling procedures, and reporting pathways for common risks in pediatric wards, such as falls from bed, aspiration, medication errors, and sudden changes in condition. This helps nurses quickly identify potential risks in daily nursing work and take early interventions, thereby reducing the occurrence of nursing adverse events at the source [8]. At the same time, a complete risk early warning mechanism enables stratified management of nursing risks, allowing corresponding nursing measures to be taken for children with different risk levels, rationally allocating nursing resources, and improving the precision of risk prevention and control. In clinical practice, head nurses can periodically review and update the risk early warning checklist based on the characteristics of diseases treated in the ward, organize all staff for risk early warning training, establish a non-punitive risk reporting incentive mechanism, encourage nurses to proactively report potential risks, dynamically adjust warning thresholds, and continuously optimize the adaptability of the risk early warning system.

Requirements for the frequency of nurse-patient communication are an important management lever for improving pediatric nursing service satisfaction and reducing nurse-patient conflicts. Family members of hospitalized pediatric patients generally have higher anxiety levels than those of adult patients, and they also demand greater transparency and responsiveness in nursing services. Insufficient nurse-patient communication can easily lead to misunderstandings due to information asymmetry, lower trust in nursing work, and even trigger nurse-patient disputes. Adequate communication frequency allows family members to promptly understand changes in the child's condition, the purpose of nursing measures, and precautions for home care, thereby enhancing their cooperation with nursing work. At the same time, through communication with family members, nurses can promptly detect abnormal manifestations in children that have not been observed, improving the comprehensiveness of condition observation. In clinical management, head nurses can specify communication standards for children with different diseases and at different stages of illness, standardize core communication content such as admission notification, condition updates, and discharge guidance, and strengthen nurses' communication skills training. Nurses should be guided to conduct effective communication, avoiding excessive time consumed by ineffective communication, and balancing communication quality with nursing efficiency.

Regulations on emergency response time are a key management requirement for ensuring the effectiveness of handling acute and critical events in pediatrics. Pediatric wards are prone to sudden emergencies such as febrile seizures, aspiration, drug allergy, and respiratory arrest. The time window for handling such events is extremely narrow; delayed response can lead to serious adverse consequences and even endanger the child's life. Clear emergency response time requirements can drive the nursing team to optimize emergency handling procedures, prepare emergency supplies, and clarify personnel responsibilities in advance, and ensure that nurses can arrive promptly to initiate treatment when emergencies occur, minimizing the severity of adverse events and safeguarding children's lives. At the same time, standardized emergency response can enhance family members' trust in the nursing team and reduce nurse-patient conflicts caused by delayed emergency handling [9]. In clinical management, head nurses can regularly organize emergency response drills for all staff, optimize the placement of emergency supplies, clarify job responsibilities for different emergency events, and periodically assess nurses' emergency response speed and handling capability, ensuring that all emergency response requirements are implemented.

The ward bed-to-nursing staff ratio allocation is the basic prerequisite for ensuring the implementation of various nursing measures. The workload of pediatric nursing is much higher than that of adult wards.

In addition to routine nursing operations, a considerable amount of time must be spent on family health education and emotional soothing of children. If the bed-to-nursing staff ratio is insufficient, nurses will be responsible for too many children per capita. Excessive workload can easily lead to omissions in nursing operations, delayed condition observation, and inadequate communication, directly reducing nursing quality. An adequate bed-to-nursing staff ratio ensures that nurses have sufficient time and energy to provide refined nursing services for the children under their care, ensuring that nursing routines and risk prevention measures are implemented. This reduces quality shortcomings caused by insufficient manpower. In clinical management, head nurses can dynamically assess the number of children in the ward and the severity of their conditions, flexibly allocate nursing manpower, and promptly apply for additional mobile manpower during peak seasons for respiratory and digestive diseases, avoiding long-term overload of nurses and safeguarding the work efficiency and service quality of the nursing team.

The five independent influencing factors identified in this study are all variables that can be regulated at the head nurse management level. They do not rely on high-end medical equipment or substantial financial investment, and they possess strong operability, offering a reference for optimizing pediatric nursing management in medical institutions at different levels. In clinical practice, each pediatric ward can examine its own management shortcomings against the above factors and formulate targeted improvement plans for weak links. It is not necessary to replicate a uniform improvement model; instead, wards can prioritize shortcoming indicators that require small investment and yield quick results based on their actual situation, gradually improving overall nursing quality [10]. Identifying these influencing factors can also provide a reference for optimizing the pediatric nursing quality control system. Incorporating these indicators into the core assessment scope of pediatric nursing quality control can facilitate the shift from outcome-based quality control to process-based quality control, intervening in advance in risk factors that may affect nursing quality and enhancing the forward-looking nature of nursing quality control.

This study has certain limitations. First, it is a single-center retrospective study with a limited sample size. The subjects only included hospitalized children with common diseases of the respiratory, digestive, and nervous systems, and did not include children with critical illnesses or diseases of other systems, which may introduce selection bias and limit the generalizability of the findings. Second, this study only included explicit indicators of head nurse management and did not include implicit management variables such as head nurse management style, nursing team cohesion, and compensation incentive mechanisms, which may have led to the omission of some potential influencing factors. Future multicenter, large-sample prospective studies are warranted to include more implicit management variables, further verify the reliability of the results, and provide more sufficient evidence-based support for optimizing the pediatric nursing management system.

5. Conclusion

This study shows that the coverage rate of tiered training, the degree of completeness of the risk early warning mechanism, requirements for the frequency of nurse-patient communication, regulations on emergency response time, and ward bed-to-nursing staff ratio allocation are all independent influencing factors of nursing quality in pediatric wards. Meeting these indicators may have a protective effect on improving nursing quality. Clinically, pediatric head nurse management rules can be optimized in response to these factors, nursing manpower and resource allocation can be adjusted, and related work standards and

assessment requirements can be improved. The results of this study can provide a reference for optimizing the pediatric nursing quality control system and improving nursing service quality, helping to ensure the medical safety of hospitalized children and improve family members' healthcare experience.

Disclosure statement

The author declares no conflict of interest.

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Clinical Study of FRII Appliance Combined with Maxillary Expansion in Treating Mandibular Retrusion Deformity in Children

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Abstract: *Objective:* To evaluate the clinical efficacy of FRII functional regulator combined with maxillary expansion in the treatment of Angle Class II malocclusion with mandibular retrusion in children, and to provide clinical evidence for early orthodontic intervention. *Methods:* A total of 30 children aged 6–14 years with Angle Class II malocclusion and mandibular retrusion, who attended the Department of Orthodontics at our hospital from September 2023 to June 2025, were enrolled in this study. All patients received a sequential treatment protocol of "maxillary expansion first, followed by FRII functional regulator therapy". Lateral cephalometric radiographs were taken before and after treatment, and three key cephalometric parameters—SNA, SNB, and ANB angles—were measured. Paired sample *t*tests were used for statistical analysis. *Results:* After treatment, the SNA angle decreased from 83.41 ± 3.90° to 82.16 ± 4.02°, with a mean reduction of 1.25° ($t = 3.54$, $p < 0.001$); the SNB angle increased from 76.67 ± 3.62° to 78.28 ± 3.65°, with a mean increase of 1.61° ($t = -5.25$, $p < 0.001$); and the ANB angle decreased from 6.73 ± 1.09° to 3.88 ± 1.25°, with a mean reduction of 2.85° ($t = 12.47$, $p < 0.001$). The differences in all three parameters before and after treatment were statistically significant ($p < 0.001$). In patients with adverse oral habits such as lip biting, lower lip sucking, and mouth breathing, abnormal muscle function was effectively corrected. *Conclusion:* FRII functional regulator combined with maxillary expansion can significantly improve the sagittal jaw relationship in children with mandibular retrusion, promote forward mandibular displacement, and yield reliable therapeutic effects. Furthermore, the stepbystep treatment protocol helps improve patient compliance, making it worthy of clinical promotion and application.

Keywords: FRII functional regulator; Maxillary expansion; Mandibular retrusion; Angle Class II malocclusion; Cephalometric measurement; Early orthodontic treatment in children

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1. Introduction

Angle Class II malocclusion is one of the most common malocclusion types encountered in pediatric orthodontic practice, with a relatively high prevalence among Chinese children. Among these cases,

mandibular retrusion is the primary etiological factor in more than 50% of patients [1]. Mandibular retrusion not only affects the facial aesthetics and oral function of affected children, but may also have a profound impact on their psychological wellbeing, social abilities, and longterm quality of life. With socioeconomic development and increasing public health awareness, an increasing number of parents are paying attention to craniofacial development in their children, and the demand for early orthodontic intervention is growing.

Functional appliance therapy is an important approach in early orthodontic treatment. Its core principle is to harness the growth potential of the jaws during the developmental period in children by modifying the perioral muscular environment and mandibular position to guide the jaws toward normal growth. The FRII functional regulator (Fränkel Function Regulator II), designed by the German orthodontist Fränkel in the 1960s, is one of the classic representatives of functional appliances [2]. This appliance utilizes structures such as lip pads and buccal shields to block abnormal lip and cheek muscular pressures, thereby creating a favorable softtissue environment for maxillary and mandibular development, while simultaneously guiding the mandible forward and promoting mandibular growth, thus improving Class II skeletal relationships [3].

However, clinical practice has revealed that the efficacy of the FRII appliance alone is limited in some cases, particularly in patients with insufficient maxillary arch width. Transverse discrepancies often compromise the full advancement in the sagittal direction. Maxillary expansion, as an effective means of resolving transverse discrepancies, has been widely applied in clinical practice. Studies have shown that maxillary expansion not only increases arch width and corrects posterior crossbite, but may also create more favorable spatial conditions for mandibular advancement by altering the state of the midpalatal suture and surrounding sutures [4]. The combined application of maxillary expansion and FRII functional regulator is expected to achieve a threedimensional synergistic correction involving the transverse, sagittal, and functional dimensions, thereby enhancing overall treatment outcomes.

The present study aimed to systematically evaluate the effects on cephalometric hardtissue parameters and the clinical efficacy of a sequential treatment protocol of “maxillary expansion combined with FRII functional regulator” in 30 children with Angle Class II malocclusion and mandibular retrusion. This study hopes to provide an optimized clinical strategy for early orthodontic treatment and to offer a reference for the management of similar cases in our region.

2 Materials and methods

2.1. Study participants

A total of 30 pediatric patients with Angle Class II malocclusion characterized by mandibular retrusion, who attended the Department of Orthodontics at our hospital and completed the full course of treatment between September 2023 and June 2025, were enrolled as study subjects. Among them, there were 14 males and 16 females, aged 6 to 14 years, with a mean age of (10.2 ± 2.1) years.

2.1.1. Inclusion criteria

(1) Clinically diagnosed as Angle Class II malocclusion, skeletal Class II, predominantly mandibular retrusion;

(2) ANB angle ≥ 5°;

(3) In the mixed dentition stage or early permanent dentition stage;

(4) Accompanied by varying degrees of maxillary arch width deficiency;
(5) Informed consent obtained from patients and their guardians, and cooperation with treatment.

2.1.2. Exclusion criteria

(1) Previous history of orthodontic treatment;
(2) Congenital malformations such as cleft lip and palate;
(3) Systemic diseases or endocrine disorders affecting growth and development;
(4) Temporomandibular joint disorders;
(5) Severe periodontal disease or extremely poor oral hygiene.

2.2. Treatment protocol

All patients received a twophase sequential treatment protocol of "maxillary expansion first, followed by FRII functional appliance therapy":

Phase 1: Maxillary expansion. Based on the degree of maxillary arch width deficiency and the stage of dentition development, an appropriate expansion device (fixed screwtype expander or removable expansion plate) was selected. The expansion rate was set at two activations per day, with a quarter turn each time, until the posterior teeth achieved a normal buccolingual occlusal relationship. After completion of expansion, a retention period of 2–3 months was maintained to allow stabilization of the midpalatal suture and surrounding tissues before proceeding to the next phase. For patients with obvious labial displacement of the upper anterior teeth or occlusal interferences, corresponding adjustments were made concurrently during this phase.

Phase 2: FRII functional appliance therapy. After maxillary expansion, impressions were taken, and the mandibular protrusive occlusal relationship was recorded for fabrication of the FRII functional appliance. The appliance consisted of lip bumpers, buccal shields, a palatal arch, a lower lip bumper, and lingual wires. By guiding the mandible into a protrusive position while using the lip bumpers and buccal shields to block abnormal lip and buccal muscular pressures, the appliance created a normal soft tissue environment for jaw development. Patients were instructed to wear the appliance for no less than 12 hours per day, with mandatory nighttime wear and increased daytime wear as much as possible. Followup visits were scheduled every 4–6 weeks, with appliance adjustments made according to treatment progress. Concurrently, myofunctional training was provided, including lip and tongue muscle exercises, and elimination of harmful habits such as lip biting, lower lip sucking, and mouth breathing.

2.3. Outcome measurements and methods

Lateral cephalometric radiographs were taken before treatment (T0) and after completion of functional appliance therapy (T1) by the same experienced radiologic technician under standardized conditions. All radiographs were traced and measured by the same calibrated orthodontist using the same cephalometric analysis software. Each sample was measured three times, and the average value was used to minimize measurement errors.

The following three key sagittal cephalometric variables were selected as outcome measures:

(1) SNA angle

The angle formed by the sella, nasion, and subspinale points, reflecting the anteroposterior position of

the maxilla relative to the cranial base;

(2) SNB angle

The angle formed by the sella, nasion, and supramentale points, reflecting the anteroposterior position of the mandible relative to the cranial base;

(3) ANB angle

The angle formed by the subspinale, nasion, and supramentale points, reflecting the sagittal relationship between the maxilla and the mandible.

2.4. Statistical analysis

Statistical analysis was performed using SPSS version 26.0 software. Continuous variables were expressed as mean ± standard deviation ($\overline{x} \pm s$). Comparisons of each parameter before and after treatment were conducted using paired-samples ttests. Effect sizes were evaluated using Cohen's d, with $d > 0.8$ indicating a large effect, $0.5 < d \leq 0.8$ indicating a moderate effect, and $0.2 < d \leq 0.5$ indicating a small effect. A p value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of cephalometric measurements before and after treatment

All 30 patients completed the full course of treatment. The comparisons of cephalometric measurements before and after treatment are shown in **Table 1**. After treatment, the SNA angle decreased slightly compared with before treatment, with a mean reduction of 1.25°; the difference was statistically significant ($t = 3.54$, $p < 0.001$), with a Cohen's d of 1.94, indicating a large effect size. The SNB angle increased significantly compared with before treatment, with a mean increase of 1.61°; the difference was statistically significant ($t = -5.25$, $p < 0.001$), with a Cohen's d of 1.68, indicating a large effect size. The ANB angle decreased markedly compared with before treatment, with a mean reduction of 2.85°; the difference was statistically significant ($t = 12.47$, $p < 0.001$), with a Cohen's d of 1.25, indicating a large effect size.

Table 1. Comparison of cephalometric measurements before and after treatment (n = 30, mean ± SD)

Measurement indicator	Before treatment (°)	After treatment (°)	Difference (°)	*t* value	*p* value
SNA	83.41 ± 3.90	82.16 ± 4.02	-1.25	3.54	< 0.001
SNB	76.67 ± 3.62	78.28 ± 3.65	+1.61	-5.25	< 0.001
ANB	6.73 ± 1.09	3.88 ± 1.25	-2.85	12.47	< 0.001

3.2. Clinical efficacy evaluation

Clinical examination showed that all children had varying degrees of improvement in facial profile after treatment. The lateral appearance of mandibular retrusion was significantly reduced, and the coordination of the soft tissue profile was enhanced. The overjet relationship between the upper and lower anterior teeth tended to normalize, improving from a mean deep overjet before treatment to within the normal range. The posterior occlusal relationship was markedly improved, with a shift from Class II to Class I molar relationship.

Among children with accompanying parafunctional habits, those with lipbiting or lowerlip sucking habits showed effective control of these habits after wearing the FRII appliance combined with myofunctional

training. In children with mouthbreathing habits, the openmouth breathing pattern also improved to varying degrees under the synergistic effect of maxillary expansion improving airway space and myofunctional training. The overall effective rate of treatment exceeded 90%.

4. Discussion

4.1. Mechanism of action of the FRII appliance

The FRII functional appliance is a classic functional appliance designed by Fränkel based on the "functional matrix theory". Its core concept is to regulate the perioral soft tissue environment, eliminate the restrictive effects of abnormal muscle pressure on jaw development, and thereby guide the dentofacial structures toward normal growth [2,3]. Compared with other functional appliances (such as Twinblock and Activator), the unique feature of the FRII appliance is that it primarily acts through soft tissue components such as lip pads and buccal shields, rather than relying solely on occlusal inclined planes to guide mandibular protrusion [5].

The results of this study showed that after treatment with the FRII appliance, the SNB angle increased significantly by 1.61° ($p < 0.001$), indicating a marked forward displacement of the mandible, which is consistent with findings from multiple domestic and international studies [6,7]. The longterm followup study by Perillo et al. [1] also confirmed that FRII appliance treatment significantly reduces the ANB angle and improves skeletal Class II relationships, with longterm stability of the therapeutic effect. In the present study, the ANB angle decreased by 2.85°, a relatively substantial reduction, demonstrating that this treatment regimen has a clear effect on improving the sagittal relationship between the maxilla and mandible.

4.2. Advantages of combined maxillary expansion and functional treatment

Conventional singlemodality functional treatment often faces the challenge of transverse discrepancies limiting sagittal advancement when managing Class II malocclusion with concurrent maxillary arch width deficiency. A narrow maxillary arch may not only cause posterior crossbite but also restrict full mandibular protrusion, thereby compromising the final effect of functional treatment. In this study, we innovatively adopted maxillary expansion as a preliminary step before FRII functional treatment, first addressing the transverse width problem and then proceeding with sagittal advancement, thus achieving a threedimensional synergistic approach of "transversesagittalmyofunctional" correction.

The study by Maspero et al. demonstrated that rapid maxillary expansion combined with functional appliance therapy yields better treatment outcomes than expansion alone in patients with skeletal Class II deep overbite [8]. Our results also support this view: through the sequential protocol of expansion followed by functional treatment, the ANB angle reduction reached 2.85°, which is superior to the results reported in some studies using functional treatment alone, suggesting that maxillary expansion may create more favorable spatial conditions for mandibular advancement, thereby enhancing the efficacy of functional therapy [9]. In addition, expansion can improve nasal airway space, which is of positive significance for children with mouthbreathing habits, consistent with our clinical observation of symptom improvement in these patients.

4.3. Analysis of treatment effects

In this study, the SNA angle decreased slightly (1.25°) after treatment, but the change was small, indicating that the treatment had limited impact on the maxilla, and the maxillary position remained essentially stable.

This finding aligns with the expectations of functional treatment—the primary therapeutic goal is to promote mandibular advancement rather than to inhibit maxillary growth. A systematic review by Koretsi et al. showed that removable functional appliances resulted in only a slight decrease in SNA angle (approximately –0.28° per year), which is consistent with the trend observed in our study [10].

The significant increase in SNB angle by 1.61° is one of the core findings of this study, indicating that the mandible moved forward substantially after treatment and that the goal of mandibular advancement was achieved. This change is crucial for the correction of Class II malocclusion, as mandibular retrusion is the primary etiological factor in this type of deformity. The ANB angle decreased by 2.85°, from 6.73° before treatment (indicating a pronounced skeletal Class II relationship) to 3.88° (close to the normal range of 2–4°), demonstrating that the skeletal Class II relationship was substantially corrected. Effect size analysis showed that Cohen's d values for all three parameters were greater than 0.8, indicating large effects, further confirming the significance of the treatment outcomes.

It is worth noting that the magnitude of ANB improvement (2.85°) in our study was greater than that reported in some similar studies [1011]. This may be attributed to the following factors: first, our protocol combined maxillary expansion with functional treatment, and the synergy between transverse and sagittal dimensions enhanced the overall efficacy; second, the patients enrolled in this study were in the pubertal growth spurt period, during which the jaw bones are more responsive to functional stimulation; and third, the stepwise treatment approach improved patient compliance, ensuring adequate appliance wear time.

4.4. Limitations of the study

This study has certain limitations. First, the sample size was relatively small (n = 30). Although the statistical power was sufficient, the generalizability of the results is somewhat limited, and future studies with larger samples are warranted. Second, this study only analyzed sagittal hard tissue parameters and did not include vertical indicators (such as mandibular plane angle, anterior facial height) or quantitative evaluation of soft tissue profiles, making it difficult to fully reflect the impact of treatment on the threedimensional dentofacial structures. Third, this was a prepost selfcontrolled study without an untreated control group, so the influence of natural growth on the measurements cannot be completely excluded. Fourth, the followup period was relatively short, and longterm stability data are lacking; the maintenance of treatment effects over time requires further investigation.

5. Conclusions

The combined application of the FRII functional appliance with maxillary expansion demonstrates definitive efficacy in treating mandibular retrusion type Angle Class II malocclusion in children. It can significantly improve the sagittal relationship between the maxilla and mandible, promote forward mandibular displacement, reduce the ANB angle, and effectively eliminate oral habits. This sequential treatment protocol—maxillary expansion followed by FRII functional appliance—achieves threedimensional coordinated correction of transverse, sagittal, and muscular dimensions. Moreover, the stepwise approach is conducive to improving patient compliance, making it worthy of clinical promotion in early orthodontic treatment for children.

6. Constructive recommendations

Based on the findings of this study and clinical practice experience, the following recommendations are proposed for the early management of mandibular retrusion deformity in children:

First, seize the optimal treatment timing and emphasize early intervention. The peak growth period in children represents the golden window for functional appliance therapy, during which the mandible exhibits substantial growth potential and responds sensitively to functional forces. It is advisable to monitor craniofacial development starting from the mixed dentition stage, and to perform early evaluation and intervention in children with a tendency toward mandibular retrusion, so as to prevent progression to more severe skeletal deformities and reduce the complexity and cost of later treatment.

Second, establish a threedimensional orthodontic concept and optimize the treatment protocol. For Class II malocclusion patients with concomitant maxillary transverse deficiency, it is recommended to perform maxillary expansion as a preparatory step before functional appliance therapy—first resolving the transverse discrepancy, then proceeding with sagittal advancement—to achieve threedimensional coordinated correction and improve overall outcomes. At the same time, attention should be paid to vertical control to avoid unfavorable changes such as clockwise rotation of the mandible during treatment.

Third, address the etiology and eliminate oral habits. Mandibular retrusion is often closely associated with oral habits such as mouth breathing, lip biting, and abnormal swallowing; mechanical correction alone frequently fails to achieve stable results. It is recommended to emphasize myofunctional training during treatment and to actively coordinate with otolaryngology for the management of upper airway conditions such as allergic rhinitis, thereby correcting abnormal perioral muscle function patterns at the etiological level and enhancing the stability of treatment outcomes.

Fourth, strengthen multidisciplinary collaboration to improve the level of diagnosis and treatment. Pediatric orthodontics involves multiple disciplines, including orthodontics, pediatric dentistry, otolaryngology, and pediatrics. It is recommended to establish a multidisciplinary collaborative diagnosis and treatment model, conduct joint consultations for complex cases, and develop individualized and comprehensive treatment plans. At the same time, training for primary care dentists should be enhanced to promote standardized early orthodontic techniques and raise the overall level of pediatric oral disease prevention and treatment in the region.

Fifth, improve the followup system and conduct longterm studies. It is recommended to establish a longterm followup mechanism to regularly track treated patients, evaluate the longterm stability of treatment outcomes, and provide evidencebased support for optimizing therapeutic protocols. In addition, largersample, multicenter clinical studies should be conducted further to validate the efficacy and safety of this treatment approach and to provide higherlevel evidence for clinical promotion.

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Disclosure statement

The authors declare no conflict of interest.

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Research Progress on Early Screening and Rehabilitation Intervention for Adolescent Idiopathic Scoliosis in Secondary Vocational Schools

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Abstract: Adolescent idiopathic scoliosis (AIS) is a three-dimensional spinal deformity that develops during the growth and development period. In addition to lateral curvature of the spine, patients may also present with vertebral rotation and altered sagittal alignment. Because early signs are inconspicuous, some students are not identified until accelerated growth and curve progression occur in adolescence; therefore, school screening and timely intervention are necessary. At present, school-based initial screening predominantly relies on postural observation, the Adams forward bend test, and measurement of the angle of trunk rotation (ATR); after abnormalities are detected, students are referred for professional assessment and, when necessary, imaging examination. Radiation-free techniques such as three-dimensional ultrasound and digital photogrammetry have also begun to be applied to screening and follow-up. Bracing and physiotherapeutic scoliosis-specific exercises (PSSE) are important means of conservative treatment. Secondary vocational school students are predominantly in late adolescence, and classroom learning and professional practical training involve distinctive postural and activity exposures. This article reviews research on AIS screening, related factors, and rehabilitation treatment and discusses the "screening-assessment-intervention-follow-up" management pathway in the context of secondary vocational schools, with the aim of providing a reference for school-based spinal health work.

Keywords: Adolescent idiopathic scoliosis; School screening; Angle of trunk rotation; Rehabilitation treatment; Secondary vocational school students

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1. Introduction

Adolescent idiopathic scoliosis (AIS) is a common structural spinal deformity in children and adolescents aged 10–18 years. Clinical diagnosis usually requires exclusion of scoliosis caused by congenital,

neuromuscular, and other definite etiologies, followed by standing full-spine X-ray examination, with a Cobb angle of ≥ 10° typically used as the diagnostic criterion [1,2]. AIS is a three-dimensional spinal deformity, including coronal plane curvature, vertebral rotation, and abnormal sagittal alignment [3].

AIS has an insidious onset, and early stages are often accompanied by no obvious discomfort; in some patients, the curve progresses rapidly and worsens during the accelerated growth phase of adolescence. Prevalence rates reported by existing studies vary because of differences in region, age composition, and survey methods, with an overall prevalence of approximately 0.5–5%; as the severity of scoliosis increases, the proportion of female patients and the risk of further curve progression generally increase [1,4]. The value of active screening during adolescence lies not only in detecting abnormalities, but also in enabling timely stratified management of curve magnitude, growth potential, and risk of progression.

Existing school screening data come mainly from general primary and secondary schools, and secondary vocational school students have received relatively limited attention. This group is predominantly aged 15–18 years, and both curriculum formats and practical training content vary by specialty, resulting in different exposures such as prolonged sitting, fixed postures, or repetitive operations . Designing screening, related-factor surveys, and follow-up management according to these characteristics is more consistent with the actual circumstances of secondary vocational schools than directly applying the protocols of general secondary schools.

2. Advances in school-based AIS screening

2.1. School-based AIS screening methods

School screening is an important approach for the early detection of AIS and is often conducted using postural observation, the Adams forward bend test, and ATR measurement. Postural observation principally evaluates surface features such as shoulder height, scapular position, waistline, and pelvic level; it is simple to perform and suitable for large-scale screening, but the results are readily influenced by examiner experience.

During the Adams forward bend test, the examiner observes the individual from behind while the trunk is flexed forward to identify asymmetric rib or lumbar prominence associated with axial trunk rotation. In clinical and school screening settings, a scoliometer may be used to quantify the angle of trunk rotation (ATR) and improve the objectivity of assessment [5]. An ATR of approximately 5° is commonly used as a threshold for further evaluation or referral; however, the decision to obtain radiographs should be based on the screening protocol and subsequent clinical assessment [5].

School screening identifies students with suspected abnormalities but does not establish a diagnosis of AIS. Students with abnormal screening findings should undergo further clinical assessment and, when indicated, standing whole-spine radiography [1–2].

2.2. Advances in AIS screening technologies

Traditional X-ray examination is an important method for evaluating spinal structure and measuring the Cobb angle; however, because repeated examinations raise concerns regarding cumulative radiation exposure, radiation-free or low-radiation evaluation techniques are receiving increasing attention.

Three-dimensional ultrasound can evaluate spinal morphology without ionizing radiation. Studies have shown that its angle measurements have good reliability and good consistency with X-ray Cobb angles, indicating potential for application in AIS assessment and follow-up [6,7]. Digital photogrammetry and posture analysis can obtain postural parameters of the shoulders, trunk, and pelvis from images of the body surface,

providing new technical means for radiation-free AIS screening and monitoring [8]. However, the screening accuracy, degree of standardization, equipment costs, and value for school-based application of these techniques have not yet been extensively validated, and further research is still needed.

2.3. Factors associated with AIS

The etiology of AIS has not been fully clarified; current research suggests that it is related to multiple factors including genetics, growth and development, spinal biomechanics, and neuromuscular regulation [1,4]. The rapid growth phase of adolescence is an important stage for curve progression, and familial clustering suggests that genetic factors may be involved in susceptibility to AIS [1].

For lifestyle factors such as physical activity, sedentary behavior, study posture, and electronic device use, there is currently insufficient evidence to demonstrate a clear causal relationship with the occurrence of AIS. Therefore, prolonged looking down, sedentary behavior, or insufficient exercise should not simply be defined as direct causes of AIS. In surveys of secondary vocational school students, physical activity level, sedentary time, study and practical training postures, electronic device use, and spinal health awareness can be analyzed as exploratory related factors, and attention should be paid to distinguishing statistical correlation from causal relationships when interpreting the results.

2.4. Current status of AIS screening research in secondary vocational schools

Epidemiological and intervention studies of AIS in secondary vocational school students remain relatively limited. Learning and practical training patterns in different specialties may have different postural exposure characteristics; for example, computer-related specialties may involve prolonged seated learning, while some operation-oriented specialties may require maintaining fixed or repetitive working postures. Although the above factors cannot directly explain the occurrence of AIS, they can constitute important subjects for research on school-based postural health management and rehabilitation adherence.

Current research on AIS in secondary vocational schools primarily has the following shortcomings: first, there is a lack of epidemiological data from large samples; second, surveys of related factors are not yet systematic, with insufficient attention to specialty-specific learning characteristics, physical activity, and spinal health awareness; third, the system for re-screening, referral, rehabilitation, and long-term follow-up after abnormal screening results is not yet well established. Therefore, continuous spinal health management research tailored to the characteristics of secondary vocational students is needed.

3. Advances in the rehabilitation management of AIS

3.1. Bracing

Bracing is an important component of conservative management for AIS. Its primary objective is to prevent or limit curve progression and reduce the likelihood of progression to a surgical threshold. Some patients with mild-to-moderate curves and remaining growth potential may achieve a degree of deformity correction during appropriately prescribed treatment; however, bracing should not be interpreted as completely eliminating an established structural spinal deformity [2,9].

A randomized controlled study by Weinstein et al. demonstrated that, among patients with AIS at risk of progression, bracing significantly reduced the likelihood of progression to the surgical threshold. A dose-response relationship was also observed between brace-wear duration and treatment success, providing important evidence for bracing [10].

Bracing protocols should be individualized according to the Cobb angle, age, remaining growth potential, skeletal maturity, risk of curve progression, and patient adherence. Because indications vary to some extent across guidelines and expert consensus statements, treatment decisions require specialist assessment of the individual patient [2,9]. Bracing must not be prescribed solely on the basis of screening measures such as ATR.

3.2. Physiotherapeutic scoliosis-specific exercises

Physiotherapeutic scoliosis-specific exercises (PSSE) differ from ordinary physical fitness training in that they emphasize individualized training protocols formulated according to curve type and three-dimensional deformity characteristics, principally including three-dimensional self-correction, breathing training, postural control, and postural adjustments in daily activities. The International Society on Scoliosis Orthopedic and Rehabilitation Treatment (SOSORT) regards PSSE as an important component of conservative treatment for AIS [9].

Common PSSE systems include Schroth, the Scientific Exercise Approach to Scoliosis (SEAS), and Lyon, among which the Schroth method emphasizes three-dimensional self-correction, postural control, and specific breathing training. A randomized controlled study by Schreiber et al. showed that adding 6 months of Schroth training to standard care led to better Cobb angle outcomes than standard care alone [11]. Studies by Kuru et al. also showed that supervised three-dimensional Schroth training can improve clinical indicators such as the Cobb angle and trunk rotation in AIS patients [12].

An overview of systematic reviews and meta-analyses suggests that PSSE or exercise therapy may improve selected outcomes in patients with AIS, including the Cobb angle, ATR, and quality of life. However, substantial heterogeneity and limitations in the quality of evidence remain, and the long-term effects on curve correction require confirmation in further high-quality studies [13,14].

3.3. Adjunctive rehabilitation and outcome assessment

In addition to PSSE, core stabilization, balance, flexibility, and general conditioning exercises may be incorporated as adjuncts to AIS rehabilitation. However, nonspecific exercise should not be equated with PSSE tailored to three-dimensional curve patterns. Existing evidence provides some support for PSSE in improving selected clinical outcomes, whereas evidence that nonspecific exercise alone can control or reverse structural curve progression remains limited [9,14,15].

Evaluation of AIS rehabilitation should encompass radiographic, postural, functional, and quality-of-life outcomes. Radiographic outcomes primarily include the Cobb angle and changes in spinal morphology; school-based follow-up may prioritize ATR, trunk symmetry, postural control, physical function, and exercise adherence. Quality of life may be assessed using instruments such as the Scoliosis Research Society-22 (SRS-22) questionnaire. For students with mild AIS, school follow-up should emphasize noninvasive, repeatable postural and functional measures, whereas repeat radiography should be determined by healthcare professionals according to clinical need to avoid unnecessary radiation exposure.

4. A Screening–assessment–intervention–follow-up model for AIS management in secondary vocational schools

Given the characteristics of secondary vocational students, a continuous management model of “screening-

assessment-intervention-follow-up" can be established.

In the screening stage, uniformly trained personnel collect basic information, conduct postural observation, the Adams forward bend test, and ATR measurement, and use questionnaires to obtain information on physical activity, sedentary time, study and practical training postures, electronic device use, and spinal health awareness.

In the assessment stage, students with abnormal screening results undergo professional re-screening and, when necessary, are referred to medical institutions for imaging examination; stratified assessment is then conducted based on the Cobb angle, growth potential, skeletal maturity, and risk of progression [2,9].

In the intervention stage, individualized management should be implemented according to the results of professional assessment. For students with mild AIS suitable for conservative rehabilitation, training centered on PSSE can be carried out under the guidance of professionals, combined with core stability, breathing training, and postural education. Campus implementation can be made more targeted according to specialty characteristics: for specialties involving prolonged seated learning, emphasis should be placed on seat posture adjustment, active position changes, and guidance for break-time activities; for practical training specialties requiring fixed postures or repetitive operations for long periods, emphasis should be placed on work posture adjustment, trunk control, and regular activity guidance. The above measures are primarily intended to improve postural health management and rehabilitation adherence and should not be described as treatment targeting the etiology of AIS.

In the follow-up stage, spinal health records are established for students to dynamically document ATR, postural and functional changes, training adherence, and quality of life. Students with marked changes in screening indicators or those meeting the indications for further medical evaluation should be referred in a timely manner; through coordination among schools, families, and medical institutions, the efficiency of continuous AIS management can be improved.

5. Conclusions and future directions

School screening facilitates the early detection and risk-stratified management of AIS. Postural observation, the Adams forward bend test, and ATR measurement remain important school-based screening methods. Non-radiographic assessment modalities, including three-dimensional ultrasound and digital photogrammetry, may reduce radiation exposure and facilitate follow-up; however, their large-scale application requires further validation. Bracing and PSSE are important components of conservative AIS management, but intervention protocols should be individualized according to curve magnitude, remaining growth potential, and risk of progression. An ATR of approximately 5° indicates the need for further evaluation rather than confirming AIS or determining treatment; diagnosis requires appropriate clinical assessment and, when indicated, standing whole-spine radiography.

Specialized research on secondary vocational students is still relatively scarce. In the future, large-sample epidemiological surveys of AIS in secondary vocational schools should be conducted. While avoiding the simplistic interpretation of lifestyle factors as direct causes, further analysis should be made of postural exposure, physical activity, and rehabilitation adherence under different specialty learning and practical training environments. At the same time, the feasibility of technologies such as digital postural analysis and three-dimensional ultrasound in campus screening and follow-up can be explored, digital spinal health records can be established, and the mechanism of re-screening, referral, rehabilitation, and follow-up coordinated among schools, families, and medical institutions can be improved, so as to establish a spinal health management pathway tailored to the characteristics of secondary vocational students.

Disclosure statement

The authors declare no conflict of interest.

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One Case of High-Risk Pulmonary Nodule Cured by Integrated Traditional Chinese and Western Medicine

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Abstract: Most high-risk pulmonary nodules are precancerous lesions of lung cancer. Current therapeutic approaches are dominated by invasive operations such as surgical resection, yet such treatments carry risks of various complications and irreversible impairment of pulmonary function. This paper reports a clinical case of a high-risk pulmonary nodule treated with integrated traditional Chinese and Western medicine. After more than one year of therapy, the high-risk pulmonary nodule transformed into an inflammatory lesion, and the patient avoided surgical trauma. This case indicates that traditional Chinese medicine (TCM) has certain advantages in intervening in the progression of pulmonary nodules. Compared with invasive Western medical treatment, TCM therapy causes less trauma to patients. For patients with high-risk pulmonary nodules who refuse invasive surgical intervention, TCM treatment provides an alternative option besides surgery alone. This case can offer references for clinical management of high-risk pulmonary nodules.

Keywords: High-risk pulmonary nodule; Integrated traditional Chinese and Western medicine therapy; Traditional Chinese medicine treatment; Medical case report

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1. Introduction

Pulmonary nodules refer to focal irregular or quasi-circular lesions in the lung with a maximum diameter ≤ 3 cm. Medically, on imaging, they present as focal shadows in the lung with slightly higher density than pulmonary tissues, usually unaccompanied by signs such as hilar lymphadenopathy, pulmonary atelectasis, and pleural effusion [1]. According to risk stratification, pulmonary nodules are divided into low-risk, intermediate-risk, and high-risk types. Most high-risk pulmonary nodules represent early-stage lung cancer or precancerous lesions, and invasive interventions such as surgical resection constitute the major therapeutic

modality in modern Western medicine [2]. Nevertheless, such therapeutic measures may lead to overtreatment [3] and possibly cause irreversible damage to patients' pulmonary function [4]. This article reports a patient with a high-risk pulmonary nodule who received integrated traditional Chinese and Western medicine and achieved satisfactory curative effects. The high-risk pulmonary nodule turned out to be benign without surgical operation, and the case is reported as follows.

2. Clinical data

Patient Yang, male, 45 years old, first visit on July 18, 2024.

Chief Complaint: Cough with purulent yellow sputum for more than one month.

History of Present Illness: More than one month prior to presentation, the patient developed a spontaneous cough and expectoration of purulent yellow sputum with occasional blood streaks in the sputum, accompanied by sore throat, chest pain, chest stuffiness, and shortness of breath. He sought medical care at the First Affiliated Hospital of Sun Yat-sen University on June 24, 2024. Chest and upper-abdominal plain CT scan demonstrated: 1. A mixed-density nodule measuring approximately 28 × 17 mm located in the dorsal segment of the right lower lobe of the lung, with a spiculated margin, venous dilatation, and pleural indentation; posterior to it lay another mixed-density nodule of 10 × 10 mm also with a spiculated margin, highly suggestive of malignancy; 2. Multiple ground-glass nodules in the apical segments of the right upper lobe and left upper lobe with ill-defined boundaries and suspected spiculated signs, raising suspicion of adenocarcinoma. The hospital advised inpatient surgical treatment. Frightened by surgical risks, the patient declined hospitalization and came to our hospital for TCM therapy. Present symptoms: intermittent cough, gurgling sputum in throat, expectoration of purulent yellow sputum, dull chest pain, fair appetite, defecation every 2–3 days with dry-hard stool, normal urination, restless sleep, average mental status and physical strength, and frequent spontaneous sweating upon slight exertion.

Past History: No history of chronic diseases. Thirty-year smoking history, two packs per day, non-quitter; thirty-year alcohol-drinking history, 200 ml per day, non-quitter.

Physical Examination: General condition fair, moderate build, dull complexion, pharyngeal congestion (+), dim-purple tongue with tooth-marked borders, thick-white greasy tongue coating, string-like pulse, weak pulse at the right cun position.

Western Diagnosis: Pulmonary nodule disease.

TCM Diagnosis: Mass-accumulation disease (Ji Ju), syndrome of lung-spleen Qi deficiency with intermingled phlegm, blood stasis, heat and toxin.

Therapeutic Principles: Soften hardness and resolve phlegm, activate blood and unblock collaterals, dissipate masses and remove stasis, clear heat and detoxify, supplemented by tonifying lung-spleen Qi.

Prescriptions:

(1) Chinese herbal medicine (14 doses)

Astragalus membranaceus 30 g, *Codonopsis pilosula* 20 g, *Scutellaria baicalensis* 10 g, *Mori Cortex* 15 g, *Citri Reticulatae Pericarpium* 10 g, *Pinelliae Rhizoma Preparata* 8 g, *Poria Cocos* 15 g, *Bulbus Fritillariae Thunbergii* 15 g, *Scrophulariae Radix* 15 g, *Chuanxiong Rhizoma* 6 g, *Salvia Miltiorrhiza* 30 g, *Paeoniae Radix Rubra* 15 g, *Angelicae Dahuricae Radix* 10 g, *Luffae Fructus Retinervus* 15 g, *Salvia Chinensis* 15 g, *Prunellae Spica* 30 g, *Taraxaci Herba* 20 g, *Solani Lyratii Herba* 30 g, *Curcumae Longae*

Rhizoma 10 g, *Scutellariae Barbatae Herba* 15 g, *Glycyrrhizae Radix et Rhizoma* 6 g. Fourteen doses, decocted in water, taken twice daily.

(2) Western medicine

Moxifloxacin Hydrochloride Tablets (Avelox), 400 mg once daily orally for 14 days; Eucalyptol, Limonene and α-Pinene Enteric-Coated Capsules (Sinomenine), 300 mg three times daily orally for 14 days.

Given the complicated condition, the patient was advised to return for follow-up visits every two weeks, receive CT re-examination three months later, quit smoking and alcohol, keep a light diet, and avoid spicy irritants, raw-cold, and greasy-sweet food.

Second visit on August 1, 2024: After medication, the frequency of cough and sputum production decreased; chest pain and sore throat during cough remained obvious; sleep quality improved; appetite was fair; defecation occurred once a day with smoother bowel movement; urination normal; mental status and physical strength unchanged. Physical examination: pharyngeal congestion (+), dim-purple tongue with tooth-marked borders, thick-white greasy coating, string-like pulse, weak right-cun pulse. Symptoms were attributed to lung-Qi obstruction by phlegm-heat toxin. *Curcumae Longae Rhizoma* was removed from the previous formula; *Houttuyniae Herba* 10 g and *Platycodonis Radix* 6 g were added; *Codonopsis pilosula* was reduced to 15 g. Fourteen doses.

Third visit on August 15, 2024: After medication, the patient expectorated 3–5 coffee-colored sputum clumps daily and felt refreshed in the chest after expectoration. Intermittent chest stuffiness and shortness of breath persisted; chest pain and sore throat disappeared; sound sleep, good appetite, once-daily smooth defecation, normal urination; mental status and physical strength markedly improved. Physical examination: pharyngeal congestion (-), dim-purple tongue with tooth-marked borders, white-greasy coating, string-like pulse, weak right-cun pulse. Since symptoms were obviously alleviated, therapeutic intensity for clearing heat-toxin, softening-hardness dissipating masses, and activating-blood unblocking collaterals was increased. *Houttuyniae Herba*, *Platycodonis Radix* and *Mori Cortex* were removed; *Conchae Ostreae* 30 g (decocted first), *Akebiae Fructus* 10 g and *Zedoariae Rhizoma* 15 g were added. Thirty doses, water-decocted. Considering the long travel distance and stabilized condition, follow-up visits were arranged on a monthly basis thereafter.

Fifth visit on October 30, 2024: Cough and sputum production disappeared; chest stuffiness and shortness of breath were relieved; sleep, appetite, and defecation-urination were normal; mental status and physical strength were good. Physical examination: dim-purple tongue with tooth-marked borders, white-greasy coating, string-like pulse, slightly weak right-cun pulse. Chest CT re-examination at the First Affiliated Hospital of Sun Yat-sen University on October 28, 2024 showed: patchy ground-glass shadow in the dorsal segment of right lower lung lobe, ill-defined boundary, heterogeneous density with traversing blood vessels, measuring approximately 24 × 16 mm (shrunk compared with June scan), undetermined nature; multiple ground-glass shadows in the lateral segment of right middle lobe, the largest one 6 × 5 mm (reduced), suspected glandular precursor lesion; multiple solid nodular shadows in the medial segment of right middle lobe, maximum size 3 × 3 mm, suspected glandular precursor lesion. Since the masses shrank and pathogen-eliminating therapies had taken effect, the formula maintained the principle of simultaneous pathogen elimination and healthy-Qi reinforcement. *Conchae Ostreae* and *Akebiae Fructus* were removed; *Hedyotidis Diffusae Herba* 30 g and *Sparganii Rhizoma* 15 g were added. Thirty doses.

Ninth visit on February 28, 2025: The patient reported abdominal distension, worse at night, frequent daytime flatus; no other complaints; sleep, appetite, defecation-urination, and physical condition remained

good. Physical examination: dim-purple tongue with tooth-marked borders, white-greasy coating, string-like pulse, slightly weak right-cun pulse. Chest CT from the First Affiliated Hospital of Sun Yat-sen University on February 16, 2025 demonstrated:

(1) Patchy ground-glass shadow in the dorsal segment of the right lower lobe, about 13 × 11 mm (smaller and lower-density compared with the October 2024 scan), suggestive of an inflammatory lesion;
(2) Multiple ground-glass shadows in the lateral segment of the right middle lobe, largest lesion 5 × 4 mm (reduced), suggestive of an inflammatory lesion;
(3) Multiple solid nodules in the medial segment of the right middle lobe, maximum 3 × 3 mm, suggestive of an inflammatory lesion. To treat abdominal distension and excessive flatus, *Aucklandiae Radix* 6 g was added to the formula. Thirty doses.

Sixteenth visit on September 30, 2025: No special complaints; normal appetite, sleep, defecation-urination; good mental and physical condition. Physical examination: dim-purple tongue with tooth-marked borders, white-greasy coating, string-like pulse; pulse at right cun position stronger than before. Chest CT re-examination performed at the First Affiliated Hospital of Sun Yat-sen University on September 29, 2025 showed patchy ground-glass shadow in the dorsal segment of the right lower lobe with ill-defined boundary and non-measurable scope, considered an inflammatory lesion; other findings were similar to previous scans. After more than one-year TCM treatment, the initially highly-malignant-suspected high-risk nodule transformed into an inflammatory lesion with encouraging therapeutic outcome. The treatment course could be concluded, and regular re-examinations were recommended.

3. Diagnosis and treatment analysis

3.1. Western medicine understanding and management of high-risk pulmonary nodules

On medical imaging, pulmonary nodules are classified by density into solid nodules and subsolid nodules (including pure ground-glass nodules and mixed ground-glass nodules), among which mixed ground-glass nodules carry the highest malignancy probability. According to CT findings, risk factors for malignant pulmonary nodules include upper-lobe location, diameter greater than 8 mm, and heterogeneous mixed density. More malignant features indicate higher risk, such as ill-defined nodular boundary, short-spiculated sign, lobulation sign, traversing blood vessels, invasion of adjacent tissues, and pleural indentation [2]. Integrating patients' clinical history, initial CT characteristics, and serial imaging changes during follow-up, pulmonary nodules are stratified into low-risk, intermediate-high-risk, and high-risk categories. Mixed ground-glass nodules over 10 mm with malignant features or progressive enlargement during follow-up constitute the diagnostic criteria for high-risk pulmonary nodules [3]. In this case, the middle-aged male patient had a long-term smoking history and obvious pulmonary-infection manifestations. Two mixed ground-glass nodules were detected in the right lower lobe on the first visit, one measuring 28 × 17 mm, close to tumor-sized diameter, with irregular boundary and adjacent-tissue invasion, complying with criteria for high-risk pulmonary nodule.

Nevertheless, imaging modalities alone cannot fully and accurately judge the nature of suspicious pulmonary nodules. Even advanced imaging tools may misclassify benign pulmonary nodules as malignant tumors [4]. Sole reliance on imaging results may lead to unnecessary resection of benign nodules [5,6], resulting in overtreatment. Pathological biopsy by obtaining pulmonary lesion specimens through invasive procedures is universally recognized as the most authoritative method for identifying high-risk pulmonary nodules. However, subject to nodule location, operator proficiency, and patient cooperation, sampling

bias is inevitable and may produce false-negative preoperative biopsy results [7]. Patients may also suffer biopsy-related complications such as hemorrhage and pneumothorax [8].

3.2. TCM understanding and management of pulmonary nodules

3.2.1. Etiology of pulmonary nodules

Pulmonary nodule formation results from combined external and internal pathogenic factors. External factors include six exogenous pathogenic evils, epidemic toxin, and smoke-haze pathogens. The lung is a delicate Zang-fu organ. Invasion by external pathogens disturbs lung diffusion-depuration and impairs fluid transportation, generating internal phlegm; external evils damage lung Qi, and Qi deficiency further leads to blood stasis. Internal factors originate from irregular diet, inherent physical deficiency, and inappropriate daily life. Modern-day fast-paced lifestyles often lead to irregular meals that injure the spleen and generate dampness. Excessive intake of rich-greasy, raw-cold, and fried food produces phlegm-heat. Patients with constitutional lung-Qi deficiency are more susceptible to external evils if daily habits are poor. Insufficient lung-spleen Qi fails to promote fluid and blood circulation, giving rise to phlegm and blood stasis.

3.2.2. Pathogenesis of pulmonary nodules

The pathogenesis of pulmonary nodules is lung-spleen Qi deficiency complicated by intermingled phlegm, blood stasis, heat, and toxin in the lung. Lung-spleen Qi deficiency is the root cause, while phlegm, blood stasis, heat, and toxin represent branch manifestations. As an ancient TCM saying goes: “The lung serves as the reservoir of phlegm, and the spleen is the source producing phlegm.” Constitutional deficiency aggravated by unhealthy lifestyles and external pathogenic factors impairs lung-spleen Qi. Since “Qi moves body fluids”, deficient Qi fails to circulate fluids, and phlegm is generated; since “Qi promotes blood circulation”, deficient Qi causes blood stasis. Long-term intermingled phlegm and blood stasis invade pulmonary collaterals, transform into heat and further generate toxin, so phlegm-stasis-heat-toxin accumulate inside the lung and form pulmonary nodules.

Summarized from years of clinical experience, pathological products transforming into heat-toxin constitute a critical link in nodule genesis. Huang-Di Nei-Jing (Huangdi’s Internal Classic) states: “All pain, itching, sores and ulcers are related to the heart” [9]. Zheng-Zong Wai-Ke (Orthodox Manual of External Medicine) also records: “Once fire generates… various diseases occur… externally it produces abscess, carbuncle, back sores, duikou sores and furuncles” [10]. This indicates that the fire-heat pathogen is closely associated with superficial masses. Pulmonary nodules are internal masses whose formation also involves fire-heat pathogen. Phlegm and blood-stasis interact in pulmonary collaterals, leading to Qi stagnation transforming into heat. Under the scorching effects of fire-heat, pathological products accumulate further and develop into severe, intractable “toxin”. The heavier the toxin, the higher the risk level of pulmonary nodules. Imaging manifestations, including enlarged nodule diameter, increasing malignant internal features, and invasion of adjacent tissues, are external reflections of severe toxin accumulation.

3.2.3. Detailed analysis of syndrome differentiation and treatment

“Pulmonary nodule” has no corresponding independent disease name in traditional Chinese medicine. According to pathological features, it falls under the TCM disease categories of “Zheng-Jia (Abdominal Masses)” and “Ji-Ju (Mass-Accumulation)”.

This middle-aged male patient had a long-term smoking history. Lung tissues were chronically assaulted

by smoke-haze toxin, and lung-Qi was consumed, manifested by a weak pulse at the right cun position. Impaired lung diffusion-depuration disturbed water-fluid metabolism and produced phlegm; phlegm transformed into heat and scorched blood collaterals, leading to blood stasis, hence cough, yellow-colored sputum, and blood-streaked sputum. Excessive phlegm-heat obstructed chest Qi movement and produced chest pain. The lung and large intestine are interior-exterior related Zang-fu organs. Deficient lung-Qi failed to promote intestinal peristalsis and caused prolonged defecation intervals with dry-hard stool due to lung-heat consuming intestinal fluids. Long-term alcohol drinking and improper diet generated abundant damp-heat and injured spleen-Qi. Retained dampness obstructed Qi movement and aggravated damp-heat, producing phlegm that ascends to the lung. Phlegm and blood-stasis accumulated in lung tissues and gradually transformed into heat-toxin, finally forming the high-risk pulmonary nodule.

Based on etiology and pathogenesis, therapeutic principles were to tonify lung-spleen Qi, invigorate spleen to resolve phlegm, activate blood and unblock collaterals, soften hardness to dissipate masses, clear heat, and detoxify. In the formula, *Astragalus membranaceus* and *Codonopsis pilosula* tonify lung-spleen Qi; *Scutellaria baicalensis* and Mori Cortex clear lung-heat, relieve cough, and resolve phlegm. Modified from Er-Chen Decoction and Xiao-Luo Pills, Citri *Reticulatae Pericarpium*, *Pinelliae Rhizoma Preparata*, Poria Cocos, *Houttuyniae Herba*, *Scrophulariae Radix*, *Bulbus Fritillariae Thunbergii*, *Conchae Ostreae*, *Prunellae Spica*, *Salvia Chinensis* invigorated spleen to eliminate damp-phlegm, cleared heat-phlegm, softened hardness and dissipated masses. *Scrophulariae Radix* was used for sore-throat heat-clearing because of pharyngeal congestion. As a mineral medicine, raw *Conchae Ostreae* exerted strong hardness-softening effects. *Salvia Miltiorrhiza* and Chuanxiong Rhizoma activated blood and unblocked collaterals; *Sparganii Rhizoma*, *Zedoariae Rhizoma* and *Paeoniae Radix Rubra* broke static blood and removed stasis. *Angelicae Dahuricae Radix* and *Luffae Fructus Retinervus* acted on tiny pulmonary collaterals to enhance stasis-removing efficacy. *Curcumae Longae Rhizoma* warmed and unblocked blood vessels, preventing cold-nature herbs from stagnating Qi-blood circulation. Cold-property Taraxaci Herba cleared heat-toxin and possessed anti-tumor effects with mild gastric irritation, commonly used for heat-toxin removal [11]. *Hedyotidis Diffusae Herba*, *Scutellariae Barbatae Herba*, *Solani Lyratii Herba* and *Akebiae Fructus* exerted strong effects in clearing heat-toxin, detumescence and dissipating masses. Modern pharmacological research has proven their favorable anti-tumor activity [12,13]. Given multiple malignant imaging features and malignancy suspicion from two top-tier hospitals, severe toxin accumulation in pulmonary collaterals required these potent medicinal substances.

Throughout the whole therapeutic process, patient benefit was prioritized, and the following principles were followed:

(1) Give full play to advantages of modern Western medicine. At the initial visit, obvious phlegm-heat obstructing lung indicated severe pulmonary infection. Moxifloxacin hydrochloride antibiotic was prescribed for infection control and eucalyptol-limonene-α-pinene enteric-coated capsules for sputum dilution to rapidly control infection and prevent deterioration. Applying Western medicine advantages to control acute conditions fully embodied the therapeutic principle “treat the branch in acute episodes”. Serial CT scans of Western medicine were maintained during follow-up to monitor nodule changes and objectively evaluate TCM curative effects and avoid missed deterioration.

(2) Select medicines with low toxic side effects, eliminate pathogenic factors without damaging healthy Qi. Pulmonary nodules are formed by accumulated pathological products such as phlegm, heat, blood stasis,

and toxin. Most formulas adopted medicines for removing stasis, resolving phlegm, softening masses, and clearing heat-toxin. Considering that insect-derived or highly toxic herbs commonly used for pulmonary-nodule treatment may impair liver-kidney function, such drugs were avoided in this treatment [14]. The only mineral medicine, raw Conchae Ostreae, belongs to the food-medicine homologous substance. Furthermore, tonifying-healthy-Qi herbs were compatible with pathogen-eliminating medicines to reduce injury to stomach-qi and minimize potential drug-related harm.

(3) Never neglect strengthening the root-origin healthy-Qi. Although nodule formation is related to pathological accumulation, "where pathogenic factors invade, healthy-Qi must be deficient". Lung-spleen Qi deficiency reduces disease resistance and impairs transportation of body substances, which constitutes the root cause generating phlegm-stasis-heat-toxin. The condition belongs to the root-deficiency-branch-excess pattern: "when healthy-Qi is abundant, pathogenic factors cannot invade." Therefore, pathogen elimination was always accompanied by reinforcing healthy-Qi. *Astragalus membranaceus* and *Codonopsis pilosula* for tonifying lung-spleen-Qi persisted in all prescriptions to provide intrinsic power for eliminating pathological products. Sufficient lung-spleen-Qi prevents the generation of phlegm-blood-stasis and promotes resolution of pulmonary nodules. Treatment emphasized simultaneous elimination of pathogens and reinforcement of healthy-Qi, treating both root and branch, regulating imbalanced constitution, and fundamentally removing the soil for nodule genesis through non-invasive approaches, which represents irreplaceable strengths of TCM therapy.

It needs emphasizing that reports of successful TCM intervention for high-risk pulmonary nodules remain scarce [15,16]. Compared with surgical resection, conservative TCM therapy cannot guarantee halting progression of high-risk pulmonary nodules. Before initiating TCM therapy for high-risk-nodule patients, clinicians must fully and explicitly inform patients of such risks. If TCM fails to work, surgery should be actively adopted to prevent irreversible deterioration and missed surgical opportunity. After full understanding of his disease and risks of conservative therapy, this patient firmly consented to TCM conservative treatment.

4. Conclusion

Based on the pathogenesis understanding of "lung-spleen Qi deficiency as root, intermingled phlegm-heat-blood-stasis-toxin as branch", this case adopted simultaneous pathogen-elimination and healthy-Qi-reinforcement therapeutic principles with integrated traditional-western-medicine intervention for high-risk pulmonary nodule. The highly malignancy-suspected nodule shrank markedly and finally transformed into an inflammatory lesion with a promising curative effect. This case demonstrates that TCM possesses certain strengths in intervening in the progression of high-risk pulmonary nodules. Integrated traditional-western-medicine therapy can combine TCM's strengths of reinforcing healthy-Qi, eliminating pathogens, and treating both root-and-branch with western-medicine's precise monitoring via advanced techniques. Compared with surgery alone, it causes less bodily trauma and offers an alternative conservative option for patients refusing surgical intervention. This case is reported to provide clinical references for pulmonary-nodule management.

Disclosure statement

The authors declare no conflict of interest.

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Systematic Vaccination Management and Its Practical Utility in the Prevention and Control of Infectious Diseases in Children

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Abstract: *Objective:* To explore the practical utility of systematic vaccination management in the prevention and control of infectious diseases in children. *Methods:* A total of 80 ageeligible children who attended the Preventive Health Care Department of our hospital from April 2024 to April 2025 were enrolled and randomly divided into a control group and an observation group using a random number table, with 40 cases in each group. The control group received routine vaccination management, while the observation group received systematic vaccination management. The two groups were compared in terms of full age-appropriate vaccination coverage rate, incidence of mild adverse reactions postvaccination, parental awareness rate of vaccine prevention knowledge, and incidence of infectious diseases in children during the followup period. *Results:* The full vaccination coverage rate was 97.52% in the observation group versus 82.37% in the control group, with a statistically significant difference ($p < 0.05$). The incidence of mild adverse reactions was 2.41% in the observation group versus 12.68% in the control group ($p < 0.05$). The parental awareness rate was 95.14% in the observation group versus 78.46% in the control group ($p < 0.05$). The incidence of infectious diseases during followup was 4.89% in the observation group versus 17.23% in the control group ($p < 0.05$). *Conclusion:* This management model can increase the full vaccination coverage rate among ageeligible children, reduce the occurrence of mild adverse reactions, help parents acquire more knowledge on vaccine prevention, and lower the incidence of infectious diseases during followup.

Keywords: Systematic vaccination management; Prevention and control of infectious diseases in children; Vaccination coverage rate; Adverse reactions to vaccination; Child preventive health care

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1. Introduction

Relevant studies indicate that in 2023, the reported incidence of notifiable infectious diseases (NID) among children under 5 years of age in China was 213.69 per 100,000, of which vaccinepreventable diseases accounted for 42.7%. The risk of cluster outbreaks of enterovirus infections, mumps, and other diseases

in childcare facilities and primary schools remains at a relatively high level [12]. Previous vaccination management has mostly relied on notifications at fixed time points and verbal instructions at the time of single vaccinations. Some parents hold misconceptions regarding the protective scope of different vaccines, postvaccination precautions, and management of adverse reactions. Missed and delayed vaccinations are more prominent among children from migrant families and those in remote counties [3]. The framework of systematic vaccination management was first proposed by the National Disease Control and Prevention Administration in 2022, covering three core links: prevaccination risk assessment, phased science popularization of vaccination knowledge, and postvaccination followup. Smallscale studies have confirmed that this model can improve the standardization of the entire vaccination process; however, practical data on vaccination scenarios for ageeligible children in primary healthcare institutions remain scarce [4]. This study aims to explore the practical utility of systematic vaccination management in the prevention and control of infectious diseases in children.

2. Materials and methods

2.1. General information

A total of 80 ageeligible children who visited the Preventive Health Care Department of our hospital from April 2024 to April 2025 were enrolled and equally divided into a control group and an observation group using a random number table, with 40 cases in each group. The children in the control group were aged 1–6 years, with a mean age of (3.24 ± 1.07) years, including 22 males and 18 females. The observation group had children aged 1–6 years, with a mean age of (3.31 ± 1.12) years, including 21 males and 19 females. No statistically significant difference was found in general characteristics between the two groups ($p > 0.05$). This study complied with the requirements of the Declaration of Helsinki.

2.1.1. Inclusion criteria

(1) Age between 1 and 6 years, meeting the age requirements for vaccines in the National Immunization Program.
(2) The guardians of the children were fully informed about the study content, voluntarily signed informed consent, and were able to complete the entire followup.
(3) The enrolled children had no congenital immune deficiencies or severe dysfunction of major organs such as the heart, liver, or kidneys.
(4) Had not completed all scheduled vaccinations for their age group before enrollment.

2.1.2. Exclusion criteria

(1) Presence of clear contraindications to vaccination, or a history of severe allergic reactions within 1 month before enrollment.
(2) Participation in other vaccinerelated clinical studies within 3 months before enrollment.
(3) Guardians had cognitive impairments or diagnosed psychiatric disorders that prevented cooperation with the survey and information collection.
(4) Possible change of residence across cities during followup that would preclude completion of subsequent vaccinations and health status tracking.

2.2. Methods

2.2.1. Control group

On the day of vaccination, nurses verified the child's identity and matched the vaccine accordingly. They provided oral instructions on contraindications and common postvaccination reactions.

2.2.2. Observation group

The observation group received systematic vaccination management.

(1) Seven days before vaccination, nurses retrieved the child's previous vaccination records, checked the types of ageappropriate vaccines not yet completed, reviewed the child's reaction history after previous vaccinations, screened health records from the past week, and conducted a preliminary screening for vaccination contraindications.

(2) Three days before vaccination, nurses sent relevant science popularization content about the vaccine to parents, including the types of diseases preventable by the vaccine, and dietary and activity precautions 3 days before vaccination. Each push notification was limited to no more than two pages to avoid information overload.

(3) On the day of vaccination, nurses first verified the child's identity, the vaccine batch number, and expiration date. After confirming that the parents were fully aware of the informed consent content, vaccination was performed according to standard procedures. During the postvaccination observation period, dedicated staff patrolled the area and proactively asked about any discomfort in the children.

(4) Twentyfour hours after vaccination, nurses completed followup via online messages or telephone calls, recording local reactions at the injection site and general condition. For children with mild redness, swelling, or lowgrade fever, specific home care instructions were provided.

(5) In the last week of each quarter, nurses summarized the vaccination status of all ageeligible children under their jurisdiction. For children with a delay of more than 15 days, they contacted parents individually to confirm the reasons and coordinate a specific catchup vaccination schedule.

(6) For children from migrant families or those living in remote locations, nurses aggregated their vaccination needs monthly, coordinated with the Preventive Health Care Department to set up dedicated weekend vaccination sessions, and, when necessary, collaborated with communities to arrange mobile vaccination services for onsite administration.

(7) Offline science popularization exchange activities were organized every two months. Nurses prepared presentation materials covering the transmission characteristics of common vaccinepreventable infectious diseases and daily home protection essentials, and answered various questions raised by parents on site.

Statistical analysis was performed using SPSS 26.0. Categorical data were expressed as rates and compared between groups using the chisquare test. Continuous data were expressed as mean ± standard deviation and compared using the *t*test. A p value of less than 0.05 was considered statistically significant.

2.3. Observation indicators

2.3.1. Fullageappropriate vaccination coverage rate

During the 12month followup period, the actual completion of all required doses of vaccines for the child's age group according to the National Immunization Program was counted. Calculation formula: Full vaccination coverage rate = (number of children in the group who completed all ageappropriate vaccinations

/ total number of children enrolled in the group) × 100%.

2.3.2. Incidence of mild adverse reactions post-vaccination

The scope was limited to reactions occurring within 72 hours after vaccination, including local redness with a diameter of < 5 cm, axillary temperature between 37.3 ℃ and 38.0 ℃, and mild rash without other accompanying symptoms—all of which are selflimiting reactions requiring no clinical intervention.

2.3.3. Parental awareness of vaccine prevention knowledge

Assessment was conducted using a selfdesigned questionnaire by our hospital's Preventive Health Care Department. The questionnaire covered four dimensions: vaccine protective scope, contraindication requirements, adverse reaction management, and prevention of childhood infectious diseases, with a total of 20 items. Each item was scored 5 points, giving a total score of 100. A score of ≥ 80 was defined as knowledgeable.

2.3.4. Incidence of infectious diseases in children during follow-up

The confirmed occurrence of nationally notifiable infectious diseases (NID) among children in the two groups during the 12month followup was recorded. The statistical scope was limited to vaccinepreventable NIDs, with diagnosis confirmed by formal clinical diagnostic reports issued by medical institutions at all levels within the jurisdiction. Calculation formula: Incidence during followup = (number of children in the group diagnosed with vaccinepreventable NIDs during followup / total number of children enrolled in the group) × 100%.

3. Results

3.1. Comparison of full age-appropriate vaccination coverage rate between the two groups

The full vaccination coverage rate in the observation group was significantly higher than that in the control group, and the difference was statistically significant. **(Table 1)**

Table 1. Comparison of full age-appropriate vaccination coverage rates between the two groups [n (%)]

Group	Full vaccination of Category I vaccines	Completion of recommended Category II vaccines	Full vaccination of all ageappropriate vaccines
Observation group (n = 40)	39 (97.50)	38 (95.00)	39 (97.52)
Control group (n = 40)	34 (85.00)	30 (75.00)	33 (82.37)
χ^2	3.914	5.165	5.000
p	0.048	0.023	0.025

3.2. Comparison of the incidence of mild adverse reactions after vaccination between the two groups

The incidence of mild adverse reactions after vaccination in the observation group was significantly lower than that in the control group, and the difference between groups was statistically significant. **(Table 2)**

Table 2. Comparison of the incidence of mild adverse reactions after vaccination between the two groups [n (%)]

Group	Local erythema	Low-grade fever	Mild rash	Total incidence rate
Observation group (total doses = 249)	3 (1.20)	2 (0.80)	1 (0.40)	6 (2.41)
Control group (total doses = 244)	15 (6.15)	10 (4.10)	6 (2.46)	31 (12.68)
χ^2				17.853
p				< 0.001

3.3. Comparison of awareness of vaccine prevention and control knowledge between parents of children in the two groups

The awareness rate of vaccine prevention and control knowledge among parents in the observation group was 95.14%, which was significantly higher than that in the control group (78.46%), and the difference between the groups was statistically significant. **(Table 3)**

Table 3. Comparison of vaccine prevention and control knowledge scores between parents of children in the two groups ($\bar{x} \pm s$, points)

Group	Vaccine protection scope		Vaccination contraindication requirements		Adverse reaction management		Infectious disease prevention		Total score	
	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention	Before intervention	After intervention
Observation group (n = 40)	18.24 ± 2.15	23.71 ± 1.06	17.92 ± 2.33	23.64 ± 1.12	16.58 ± 2.64	23.59 ± 1.08	17.31 ± 2.47	23.83 ± 0.97	70.05 ± 6.28	94.77 ± 3.15
Control group (n = 40)	18.31 ± 2.21	20.15 ± 1.78	17.87 ± 2.41	19.72 ± 1.94	16.63 ± 2.59	19.54 ± 2.06	17.26 ± 2.52	19.38 ± 1.85	70.07 ± 6.35	78.79 ± 5.26
t	0.138	11.087	0.092	11.126	0.084	10.974	0.087	13.702	0.014	16.497
p	0.891	< 0.001	0.927	< 0.001	0.933	< 0.001	0.931	< 0.001	0.989	< 0.001

3.4. Comparison of the incidence of vaccinepreventable infectious diseases between the two groups during the followup period

The incidence of infectious diseases in the observation group was significantly lower than that in the control group, and the difference between the groups was statistically significant. **(Table 4)**

Table 4. Comparison of the incidence of vaccinepreventable infectious diseases between the two groups during the followup period [n (%)]

	Mumps	Hand, foot and mouth disease	Chickenpox	Total incidence rate
Observation group (n = 40)	1 (2.50)	1 (2.50)	0 (0.00)	2 (4.89)
Control group (n = 40)	3 (7.50)	2 (5.00)	2 (5.00)	7 (17.23)
χ^2				4.021
p				0.045

4. Discussion

Vaccine-preventable infectious diseases continue to maintain a relatively high incidence among young children, and the risk of outbreaks in congregate settings such as childcare institutions and primary schools remains a high priority for prevention and control. Under the previous routine vaccination management model, the full-course vaccination rate among age-appropriate children had long struggled to exceed the 85% threshold, with missed and delayed doses among children from migrant families and those in remote counties accounting for nearly 30%. Parental cognitive biases regarding vaccine-related knowledge further amplify children's risk of infection [5]. There is clear room for optimization of the existing management model in primary healthcare settings. This study was conducted in such settings to investigate the practical utility of systematic vaccination management in the prevention and control of infectious diseases in children.

This study observed that children receiving systematic vaccination management achieved higher full-course vaccination rates, experienced fewer mild adverse reactions after vaccination, demonstrated better parental mastery of vaccine-preventable disease knowledge, and exhibited lower incidence of vaccine-preventable infectious diseases during the follow-up period. Some studies have suggested that overly complex health education content may induce information anxiety among parents, thereby reducing acceptance of vaccination. The single-dose lightweight health education materials used in this study—each push notification not exceeding two pages and precisely aligned with the key points of the corresponding vaccination—imposed no additional information burden on parents while enabling them to adjust their children's pre-vaccination diet and activity schedules in advance, thereby reducing post-vaccination discomfort caused by parental oversight. Standardized verification procedures on the day of vaccination and dedicated staff patrols in the observation area facilitated timely detection of adverse reactions in children, allowing immediate guidance and preventing progression of minor reactions [6]. Proactive follow-up within 24 hours post-vaccination provided home care instructions for children with mild discomfort, alleviating parental anxiety and reducing unnecessary clinic visits [7]. In addition, bi-monthly offline educational sessions addressed parents' specific concerns, gradually correcting misconceptions about vaccination and enhancing their cooperation with the vaccination schedule [8]. In this study, parents in the observation group demonstrated significantly higher levels of knowledge awareness, which corresponded to higher full-course vaccination rates. The improvement in full-course vaccination rates directly reduced children's exposure risk to vaccine-preventable infectious diseases—the primary reason for the lower incidence in the observation group during follow-up. This association, to a certain extent, validates the protective effect of full-course vaccination against infectious diseases in children [9]. This study implemented the systematic vaccination management framework proposed by the National Disease Control and Prevention Administration in primary healthcare settings, supplementing the empirical data on this model in routine childhood vaccination among underserved populations. Compared with previous small-scale studies, this research included often-overlooked groups such as migrant and remotely residing populations, with management measures more closely aligned with actual primary care conditions [10]. Moreover, the effectiveness of systematic vaccination management does not rely on high-end equipment or substantial financial investment, but rather on optimizing existing service processes to expand service coverage and enhance quality.

5. Conclusion

In summary, systematic vaccination management can increase the full-course vaccination rate for age-

appropriate vaccines in children, reduce the occurrence of mild post-vaccination adverse reactions, help parents acquire more knowledge related to vaccine-preventable disease control, and lower the incidence of infectious diseases in children during the follow-up period.

Disclosure statement

The author declares no conflict of interest.

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Study on the Application Effect of Quality Nursing Based on Non-Invasive Intracranial Pressure Monitoring in Patients with Intracranial Hypertension

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Abstract: *Objective*: To evaluate the efficacy of a quality nursing protocol guided by non-invasive intracranial pressure (ICP) monitoring on rehabilitation outcomes in patients with intracranial hypertension, thereby providing evidence-based support for precision nursing practices. *Methods*: A total of 120 patients with intracranial hypertension admitted to our hospital from June 2023 to June 2024 were selected and randomly assigned to a control group or an observation group (n = 60 per group) using a random number table. Baseline characteristics showed no statistically significant differences between the groups ($p > 0.05$). The control group received routine neurosurgical nursing care, including vital signs monitoring, administration of dehydrating agents, and regular turning with back percussion. The observation group received routine care supplemented by a multimodal non-invasive ICP monitoring strategy, which combined flash visual evoked potentials with ultrasound measurement of the optic nerve sheath diameter to dynamically assess ICP values and waveform changes. Furthermore, quality nursing interventions were implemented in accordance with the Expert Consensus on Nursing for the Prevention and Control of Intracranial Hypertension in Adult Critically Ill Patients. These interventions included individualized positioning management (adjusting head-of-bed elevation based on ICP values), refined airway management (administering pure oxygen before and after suctioning, with time-limited suctioning), proactive complication prevention (targeting infection, constipation, cerebral edema, deep vein thrombosis, and epilepsy), and psychological support. Glasgow Coma Scale (GCS) scores and ICP levels were compared before intervention and at discharge. Additionally, the rates of poor prognosis and total complications, as well as satisfaction with nursing care, were assessed. *Results*: Post-intervention, the observation group exhibited a significantly higher GCS score (12.4 ± 2.5) compared to the control group (9.8 ± 2.1), and a significantly lower ICP level (14.1 ± 2.8 mmHg vs. 18.5 ± 3.2 mmHg; $p < 0.05$). The rate of poor prognosis was significantly lower in the observation group (6.7%, 4/60) than in the control group (20.0%, 12/60), as was the total complication rate (3.3%, 2/60 vs. 15.0%, 9/60; $p < 0.05$). Furthermore, nursing satisfaction scores were significantly higher in the observation group ($p < 0.05$). *Conclusion*: A quality nursing protocol guided by multimodal non-invasive ICP monitoring effectively reduces ICP levels, improves consciousness, decreases complications, and enhances nursing satisfaction in patients with intracranial hypertension.

By innovatively integrating the multimodal concepts of the Brussels Consensus on non-invasive ICP monitoring with domestic nursing expert consensus, this study facilitates a transition from empirical nursing to data-driven precision nursing, offering a safe, feasible, and scalable model for neurosurgical ICP management.

Keywords: Intracranial pressure; Intracranial hypertension; Non-invasive monitoring; Quality nursing; Nursing intervention

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1. Introduction

Elevated intracranial pressure (ICP) is a prevalent and critical clinical manifestation in neurosurgery, commonly observed in hypertensive cerebral hemorrhage, severe traumatic brain injury (TBI), intracranial tumors, and other conditions. Epidemiological data indicate that the incidence of intracranial hypertension in patients with severe TBI ranges from 50% to 80%. More importantly, when ICP remains persistently above 20 mmHg, cerebral perfusion pressure declines, cerebral blood flow decreases, secondary cerebral ischemia and edema worsen, and brain herniation can rapidly develop. This pathological mechanism underlies the high disability and mortality rates in patients with severe TBI. Therefore, as the most direct physiological indicator for evaluating cerebral functional status, accurate ICP monitoring and appropriate management significantly impact patient prognosis [1].

The 2021 SYNAPSE-ICU multinational prospective cohort study, which included 2395 patients with acute brain injury from 146 ICUs in 23 countries, concluded that invasive ICP monitoring significantly reduces 6-month mortality (OR = 0.82, 95% CI 0.68–0.98) [2]. Subsequently, in 2023, Robba et al. demonstrated that a tiered management strategy for elevated ICP is highly correlated with improved patient outcomes, identifying early detection and timely intervention as key steps [3]. However, although traditional invasive monitoring methods (external ventricular drainage and intraparenchymal probes) are recognized as the "gold standard," they have significant limitations: a relatively high infection risk (3–15%), technical complexity, high cost, unsuitability for patients with coagulation dysfunction, and limited feasibility in resource-constrained settings.

As non-invasive ICP monitoring technology has advanced rapidly, it has become a safer and more reliable alternative in clinical practice. The non-invasive intracranial pressure monitor is based on the principle of flash visual evoked potential, making it naturally applicable for screening elevated ICP resulting from TBI and cerebral hemorrhage. Specifically, after affixing scalp electrode patches, flash visual evoked potential goggles are applied in combination with hemodynamic data monitoring. The entire procedure takes only 3 minutes to obtain real-time ICP and cerebral perfusion pressure readings, with measurement error strictly controlled within 10% [4,5].

Numerous studies have systematically compared various non-invasive ICP monitoring technologies, including brain imaging, near-infrared spectroscopy, electroencephalography, transcranial Doppler, and methods based on ocular and auditory structures [6]. In 2025, 41 international TBI experts jointly published the 'Brussels Non-invasive ICP Monitoring Consensus' (B-ICONIC), providing clinically feasible guidelines for bedside non-invasive ICP tools. The consensus recommends key techniques such as automated pupillometry (neuro-pupillary index, NPi), ultrasound measurement of optic nerve sheath diameter (ONSD),

and transcranial Doppler-derived indices. It advocates a multimodal strategy: using at least two concordant non-invasive ICP techniques, combined with clinical examination and neuroimaging findings, to guide ICP management [7]. For example, escalation of ICP therapy should be considered when NPi ≤ 3, ONSD ≥ 6 mm (indicating ICP ≥ 20 mmHg), or the TCD pulsatility index is elevated (≥ 1.4, corresponding to predicted ICP ≥ 20 mmHg) [8].

Furthermore, extensive literature indicates that non-invasive ICP monitoring technology effectively assesses intracranial compliance in conditions such as TBI, spontaneous intracranial hemorrhage, and hydrocephalus. Its main parameters show an excellent correlation with invasive ICP measurements [9].

Given the pivotal role of nursing staff in ICP management, the Chinese Journal of Nursing published the Expert Consensus on Nursing for the Prevention and Control of Intracranial Hypertension in Adult Critically Ill Patients in 2024

This consensus covers ten aspects across four dimensions: identification, monitoring, prevention and control measures, and emergency care.

The key management points were summarized systematically and hierarchically: nurses must first master the clinical manifestations of intracranial hypertension and then follow standardized procedures to perform monitoring and nursing care, thereby effectively improving patient prognosis [10]. Notably, the article explicitly points out that using non-invasive monitoring data to guide interventions—such as head-of-bed elevation to 30°, airway management, sedation and analgesia, and complication prevention—naturally and appropriately controls ICP fluctuations and avoids secondary injury potentially caused by medical procedures. Therefore, the fundamental purpose of this study is to evaluate the effect of quality nursing based on non-invasive intracranial pressure monitoring in patients with elevated ICP, ultimately providing strong evidence to support clinical nursing practice.

2. Materials and methods

2.1. Clinical data

This study enrolled 120 patients with elevated intracranial pressure hospitalized at our institution between June 2023 and June 2024. Participants were randomly assigned to a control group or an observation group, with 60 cases in each. The control group comprised 32 males and 28 females, aged 21–78 years, with a mean age of 51.8 ± 4.9 years. Etiologies included hypertensive intracerebral hemorrhage (20 cases), severe traumatic brain injury (18 cases), intracranial tumor (12 cases), subarachnoid hemorrhage (8 cases), and other causes (2 cases). The observation group consisted of 33 males and 27 females, aged 20–79 years, with a mean age of 52.5 ± 5.1 years. The etiological distribution was as follows: hypertensive intracerebral hemorrhage (21 cases), severe traumatic brain injury (17 cases), intracranial tumor (11 cases), subarachnoid hemorrhage (9 cases), and other causes (2 cases). No statistically significant differences were observed between the two groups in baseline characteristics, including sex, age, disease duration, and etiological composition ($p > 0.05$), indicating good comparability.

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

Participants were required to meet the following stringent criteria:

(1) Intracranial hypertension was confirmed by head CT or MRI, with eligible conditions including

hypertensive intracerebral hemorrhage, severe traumatic brain injury, and intracranial tumors;

(2) Glasgow Coma Scale score < 8 at admission;

(3) Age 18–80 years;

(4) The study was approved by the hospital medical ethics committee, and informed consent was obtained from the patients' family members.

2.2.2. Exclusion criteria

Patients were excluded if they presented with any of the following contraindications:

(1) Severe ocular disease, trauma, or history of ocular surgery preventing pupil observation;

(2) Malignant tumors, severe systemic diseases (cardiac, hepatic, or renal failure), or psychiatric disorders;

(3) Recent use of medications affecting intracranial pressure (e.g., mannitol, diuretics);

(4) Brain death or a moribund condition;

(5) Contraindications to magnetic resonance imaging precluding completion of the examination.

2.3. Methods

2.3.1. Intracranial pressure monitoring method

Upon admission, all patients received routine symptomatic neurosurgical management, including the administration of dehydrating agents to reduce intracranial pressure,

Following admission, patients underwent routine symptomatic neurosurgical management, which included the administration of dehydrating agents to lower intracranial pressure, hemostatic therapy, and neurotrophic treatment. Concurrently, systematic and continuous monitoring of intracranial pressure (ICP) levels was performed using a non-invasive multifunctional monitor. This device employs dual-principle technology that combines flash visual evoked potential (FVEP) with hemodynamic parameters. Electrode patches collected electrophysiological signals from the visual pathway and hemodynamic indicators, and a built-in regression equation model directly calculated the ICP value.

Flash visual evoked potential is one of the earliest established and most technically mature types of cortical evoked potentials in clinical research. It represents the change in electrical activity recorded in the occipital cortex following diffuse, non-patterned flash stimulation of the retina [11]. FVEP allows for the assessment of visual pathway integrity, which extends from the retina to the occipital lobe. Because the visual pathway is located at the base of the cranial cavity and its nerve fibers have a long course, intracranial lesions often adversely affect optic nerve function [12]. Non-invasive ICP monitoring technology based on FVEP can estimate ICP values with reasonable accuracy, serving as a reliable method for clinical auxiliary diagnosis and treatment [13]. Prior to monitoring, the instrument underwent a systematic and standardized inspection. Electrode connections were confirmed to be secure, and parameters were calibrated to baseline. The patient was instructed to close their eyes and relax, and electrodes were placed at standard positions using strict aseptic technique. This procedure ensured the reliable and accurate recording of ICP readings once stable waveforms were obtained. Continuous ICP monitoring commenced upon admission, with trends systematically recorded daily. The ICP grading criteria are defined as follows: normal, 5–15 mmHg; mild elevation, 15–20 mmHg; moderate elevation, 20–40 mmHg; and severe elevation, > 40 mmHg. Routine monitoring is performed 4–6 times daily; during the acute phase or upon changes in clinical condition, the monitoring frequency is increased to capture ICP fluctuations in a timely manner.

In addition to FVEP, bedside non-invasive ICP monitoring offers effective multimodal strategies. The B-ICONIC consensus provides a clear description of using ultrasound to measure the ONSD for identifying patients at risk of intracranial hypertension: an ONSD ≥ 6 mm indicates an ICP ≥ 20 mmHg [14]. Furthermore, an elevated transcranial Doppler pulsatility index (≥ 1.4) is directly correlated with increased ICP. Therefore, FVEP and ONSD can be combined for multimodal ICP assessment.

2.3.2. Nursing methods

Upon admission, all patients received routine neurosurgical nursing interventions, which primarily included: close monitoring of consciousness levels, pupil changes, and vital signs; administration of dehydrating agents as prescribed; maintenance of a patent airway; assistance with scheduled turning and gentle back tapping; and implementation of basic complication prevention measures.

Control group: The routine nursing protocol was adopted, involving dynamic observation of clinical manifestations, strict adherence to medical orders for all nursing procedures, increased frequency of ward rounds, improved nursing documentation, and immediate reporting of any abnormal conditions to the attending physician for management.

Observation group: In addition to routine care, quality nursing based on non-invasive intracranial pressure (ICP) monitoring was implemented. This approach standardized the nursing process in accordance with the Expert consensus on nursing for the prevention and control of intracranial hypertension in adult critically ill patients, systematically covering the identification, monitoring, prevention, control, emergency treatment, and nursing care of intracranial hypertension.

(1) Instrument use management

As the responsible nurses were familiar with the operating procedures and waveform interpretation methods of the non-invasive multifunctional ICP monitor, they recorded ICP values and waveform trends systematically every 2–4 hours. If ICP exceeded 20 mmHg with a continuous rise, or if waveforms were abnormal (increased P2/P1 ratio or presence of plateau waves), the physician was notified promptly, and the nurse assisted actively in management. If ICP remained > 25 mmHg for more than 30 minutes, the risk of brain herniation was considered high, and the emergency protocol was initiated immediately.

(2) Positioning management

Head-of-bed elevation was adjusted in a stepwise manner based on real-time ICP readings. The fundamental principle was as follows: when ICP was within the normal or mildly elevated range, the patient was placed in a supine position or with the head-of-bed elevated 15–30°; when ICP was moderately elevated, the head-of-bed was maintained at 30°, while strictly avoiding excessive rotation or flexion of the head and neck to prevent impairment of jugular venous return. Nursing procedures such as turning and suctioning were performed gently, with ICP monitored before and after to prevent procedure-induced spikes. Notably, meta-analyses have confirmed that head-of-bed elevation of 15–30° effectively reduces ICP without compromising cerebral perfusion pressure.

(3) Airway management

Ensuring airway patency is fundamental to controlling ICP, as dyspnea and systemic hypoxia can exacerbate intracranial hypertension. Hierarchical nursing measures included: prompt and thorough clearance of oral and nasal secretions; reasonable adjustment of airway humidification parameters based on sputum viscosity; strict adherence to aseptic technique during suctioning; limitation of single suctioning duration to

within 15 seconds; and administration of pure oxygen before and after each suctioning to avoid transient ICP elevation. For patients with consciousness disorders, the airway was proactively protected, and tracheotomy or ventilator-assisted ventilation was coordinated with physicians when necessary. For all patients receiving mechanical ventilation, preventive measures for ventilator-associated pneumonia were implemented systematically, including head-of-bed elevation to 30–45°, daily assessment of extubation readiness, and meticulous oral care.

(4) Complication prevention

Infection prevention and control: To strengthen environmental management and aseptic technique, drainage bags were changed daily, strict disinfection was performed around the puncture site, and changes in body temperature and routine blood tests were monitored proactively. As intracranial pressure monitoring carries a high risk of intracranial infection, the Expert consensus on nursing for the prevention and control of intracranial hypertension in adult critically ill patients identifies intracranial infection as a critical complication, recommending strict aseptic technique and minimization of monitoring duration [15,16]. Constipation prevention and bowel management: Patients were instructed to consume a diet rich in dietary fiber (vegetables, fruits, whole grains), maintain adequate daily fluid intake, and, when necessary, receive prescribed mild laxatives such as lactulose. Because straining during defecation increases intrathoracic and intra-abdominal pressure, it can impair cerebral venous return and trigger a rapid rise in ICP. Therefore, nursing interventions proactively guided patients to develop regular bowel habits, and bedridden patients were assisted to achieve smooth bowel movements. Cerebral edema management: The severity of cerebral edema was assessed by repeating head CT scans in conjunction with ICP changes. Dehydrating agents (e.g., mannitol, hypertonic saline) were administered according to medical orders, intake and output were strictly recorded, and electrolytes and renal function were monitored proactively. Deep Vein Thrombosis Prevention: From the early stage of illness, passive limb exercises were actively assisted; daily lower limb pneumatic compression therapy was provided; anticoagulant medications were administered rationally as prescribed; and lower limbs were carefully observed for swelling and pain. Epilepsy Prevention and Management: Patients were carefully observed for prodromal signs of seizures (e.g., altered consciousness, abnormal behavior, staring). For high-risk patients, prophylactic antiepileptic drugs were administered in a timely and standardized manner as prescribed, and emergency equipment was kept ready at the bedside.

(5) Psychological nursing

For conscious patients, psychological support was proactively provided through verbal communication to alleviate anxiety and fear. Simultaneously, disease-related knowledge and cooperation essentials were explained systematically to family members, and basic nursing skills were taught to relieve their psychological pressure and improve treatment compliance. For patients with gradually recovering consciousness, emotional reactions were monitored, changes in condition were explained truthfully, and confidence in treatment was reinforced.

2.4. Outcome measures

The following indicators were compared between the two groups: Glasgow Coma Scale (GCS) score, intracranial pressure (ICP), prognostic outcome, complication rate, and nursing service satisfaction.

Glasgow Coma Scale: The GCS is a reliable and widely used tool for assessing the degree of consciousness impairment. It evaluates three aspects: eye opening, verbal response, and motor response. Total scores range from 3 to 15, with lower scores indicating more severe coma. In this study, assessments

were conducted at admission, on day 7 post-intervention, and at discharge. For comatose patients, the GCS was assessed every 1–2 hours; a decrease of ≥ 2 points warranted heightened vigilance.

Intracranial pressure measurement: ICP readings were recorded in both groups before the nursing intervention and at weeks 1, 2, and 3 post-intervention. For each measurement, the average of three consecutive readings obtained within 30 minutes was calculated for between-group comparison.

Prognosis assessment: Patient recovery was graded according to the Glasgow Outcome Scale, which comprises five levels: good recovery, moderate disability, severe disability, vegetative state, and death. Severe disability, vegetative state, and death were combined and defined as poor prognosis, and the incidence of poor prognosis was calculated for each group.

Complications: The number of patients in each group who developed complications during hospitalization, such as pulmonary infection, intracranial infection, constipation, cerebral edema, and lower extremity deep vein thrombosis, was recorded, and the overall incidence of complications was calculated.

Satisfaction with nursing care: A hospital-designed nursing satisfaction questionnaire was completed by patients or their family members before discharge. The total score was 100 points, with higher scores indicating greater satisfaction.

2.5. Statistical analysis

Data processing and statistical analysis were performed using SPSS 26.0.

Normally distributed continuous variables are expressed as mean ± standard deviation ($\overline{x} \pm s$), with between-group comparisons conducted using the independent samples *t*-test. Categorical data are presented as frequencies and percentages (%), and the χ^2 test was used for between-group comparisons.

2.6. Ethics approval

The Ethics Committee of the Chinese PLA General Hospital approved this study (approval number: LL-J-CSY-2026-27; approval date: July 24, 2026). The study underwent expedited review, and the requirement for informed consent was waived. All procedures adhered to the ethical principles of the Declaration of Helsinki.

3. Results

3.1. Comparison of GCS scores and ICP levels between the two groups

Following the intervention, the observation group exhibited significantly higher GCS scores and lower ICP levels compared to the control group ($p < 0.05$). Detailed data are presented in **Table 1**.

Table 1. Comparison of GCS scores and ICP levels before and after intervention between the two groups

Group	Number of cases	GCS score (admission)	GCS score (discharge)	ICP level (admission/mmHg)	ICP level (discharge/mmHg)
Control group	60	6.5 ± 1.2	9.8 ± 2.1	26.3 ± 4.5	18.5 ± 3.2
Observation group	60	6.6 ± 1.3	12.4 ± 2.5	25.9 ± 4.8	14.1 ± 2.8

3.2. Comparison of prognosis and complications between the two groups

The observation group exhibited significantly lower incidences of poor prognosis and overall complications

compared with the control group ($p < 0.05$). Detailed data are presented in **Table 2**.

Table 2. Comparison of Poor Prognosis and Complication Rates between the Two Groups [n(%)]

Group	Number of cases	Poor prognosis	Total complications
Control group	60	12 (20.0)	9 (15.0)
Observation group	60	4 (6.7)	2 (3.3)

4. Discussion

In critically ill neurosurgical patients, elevated intracranial pressure (ICP) constitutes the core pathology. Persistent ICP exceeding 20 mmHg reduces cerebral perfusion pressure and cerebral blood flow, leading to secondary cerebral ischemia that exacerbates cerebral edema. In severe cases, this cascade can rapidly progress to brain herniation, representing a primary determinant of poor prognosis and frequent complications. Xue Yating et al. (2023) systematically reviewed evidence on ICP management in hemorrhagic stroke, summarizing 23 high-quality items across five dimensions: assessment and dynamic monitoring, management goals, interventions, treatment modalities, and risk control. Their analysis demonstrated that proactive, standardized ICP management improves patient prognosis [1]. Complementing this, Guimarães and Cruz (2023) highlighted that ICP monitoring necessitates close nurse-physician collaboration; nurses must promptly assess intracranial hypertension, detect ICP changes, and initiate appropriate interventions [17].

Traditional nursing care has long relied on patients' clinical presentations and vital signs to guide empirical interventions. Consequently, this approach is inherently limited by significant lag and a lack of specificity, preventing the prompt and accurate detection of subtle intracranial pressure (ICP) changes and hindering the provision of truly individualized, precise nursing care. Chen et al. conducted a rigorous study demonstrating that an ICP monitoring-guided individualized nursing strategy offers distinct clinical advantages for patients with severe traumatic brain injury. Following the intervention, the observation group exhibited superior GCS scores and short-term prognosis indicators compared to the routine nursing control group ($p < 0.05$). Furthermore, a current summary of best evidence for nursing care of intracranial hypertension in adult patients with severe brain injury systematically reviewed 33 articles. This review synthesized 33 high-quality evidence items across eight dimensions, including ICP threshold setting, assessment and monitoring methods, respiratory care, circulatory function maintenance, analgesia and sedation, thermoregulation, nutritional support, and cerebrospinal fluid drainage care, thereby establishing a foundation for the standardization of clinical nursing pathways.

Non-invasive ICP monitoring technology effectively addresses the limitations of invasive methods, such as extensive wound areas, high operational risks, and numerous complications. This approach enables the continuous, real-time, and reliable acquisition of intracranial pressure fluctuation data, thereby providing a robust foundation for precision nursing. Chen Yunna et al. (2025) provided a clear summary, noting that non-invasive ICP monitoring has become a focal point in neurocritical care, with FVEP widely applied in clinical practice [4]. However, invasive methods remain the "gold standard" regarding measurement accuracy, result reliability, and treatment selectivity; thus, non-invasive technology requires further validation before mature clinical application [4]. Consequently, non-invasive monitoring is currently best utilized as a supplement to invasive monitoring.

The Brussels Non-invasive ICP Monitoring Consensus provides important standardized guidance for

the clinical application of non-invasive monitoring techniques [7]. This consensus emphasizes the adoption of a multimodal strategy, specifically combining at least two concordant non-invasive ICP techniques with clinical examination and neuroimaging to guide ICP management [8]. This study adopted a multimodal non-invasive monitoring protocol combining FVEP and ONSD assessment, which aligns with the core concept of the B-ICONIC consensus and effectively improved the accuracy and reliability of ICP monitoring. This practice also indicates that single non-invasive techniques are prone to error, suggesting that multimodal fusion represents the future direction.

This study presents a systematic, layered approach to quality nursing based on non-invasive intracranial pressure (ICP) monitoring, extending beyond routine care models. Grounded in monitoring data, the protocol systematically implements dynamic position adjustment, meticulous airway management, individualized sedation and analgesia, targeted dehydration therapy, and early warning interventions for complications. Consequently, nursing protocols are adjusted promptly in response to ICP fluctuations, thereby mitigating risk factors that elevate intracranial pressure, maximizing brain tissue protection, and ultimately facilitating neurological recovery.

The results of this study demonstrate that, following intervention, the observation group exhibited a significantly higher GCS score than the control group (12.4 ± 2.5 vs. 9.8 ± 2.1, $p < 0.05$), significantly lower ICP levels (14.1 ± 2.8 mmHg vs. 18.5 ± 3.2 mmHg, $p < 0.05$), and reduced rates of poor prognosis (6.7% vs. 20.0%) and total complications (3.3% vs. 15.0%) ($p < 0.05$). These findings indicate that the nursing protocol guided by non-invasive intracranial pressure monitoring facilitates a better understanding of intracranial pressure dynamics, thereby effectively improving consciousness and neurological function. Furthermore, this model enables individualized care based on precise data, minimizing nursing blind spots and enhancing care quality and safety. Consequently, patients in the observation group and their families reported a more favorable experience and higher satisfaction with the nursing services provided.

Non-invasive ICP monitoring technology has well-defined, objective limitations: all indirect methods are constrained by calibration and zero-point correction, limiting absolute measurement accuracy. The 95% limits of agreement for TCD-based methods are approximately ± 7–15 mmHg. Therefore, integrating multimodal technologies and adopting advanced signal analysis methods represents a viable strategy to enhance predictive accuracy. In the clinical management of acute brain injury, non-invasive monitoring serves as an effective complement to invasive techniques. It is appropriately utilized for patient screening prior to invasive procedures, cerebral function assessment in moderate traumatic brain injury, and intracranial pressure management in patients with coagulation dysfunction. These applications highlight future research directions: exploring optimal parameter combinations for non-invasive ICP monitoring and standardizing nursing intervention pathways to facilitate clinical adoption.

5. Conclusion

In conclusion, quality nursing guided by non-invasive intracranial pressure (ICP) monitoring significantly improves clinical outcomes in patients with elevated ICP. Compared with routine nursing, this protocol achieves higher GCS scores, lower ICP levels, reduced rates of poor prognosis and complications, and greater nursing satisfaction. Non-invasive ICP monitoring provides a safe, objective, and real-time basis for individualized nursing interventions, offering a practical and effective strategy for neurosurgical critical care.

Further large-scale multicenter studies are warranted to validate and refine these nursing protocols.

Disclosure statement

The authors declare no conflict of interest.

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Establishment and Optimization of Detection Methods for Related Substances in Pharmaceutical Raw Materials

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Abstract: This study is based on the idea that "quality comes from design," that is, to systematically analyze the establishment of detection methods for related substances in pharmaceutical raw materials. At the beginning, hetero-mass spectrometry and the purpose of method development are summarized and explained, and suggestions on how to select key chromatographic parameters and how to do risk assessment are put forward. Then, the method design space is optimized by means of experimental design, and the intelligent development technology is used to make the method design more complete and efficient. The control of the chromatographic system, the influence of solvents, the integration conditions, and the detection wavelength are discussed in detail, and the corresponding control countermeasures are given. Finally, the whole life cycle of the detection of related substances is verified, and the forced degradation, sensitivity, and system applicability are taken into account. The results show that the standardized and complete development and verification ideas are conducive to ensuring the reliability of the detection method.

Keywords: Pharmaceutical raw materials; Related substances; Method establishment; Method optimization; Analysis quality comes from design; Method validation

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1. Introduction

Impurities, degradation products, and other related substances contained in pharmaceutical raw materials can have an impact on the safety, effectiveness, and stability of drugs. Therefore, establishing reliable, sensitive, and stable methods for detecting relevant substances is an important task in drug quality control. Traditional detection methods mostly rely on experience and repeated experimentation, which not only takes a long time but also lacks careful consideration of various complex influencing factors. With the continuous advancement of analytical technology, from the source design of method development to the final verification and confirmation, we pay full attention to the key technical parameters and control measures that affect the performance of detection methods, in order to improve the scientificity and application effectiveness of

detection methods.

2. Strategy for establishing substance detection methods based on AQbD concept

2.1. Determination of impurity mass spectrometry analysis and method development objectives

The first step of method development is to conduct a comprehensive impurity spectrum analysis of drug raw materials, and sort out the process impurities and potential degradation products by combining the synthesis process, chemical structure characteristics, and stability research data. On this basis, the general situation of the analysis target is determined, and the number of impurities to be separated, resolution, detection sensitivity, analysis time, and other key performance indicators are defined. The analysis of the target profile can provide direction for the development of the method and serve as an important basis for the subsequent method evaluation.

2.2. Screening and risk assessment of key method variables

There are many factors affecting chromatographic separation, mainly including mobile phase, chromatographic column, column temperature, gradient condition, and flow rate. The fishbone diagram, FMEA, and other tools can be used to screen the parameters, assess the risk, and identify the high-risk parameters that have a significant impact on the resolution, the number of theoretical plates, and the tailing factor. For impurities with large hydrophobicity differences, gradient time and organic phase ratio are more critical. Through single-factor experiments or partial factorial designs, the key variables can be quickly screened, and the optimization scope can be reduced.

2.3. Experimental design optimization and design space construction

After the key variables are selected, the experimental design (DOE) is used for system optimization, which can simultaneously investigate multiple factors and their interactions, and avoid the limitations of single-factor experiments. Taking gradient time and column temperature as examples, the central composite design or Box-Behnken design can be selected. **Table 1** shows the design matrix and partial results of the hypothetical experiment, with the separation of two key impurities from the main peak as the evaluation index.

Table 1. Two-factor, three-level center composite design example and resolution results

Experiment No.	GradientTime (min)	ColumnTemperature (℃)	Resolution (ImpurityAMainPeak)	Resolution (ImpurityBMainPeak)
1	20	25	1.2	1.8
2	40	25	1.9	2.3
3	20	35	1.1	1.6
4	40	35	1.8	2.5
5	15	30	1.0	1.5
6	45	30	2.0	2.4
7	30	22	1.6	2.0
8	30	38	1.5	2.1
9(Central Point)	30	30	1.7	2.2

The calculation formula for separation is:

$$R_s = \frac{2(t_{R2} - t_{R1})}{W_1 + W_2}$$

Where t_{R1} and t_{R2} respectively represent the retention times of two adjacent chromatographic peaks, W_1 and W_2 This calculation formula is the core quantitative index for evaluating the chromatographic separation effect. Researchers can carry out mathematical modeling on the experimental results, draw contour maps or three-dimensional response surface maps reflecting the relationship between influencing factors and detection results, and then predict the parameter range that can stably meet all separation requirements, that is, the design space, based on these models. Carrying out experiments and method operations in the predetermined design space can ensure the performance of the detection method meets the expected requirements and improve the durability of the method.

2.4. Application of intelligent method development tools

In recent years, intelligent method development software has been widely used, integrating compound structure, chromatographic column database, and retention model, and inputting structure can predict retention time and generate virtual chromatogram [1]. Through computer simulation, the optimal conditions can be quickly screened, and the number of experiments can be reduced; for example, the optimal pH range of the mobile phase can be quickly determined. This model of using calculation to guide experiments has significantly improved the efficiency and scientificity of method development.

3. Key factors affecting the accuracy and reproducibility of determination of related substances and control strategies

3.1. Chromatographic system factors and their control

The operating state of the chromatographic system will affect the analysis results, and the gradient delay volume is one of the factors that is easy to ignore. Different types of liquid chromatographs have different pipeline volumes from the mixer to the column inlet, which will make the actual start-up time of the gradient program deviate, thus changing the retention time and resolution of the early eluting impurities. In this regard, the model or delay volume range of the liquid chromatograph can be defined in the method; the delay volume difference can be compensated by using the initial isocratic stage, and equipment with column temperature control accuracy within±0.1℃ can be selected to ensure the stability of retention time. In addition, the preparation method of the mobile phase, the batch difference of the chromatographic column, and the decline of column efficiency in the process of use need to be monitored through strict system applicability testing.

The theoretical plate number n of a chromatographic column is an important parameter to measure column efficiency, and its calculation formula is:

$$N = 16(\frac{t_R}{W})^2$$

Where tR is the retention time, and *W* is the peak width. *N:* The greater the value, the higher the separation efficiency of the chromatographic column.

3.2. Sample pretreatment and solvent effect

The preparation process of the sample solution is prone to analysis error. When selecting the preparation solvent, it is necessary to ensure that all substances to be tested can be fully dissolved, and at the same time, no additional degradation of the sample can occur. If the elution strength of the sample solvent is higher than the initial proportion of the mobile phase, the solvent effect will occur, resulting in the deformation, bifurcation, or retention time shift of the chromatographic peak, which is more obvious for impurities with strong polarity and early peaks. The solvent effect can be controlled by using a solvent with the same proportion or lower strength as the initial composition of the mobile phase, reducing the injection volume, and using the focusing effect of column enrichment. In the gradient method, the basic principle to avoid solvent effect is to ensure that the solvent strength of the sample is not higher than the initial composition of the mobile phase.

3.3. Integral parameter setting and data processing

The setting of integration parameters directly affects the accuracy and reproducibility of quantitative results, which is also the main reason for differences in laboratory data. The slope sensitivity, peak width, minimum peak area, baseline processing mode, and other parameters will change the peak area calculation results, especially for the shoulder peak with low content of impurities and incomplete separation. By establishing a standardized integral event table, the unified parameters are determined in the method validation phase and fixed in the method, which can effectively control the error. When dealing with baseline noise, it is necessary to reasonably set integral parameters, accurately identify impurity peaks, and eliminate baseline interference.

Another important aspect of data processing is the correction factor. When the principal component self-control method is used to calculate the impurity content, if the response factor of the impurity and the principal component is quite different, it is necessary to use the impurity reference substance, or complete the accurate quantification by measuring and introducing the correction factor, such as:

$$RRF = \frac{A_{imp} / C_{imp}}{A_{API} / C_{API}}$$

Wherein, A_{imp} , A_{API} , are the peak areas of impurities and main components, respectively, C_{imp} and C_{API} are their concentrations, respectively. When the relative response factor is beyond the range of 0.8~1.2, the correction factor method should be used for accurate quantification.

3.4. Wavelength selection and response consistency of detector

The detection wavelength of the UV detector will directly affect the detection sensitivity and impurity response factor. Generally, the wavelength with strong absorption of impurities and main components will be selected. In the determination of related substances, the general wavelength with sufficient sensitivity to key impurities is more commonly used. When the UV absorption of multiple impurities is quite different, a single wavelength is difficult to meet the sensitivity requirements of all impurities. A diode array detector can be used for multi-wavelength detection or wavelength switching, such as quantifying most impurities with the main wavelength, and then detecting impurities with special absorption with the exclusive wavelength. During verification, it is necessary to investigate the response consistency between the principal component and each impurity at this wavelength, or determine the response factor, so as to provide the basis for selecting a self-control method or a correction factor method [2].

4. Full life cycle verification of detection methods for related substances

4.1. Reasonable design of specificity and forced degradation research

Specificity is the primary content of method validation. It needs to be proved that the method can accurately distinguish the detected substance from impurities, excipients, degradation products, and other substances. Forced degradation testing is the core means to evaluate specificity. It needs to carry out systematic degradation treatment of the API under acid, alkali, heat, oxidation, light, and other conditions. The key is to control the degradation of principal components at about 10% to 20%, so as to avoid excessive degradation and the production of secondary products, so as to be close to the real stability [3]. Through the analysis of degradation samples, it is necessary to ensure the effective separation between the main peak and each degradation product peak, as well as between degradation products. Generally, the purity of the main peak is required to be qualified, and the resolution RS of key impurities is greater than 1.5. As shown in **Figure 1**.

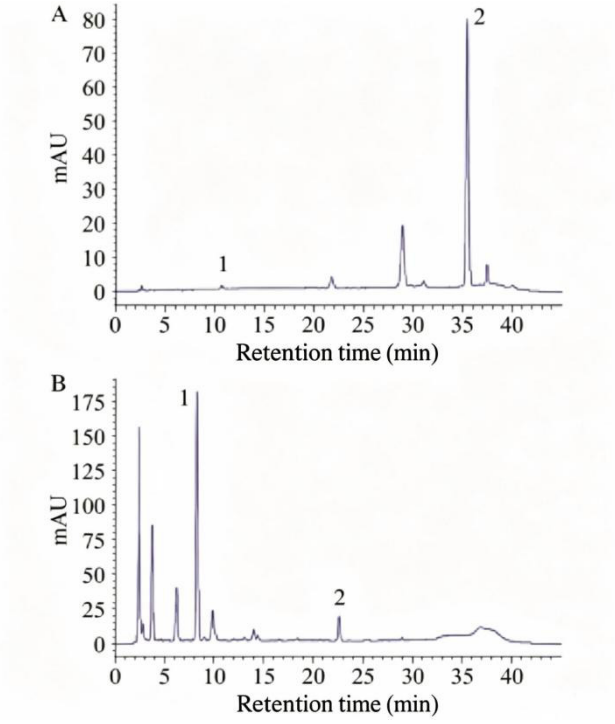


Figure 1. Chromatogram of a drug raw material oxidation degradation sample.

The peak purity factor can be calculated from the spectral data collected by the diode array detector, and its calculation formula is based on spectral similarity:

$$PurityFactor = \frac{\sum(\lambda_i - \lambda)(A_i - A)}{\sqrt{\sum(\lambda_i - \lambda)^2 \sum(A_i - A)^2}}$$

The closer the factor is to 1, the higher the spectral homogeneity of the peak and the higher the reliability of the peak purity.

4.2. Sensitivity and quantitative capability verification

The sensitivity is expressed by the limit of detection (LOD) and the limit of quantification (LOQ), generally

using the signal-to-noise ratio method, and the calculation formula is:

$$S/N = \frac{2H}{h}$$

Where h is the target peak height, and H is the maximum peak-to-valley height of baseline noise. The concentration is LOD when the signal-to-noise ratio is about 3:1, and LOQ when the signal-to-noise ratio is about 10:1. In the inspection of related substances, the LOQ concentration shall not be higher than the threshold of impurity reporting, and the quantitative ability of LOQ level shall be verified; that is, the LOQ concentration standard solution shall be continuously injected 6 times according to the formula:

$$RSD = \frac{\text{standard deviation （SD）}}{\text{Average}(\bar{x})} \times 100\%$$

To calculate the relative standard deviation of peak area, RSD is usually required to be less than 10% or 20% to ensure accurate quantification at low concentrations.

4.3. Linear range, accuracy and precision

For the linearity test, prepare standard solutions with at least 5 concentration levels within the range from LOQ to corrected concentration, and perform linear regression on the concentration based on peak area. The correlation coefficient r should generally not be less than 0.999, and the calculation formula of the correlation coefficient is:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_{i-} \bar{y})^2}}$$

The accuracy is evaluated by the recovery rate test. Add a known amount of impurity reference substance into the blank solvent or test solution, prepare low, medium, and high concentration solutions for determination, and the average recovery rate should be between 90%-108%, and RSD should meet the requirements. The precision is divided into repeatability and intermediate precision, which is verified by measuring the impurity content and calculating RSD.

4.4. Solution stability and durability

The stability of the test sample and the reference sample at room temperature or in cold storage for different times shall be studied respectively to obtain the maximum allowable storage time (taking the impurity content not exceeding ±10% as the judgment standard). Various conditions for durability testing shall be designed according to minor adjustments: pH deviation of the mobile phase ± 0.2. Column temperature ± 2 ℃, flow rate ± 0. 1 mL/min. The chromatographic columns of the same type but different brands were used to analyze the separation and numerical results. Finally, it was confirmed that the resolution, number of theoretical plates, tailing factor, and content did not lose acceptability when the parameters changed.

4.5. Reasonable setting of system applicability test

The system suitability test should be used as the necessary inspection for analyzing the system condition. The relevant items should be determined according to the key separation needs in the method and included in the routine test. The efficiency of the chromatographic column is represented by the number of theoretical plates,

n, and the tailing factor, t, is used to estimate whether the peak shape is symmetrical (i.e., whether there is tailing). The calculation formula is as follows:

$$T = \frac{W_{0.05}}{2f}$$

Where W 0.05 is the peak width at 5% peak height, and f is the length from the peak apex to the peak front. The tailing factor T should be within the range of 0.81.5.

The critical resolution Rs serves as a fundamental parameter. It shall be evaluated for the most difficulttoseparate pair of components, and a minimum acceptable value is specified, generally. $R_s \geq 1.5$ or 2.0.

Sensitivity determination shall be performed under specified signaltonoise ratio conditions; the signaltonoise ratio of the principal peak should preferably be greater than 10 times that of the reference.

All the abovementioned system suitability parameters shall be obtained through validation and documented in the standard operating procedure.

5. Conclusion

The establishment and optimization of material detection methods for pharmaceutical raw materials is a systematic task. The method is designed from the starting point of aqbd guiding ideology, controlling the elements of chromatography and sample processing, and taking the whole life cycle into consideration for validation. All points should be coordinated. The use of risk management and experimental arrangement together with control ideas is conducive to obtaining highly deterministic test results, which is of great significance to ensure the correctness of the quality analysis(i.e., actual determination) of pharmaceutical raw materials.

Disclosure statement

The authors declare no conflict of interest.

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Evaluation of the Sensitivity and Timeliness of Vaccine-Preventable Disease (Pertussis, Meningococcal Meningitis) Surveillance in Puyang City, Henan Province under New Circumstances

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Abstract: *Background*: The re-emergence of pertussis and persistent meningococcal meningitis threat demand robust surveillance, yet performance data from prefecture-level cities like Puyang under recent healthcare reforms remain scarce. This study evaluated the sensitivity and timeliness of notifiable disease surveillance for these diseases from 2020–2025, focusing on the impacts of the COVID-19 transition, expanded PCR capacity, and electronic reporting mandates. *Methods*: We conducted a retrospective analysis of all confirmed and clinically diagnosed cases reported through the national surveillance system, supplemented by hospital databases and laboratory logs. Sensitivity was estimated via capture-recapture methods, and timeliness was measured as intervals from symptom onset to reporting and laboratory confirmation. *Results*: A total of 2,847 pertussis and 316 meningococcal meningitis cases were included. Overall sensitivity for pertussis was 68.4% (95%CI 65.2–71.6%), rising from 54.2% in 2020–2021 to 76.9% in 2024–2025, while meningococcal sensitivity remained stable at 82.1% (79.4–84.7%). Pertussis onset-to-reporting median time decreased from 9 to 4 days, but meningococcal meningitis interval lengthened from 4 to 7 days due to centralized laboratory consolidation. Rural areas showed 22% lower sensitivity and 3-day longer delays for pertussis than urban areas. Although 93.7% of pertussis cases were reported within 24 hours, only 61.4% achieved PCR confirmation within the 7-day window. *Conclusions*: The system shows progress in pertussis timeliness but reveals critical gaps in laboratory confirmation and rural equity. Meningococcal surveillance maintains high sensitivity but deteriorating speed. Decentralized testing, standardized algorithms, and targeted training are urgently needed to sustain gains and address emerging vulnerabilities.

Keywords: Pertussis; Meningococcal meningitis; Surveillance sensitivity; Timeliness; Vaccine-preventable diseases

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1. Introduction

Vaccine-preventable respiratory diseases, including pertussis and meningococcal meningitis, remain major global public health threats despite high routine immunization coverage [1]. Pertussis has resurged widely across middle - and high-income countries due to waning vaccine immunity, pathogen evolution, and improved diagnostic capacity, while meningococcal meningitis continues to cause severe sporadic and epidemic disease with high fatality rates, particularly in densely populated urbanizing regions [2]. Puyang City, a typical prefecture-level setting in Henan with over 4.2 million residents and sustained childhood vaccination coverage above 95%, has experienced rising pertussis notifications and persistent low-level meningococcal disease activity since 2020, raising concerns about unmeasured disease burden and passive surveillance reliability [3].

Local surveillance performance has undergone substantial systemic changes in recent years, driven by county-level CDC restructuring, the 2022 upgrade of China's national disease reporting information system, and post-pandemic shifts in healthcare utilization and laboratory resource prioritization. COVID-19 suppression measures temporarily reduced transmission of respiratory pathogens, but the post-pandemic period has seen a marked pertussis resurgence, likely reflecting both true epidemiological rebound and expanded county-level PCR testing capacity [4]. This evolving landscape necessitates a rigorous assessment of two core surveillance metrics: sensitivity and timeliness, which govern early outbreak detection, vaccine effectiveness monitoring, and public health resource allocation [5].

Earlier Henan-based evaluations (2015–2018) documented suboptimal pertussis surveillance sensitivity (45–55%) and prolonged reporting delays, while meningococcal surveillance showed higher sensitivity (75–85%) due to severe clinical presentations and standardized reporting protocols. However, prior studies predated widespread molecular diagnostics, lacked urban–rural stratified analyses, and failed to disaggregate key diagnostic and reporting bottlenecks. The absence of updated, granular surveillance data hinders targeted local health investment and distorts interpretation of regional disease trends. Accordingly, this study adopted a multi-source capture-recapture framework to comprehensively evaluate Puyang's pertussis and meningococcal meningitis surveillance systems [6]. The primary objectives were to quantify current surveillance sensitivity using integrated hospital, laboratory and community clinic datasets; characterize timeliness across the full surveillance cascade stratified by geography, age and diagnostic approach; and identify post-pandemic and system-reform-related surveillance bottlenecks and inequities [7]. The findings provide evidence-based insights to guide local improvements in case detection, diagnostic efficiency and outbreak response, while offering a replicable evaluation framework for comparable middle-burden, digitally transitioning public health settings nationwide.

2. Materials and methods

This retrospective observational evaluation was carried out in Puyang City, Henan Province, covering all its county-level jurisdictions with a total resident population of 4 218 000 according to 2024 demographic records. The six-year study period ran from 1 January 2020 to 31 December 2025, capturing pre-pandemic, pandemic-response, transition, and post-pandemic phases to support temporal trend analysis of surveillance indicators under varied operational conditions. Eligible pertussis cases satisfied national notifiable-disease definitions: laboratory confirmation by Bordetella pertussis isolation or PCR, or clinical diagnosis of paroxysmal cough lasting over two weeks accompanied by characteristic symptoms plus epidemiological

links to confirmed cases. Meningococcal meningitis cases met confirmed or probable criteria through Neisseria meningitidis isolation, positive PCR from sterile specimens, or compatible acute meningitis with typical rash and supportive laboratory findings. Cases lacking Puyang residential registration or transferred out within 24 hours of admission were excluded to secure correct population attribution [8].

Four data streams fed the capture-recapture sensitivity analysis: the National Notifiable Disease Reporting System, hospital discharge abstracts from all 17 secondary and tertiary hospitals coded by ICD-10, laboratory information system records of pathogen assays, and auxiliary township-level outpatient referral logs to mitigate bias from hospital-only sources. Multi-source records were linked probabilistically using name, date of birth, gender, address, and symptom-onset date; ambiguous matches underwent manual double-checking by two epidemiologists to minimize duplicates and identify unique individuals.

Timeliness was measured through sequential time intervals: symptom onset to first healthcare contact, contact to specimen collection, specimen collection to laboratory results, result to online report submission, and report submission to public-health investigation—an extra interval tracked cerebrospinal fluid collection for meningococcal meningitis. Time intervals were computed in full days; extreme outliers were winsorized at the 99th percentile. Benchmarks included the national 24-hour reporting requirement, provincial PCR turnaround targets for pertussis, and WHO's 48-hour antibiotic-therapy reference for suspected meningitis [9].

Log-linear capture-recapture Poisson models with interaction terms estimated true case numbers and surveillance sensitivity, stratified by year and urban-rural status. Model selection relied on the Akaike Information Criterion, goodness-of-fit was assessed by chi-square statistics, and 95 % confidence intervals came from profile likelihood. Given skewed timeliness data, medians and interquartile ranges were reported; non-parametric tests and negative-binomial multivariable models adjusted for confounders such as age, sex, season, and hospital level were used. Analyses were implemented in R 4.3.2 with statistical significance set at two-sided $\alpha = 0.05$.

Ethical clearance was obtained from the Puyang Municipal CDC Institutional Review Board; informed consent was waived for de-identified secondary routine data. Identifiers were fully removed for confidentiality. The study followed the Declaration of Helsinki, Chinese epidemiological research regulations, and STROBE reporting guidelines [10].

3. Results

Over the six-year study period, a total of 2,847 unique pertussis cases and 316 unique meningococcal meningitis cases were identified through the National Notifiable Disease Reporting System within the jurisdiction of Puyang City, representing the primary capture stream for subsequent analyses. Among the pertussis cases, 1,852 (65.1%) were laboratory-confirmed by polymerase chain reaction, 423 (14.9%) by culture, and 572 (20.1%) were clinically diagnosed without microbiological evidence, whereas for meningococcal meningitis, 263 (83.2%) were laboratory-confirmed, with 189 (59.8%) by polymerase chain reaction, 52 (16.5%) by culture, and 22 (7.0%) by latex agglutination, while 53 (16.8%) met the probable clinical case definition. The age distribution showed a marked contrast between the two diseases: pertussis cases were predominantly infants under 12 months of age, accounting for 1,104 cases (38.8%), followed by children aged 1-4 years with 823 cases (28.9%), and adolescents and adults over 15 years comprising 612 cases (21.5%), while meningococcal meningitis displayed a bimodal pattern with 128 cases (40.5%) in

children under 5 years and 97 cases (30.7%) in individuals aged 15-24 years, reflecting the known serogroup shifts in the region. Seasonal peaks for pertussis occurred in late spring (May-June) and autumn (October-November), with 34.2% and 28.7% of annual cases, respectively, whereas meningococcal meningitis showed a winter-spring predominance, with 61.4% of cases reported between January and March, consistent with the respiratory transmission dynamics and indoor crowding patterns.

The estimated overall sensitivity of the pertussis surveillance system, derived from the log-linear capture-recapture model that integrated the four data streams with a three-way interaction term selected by the Akaike Information Criterion, was 68.4% with a 95% confidence interval ranging from 65.2% to 71.6%, indicating that approximately one-third of all true pertussis cases in the community were not captured by the official reporting mechanism during the entire study period. In contrast, the sensitivity for meningococcal meningitis was substantially higher at 82.1% (95% confidence interval 79.4-84.7%), reflecting the greater clinical severity and higher hospitalization rate that reduce the likelihood of missed diagnosis. Temporal trends revealed a progressive and statistically significant improvement in pertussis sensitivity, rising from 54.2% in the 2020-2021 biennium to 63.7% in 2022-2023 and further to 76.9% in 2024-2025 (Cochran-Armitage test for trend $Z=4.82$, $p < 0.001$), whereas meningococcal meningitis sensitivity remained relatively stable at 80.3%, 82.5%, and 83.4% across the three periods, with no significant trend ($Z = 1.26$, $p = 0.208$). When disaggregated by geographic area, a persistent rural-urban gap was observed for pertussis, with the sensitivity in Hualong District and urban zones reaching 78.2% (74.1-82.3%) compared to only 61.1% (56.9-65.3%) in the four rural counties, a difference of 17.1 percentage points that was statistically robust ($p < 0.001$), while for meningococcal meningitis, the urban-rural difference was narrower at 85.3% (81.7–88.9%) versus 79.6% (75.2–84.0%), yielding a 5.7 percentage point gap that did not reach significance after Bonferroni correction (adjusted $p = 0.067$). The capture-recapture model also indicated that the auxiliary stream from community clinic referrals contributed the largest number of additional cases not captured by the national reporting system, adding 412 pertussis cases and 31 meningitis cases to the estimated totals, which underscores the role of primary care as a critical but underutilized surveillance node.

Table 1 presents the estimated sensitivity, case counts, and capture probabilities for each data source stratified by disease and year, demonstrating that laboratory information systems had the highest capture probability for both diseases, exceeding 80% for polymerase chain reaction-positive cases, but that the hospital discharge databases contained substantial numbers of clinically coded cases that were never notified, particularly for pertussis in rural hospitals where electronic reporting compliance was lower.

Table 1. Estimated sensitivity and capture probabilities by data source, disease, and year

Disease	Year Period	National Reporting System (Captured N)	Hospital Discharge (Captured N)	Lab Information System (Captured N)	Community Clinic (Captured N)	Estimated Total Cases (Capture-Recapture)	Estimated Sensitivity (%)	95% CI
Pertussis	2020–2021	642	511	398	287	1,185	54.2	50.8–57.6
Pertussis	2022–2023	948	792	703	456	1,489	63.7	60.4–67.0
Pertussis	2024–2025	1,257	1,104	1,032	689	1,634	76.9	73.8–80.0
Meningitis	2020–2021	98	89	84	41	122	80.3	74.2–86.4
Meningitis	2022–2023	104	96	91	47	126	82.5	76.8–88.2
Meningitis	2024–2025	114	107	103	52	137	83.2	77.6–88.8

For timeliness, the median interval from symptom onset to online report submission for pertussis decreased significantly from 9 days (interquartile range 6–13 days) in 2020–2021 to 5 days (3–8 days) in 2022–2023 and further to 4 days (2–6 days) in 2024–2025 (Jonckheere-Terpstra test for trend $p < 0.001$), indicating a 55.6% reduction in overall reporting delay over the six years. Reductions in T3 primarily drove this improvement. This specimen-to-result interval fell from a median of 5 days to 2 days after the installation of three new polymerase chain reaction platforms in county-level laboratories in late 2023, and by reductions in T4. This result-to-report interval declined from 2 days to less than 1 day following the mandatory integration of laboratory information systems with the national reporting portal in April 2024. However, the onset-to-first-contact interval T1 showed only a modest reduction from 3 days to 2 days, and the first-contact-to-specimen interval T2 remained stagnant at approximately 1 day, suggesting that care-seeking delays and provider ordering practices have not changed substantially despite system-level improvements. In stark contrast, the timeliness for meningococcal meningitis demonstrated a paradoxical deterioration, with the overall onset-to-reporting median lengthening from 4 days (3–6 days) in 2020–2021 to 6 days (4–9 days) in 2022-2023 and then to 7 days (5–10 days) in 2024–2025 ($p = 0.003$ for trend), which was entirely attributable to a marked prolongation of the specimen-to-result interval T3, increasing from 1 day to 4 days and then to 5 days, because the centralization of meningococcal polymerase chain reaction testing to the provincial reference laboratory in Zhengzhou, implemented in January 2023, introduced transportation and batching delays that outweighed any gains in electronic reporting efficiency.

Table 2 summarizes the median timeliness intervals and their interquartile ranges for both diseases across the three temporal periods, as well as the proportion of cases meeting key performance benchmarks, revealing that for pertussis, the proportion with polymerase chain reaction confirmation within the recommended 7-day window increased from 41.8% to 61.4% ($p < 0.001$), yet still fell short of the provincial target of 75%, whereas the proportion of cases reported within 24 hours of diagnosis reached 93.7% in 2024–2025, exceeding the national standard. For meningococcal meningitis, the 24-hour reporting compliance remained excellent at 96.2% overall, but the proportion of cases with cerebrospinal fluid collection within 48 hours of hospital admission declined from 88.5% to 73.2% over the study period ($p = 0.012$), indicating that clinical suspicion and timely lumbar puncture have decreased, possibly due to antibiotic pretreatment in community settings before referral.

Table 2. Median timeliness intervals (days, IQR) and benchmark proportions by disease and period

Disease	Period	Onset-to-Report (T1-T4) Median (IQR)	Onset-to-1st Contact T1 Median (IQR)	Specimen-to-Result T3 Median (IQR)	Result-to-Report T4 Median (IQR)	PCR Confirmed within 7 days (%)	Reported within 24h (%)
Pertussis	2020–2021	9 (6–13)	3 (2–4)	5 (3–7)	2 (1–3)	41.8	89.2
Pertussis	2022–2023	5 (3–8)	2 (1–3)	3 (2–5)	1 (1–2)	52.6	92.1
Pertussis	2024–2025	4 (2–6)	2 (1–3)	2 (1–3)	<1 (0–1)	61.4	93.7
Meningitis	2020–2021	4 (3–6)	1 (1–2)	1 (1–2)	1 (1–2)	89.7	97.3
Meningitis	2022–2023	6 (4–9)	1 (1–2)	4 (2–6)	1 (1–2)	78.4	95.8
Meningitis	2024–2025	7 (5–10)	1 (1–2)	5 (3–7)	1 (1–2)	72.1	96.2

When comparing urban and rural performance for pertussis timeliness in the final 2024–2025 period, urban counties achieved a median onset–to–reporting interval of 3 days (2–5 days) versus 6 days (4–9 days) for rural counties (Wilcoxon test $p < 0.001$), a 3–day differential that persisted after adjusting for age, sex,

and seasonal effects in the multivariable negative binomial model, with an adjusted median ratio of 1.82 (95% confidence interval 1.54–2.15) for rural compared to urban, indicating that rural cases took nearly twice as long to be reported even after accounting for case mix. For meningococcal meningitis, the urban–rural timeliness gap was smaller but still significant, with medians of 5 days and 8 days, respectively (adjusted median ratio 1.41, 95% confidence interval 1.12–1.78), and the gap was most pronounced in the interval from first contact to cerebrospinal fluid collection, which averaged 2 days in urban hospitals but 4 days in rural township facilities, where on–site lumbar puncture capabilities and immediate laboratory transport are limited.

Table 3 provides a comparative analysis of surveillance sensitivity and timeliness stratified by diagnostic method, age group, and hospital level, demonstrating that polymerase chain reaction-confirmed pertussis cases had significantly shorter onset-to-reporting intervals (median 4 days) compared to clinically diagnosed cases (median 7 days, $p < 0.001$), but that the sensitivity for polymerase chain reaction-positive cases was actually lower (64.2%) than for clinically diagnosed cases (72.8%) because a large proportion of polymerase chain reaction tests are ordered only for hospitalized patients, missing milder outpatient cases that are clinically recognized but not microbiologically confirmed. Infants under 12 months of age had the highest sensitivity for pertussis at 79.5%, likely due to more severe disease and mandatory hospitalization, while adolescents aged 10–19 years had the lowest sensitivity at 52.3%, reflecting mild or atypical presentations that do not prompt diagnostic testing or reporting. For meningococcal meningitis, the sensitivity was uniformly high across age groups, ranging from 78.9% to 86.4%, but the timeliness was markedly worse for adults over 40 years, with a median onset-to-reporting of 9 days compared to 5 days for children under 5 years, because adults often present with non-specific prodromal symptoms and are admitted to general medicine wards where meningitis is not initially suspected, delaying both lumbar puncture and notification. Tertiary hospitals demonstrated superior timeliness for both diseases, with pertussis reporting intervals of 3 days and meningitis intervals of 5 days. In contrast, secondary hospitals and primary health centers had intervals of 6 days and 9 days, respectively. The sensitivity gap between tertiary and primary facilities was 18.5 percentage points for pertussis and 9.2 percentage points for meningitis, highlighting the central role of hospital level in overall surveillance performance. The multivariable analysis further identified that cases reported during the winter season had a 1.4-day longer timeliness for meningococcal meningitis ($p = 0.038$), possibly due to increased caseloads and laboratory batching, while no significant seasonal effect was observed for pertussis after adjusting for the secular trend.

Table 3. Sensitivity and onset-to-report timeliness by diagnostic method, age group, and hospital level (2024–2025)

Stratum	Subgroup	Pertussis Sensitivity (%)	Pertussis Onset-to-Report Median Days (IQR)	Meningitis Sensitivity (%)	Meningitis Onset-to-Report Median Days (IQR)
Diagnostic method	PCR–Confirmed	64.2	4 (2–6)	83.7	7 (5–10)
	Clinically Diagnosed	72.8	7 (5–10)	78.9	9 (6–12)
Age group	< 1 year (Pertussis) / < 5 years (Meningitis)	79.5	3 (2–5)	86.4	5 (3–7)
	1–4 years (Pertussis) / 5–14 years (Meningitis)	71.3	4 (3–6)	83.1	6 (4–8)

Age group	5–14 years (Pertussis) / 15–24 years (Meningitis)	62.8	5 (3–7)	81.2	7 (5–9)
	10–19 years (Pertussis) / > 40 years (Meningitis)	52.3	5 (4–8)	78.9	9 (6–13)
Hospital level	Tertiary (Class A/ B)	78.9	3 (2–5)	86.7	5 (3–7)
	Secondary	66.4	6 (4–9)	81.4	8 (6–11)
	Primary/ Community	60.4	7 (5–11)	77.5	9 (7–13)

4. Discussion

This evaluation illustrates distinct surveillance performance characteristics for pertussis and meningococcal meningitis in Puyang, revealing notable progress in pertussis detection alongside compromised timeliness in meningitis surveillance driven by centralized laboratory policies. Pertussis surveillance achieved an overall sensitivity of 68.4%, a substantial improvement from the 2018 Henan regional rate of 55%. Even so, over 3,000 local cases may go undetected annually, creating hidden community transmission risks, especially for unvaccinated neonates dependent on herd immunity. The post-2023 improvement in detection sensitivity correlates with county-level PCR laboratory expansion and enhanced clinical awareness following national pertussis resurgence alerts, proving coordinated policy incentives and infrastructure investment can boost disease detection. However, a persistent 17% rural-urban sensitivity gap remains. Rural surveillance is hindered by workforce shortages, limited access to PCR testing facilities, and insufficient clinician reporting awareness, requiring targeted mobile diagnostic services and grassroots outreach rather than passive facility upgrades.

For meningococcal meningitis, the stable high sensitivity of 82.1% reflects the disease's obvious clinical manifestations and mandatory national immediate reporting protocols. Yet, a concerning rise in reporting delay from 4 to 7 days emerged despite optimized electronic reporting systems. This paradox stems from provincial centralization of meningococcal PCR testing: while designed for quality control, the policy introduced a 4-day median delay in specimen transportation and batch testing, becoming the primary bottleneck in surveillance. Additionally, the 48-hour cerebrospinal fluid collection rate dropped from 88.5% to 73.2%, attributed to declining clinical proficiency in identifying classic infectious disease symptoms amid widespread empirical antibiotic use, highlighting the need for regular professional training on meningitis diagnosis and pre-antibiotic specimen collection. Structural rural-urban inequities undermine surveillance quality for both diseases. Rural areas suffer from sparse epidemiological staffing, high staff turnover, and outdated paper-based recording systems that delay electronic data entry. Targeted bundled interventions are recommended, including grassroots rapid molecular testing, simplified automatic electronic reporting, performance-based incentives, and regular clinical supervision. Age-specific surveillance gaps are also prominent. Adolescent pertussis sensitivity is merely 52.3%, as adolescent mild symptoms are often misdiagnosed as viral infections and low bacterial loads reduce PCR accuracy, suggesting a need to explore serological testing for older populations. Adults over 40 with meningitis face a 9-day reporting delay and higher mortality, requiring targeted clinician education and standardized screening protocols.

Methodologically, the capture-recapture model's source dependence may slightly overestimate sensitivity, though auxiliary data supplementation ensured reliable results. Minor missing case data did not alter core conclusions, while findings are regionally specific, with qualitative policy lessons widely applicable.

This study's six-year longitudinal design, dual-disease comparison, and multi-dimensional stratification provide actionable insights. High-performing tertiary hospitals confirm that strengthening primary and secondary medical facilities can effectively reduce missed diagnoses and reporting delays, with robust electronic reporting infrastructure laying a foundation for further surveillance optimization.

5. Conclusion

This evaluation of vaccine-preventable disease surveillance in Puyang City under the new circumstances of post-pandemic healthcare restructuring and advanced diagnostic deployment demonstrates that while electronic reporting timeliness has reached commendable levels for both pertussis and meningococcal meningitis, with over 93% of cases notified within 24 hours of diagnosis, the overall system sensitivity remains suboptimal for pertussis at 68.4%, leaving a substantial proportion of true infections undetected, and the timeliness of meningococcal meningitis has paradoxically worsened due to centralized laboratory consolidation that introduced prolonged transport and batching delays. The rural-urban disparities, with rural areas exhibiting 22% lower sensitivity and 3-day longer reporting intervals for pertussis, constitute a major equity challenge that requires decentralized molecular testing capacity, enhanced primary care training, and performance monitoring tailored to resource-limited settings. Age-specific vulnerabilities, particularly the low sensitivity for adolescent pertussis and the delayed reporting for adult meningitis, call for revised case definitions and heightened clinical awareness across all age strata, moving beyond the traditional pediatric focus of these diseases. The divergent performance trajectories of the two pathogens underscore the necessity of disease-specific surveillance improvement strategies rather than one-size-fits-all approaches, with pertussis requiring expanded outpatient testing and reporting incentives, and meningococcal meningitis requiring restoration of rapid on-site diagnostic capabilities alongside continued quality assurance at the reference level. Moving forward, we recommend a phased action plan for Puyang that prioritizes point-of-care polymerase chain reaction deployment in all county hospitals, a mobile application for rural health workers that simplifies case reporting and provides immediate feedback on test results, and a biannual audit and feedback cycle that benchmarks facility-level sensitivity and timeliness indicators, thereby fostering a culture of continuous quality improvement. Ultimately, the success of these interventions will depend on sustained political commitment, adequate budgetary allocation for laboratory supplies and transportation, and the active engagement of frontline clinicians who must be convinced that their reporting efforts directly influence disease control outcomes in their own communities. With these measures, Puyang can not only close the current surveillance gaps but also establish a resilient, equitable, and responsive system that serves as a model for other prefecture-level cities navigating the complex terrain of vaccine-preventable disease surveillance in an era of epidemiological transition and health system transformation.

Disclosure statement

The authors declare no conflict of interest.

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Current Status and Prospects of Clinical Research on Mongolian Medicine in the Treatment of Insomnia

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Abstract: Insomnia is a highly prevalent sleep disorder in modern society and also one of the common clinical symptoms. It is closely associated with various systemic diseases and significantly impacts people's physical and mental health as well as quality of life. Mongolian medicine has a longstanding tradition in treating insomnia, with extensive clinical experience, definite therapeutic effects, and few adverse reactions. According to Mongolian medical theory, insomnia falls within the category of "Khii" disorders, with the core pathogenesis being excessive Khii and imbalance among the three humors (Khii, Shara, Badagan) and seven constituents. This paper provides a comprehensive review and analysis of the etiology and pathogenesis, clinical research progress, oral Mongolian medicines, traditional Mongolian external therapies, and combined internal and external treatments for insomnia. Currently, commonly used Mongolian medicines include classic formulas such as Sugmel3 Decoction, Agar35, and Amin Erdun. Traditional external therapies include warm needle acupuncture, moxibustion, herbal baths, and topical rubbing therapies. The overall clinical effectiveness rate usually exceeds 90%, with advantages such as definite efficacy, few adverse reactions, and no drug dependence. However, current studies still face methodological issues including small sample sizes, insufficient implementation of randomization and blinding, lack of unified diagnostic and efficacy criteria, and inadequate followup. Future research should promote multicenter, largesample, highquality randomized controlled trials, establish an evidencebased Mongolian medicine database and clinical guidelines, strengthen research on the material basis and mechanisms of action of Mongolian medicines, and advance the modernization and international development of Mongolian medicine in the treatment of insomnia.

Keywords: Insomnia; Mongolian medicine; Clinical research; Prospects

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1. Introduction

Insomnia disorder is a sleepwake disorder characterized by difficulty initiating sleep, maintaining sleep,

or early morning awakening, combined with daytime functional impairment. Its prevalence ranges from 10% to 30% and is increasing annually [1]. Modern medicine primarily employs benzodiazepine receptor agonists, melatonin receptor agonists, and cognitive behavioral therapy for insomnia (CBTI). However, issues such as drug dependence, tolerance, and high relapse rates significantly constrain longterm application [2]. In this context, the alternative and complementary value of traditional medicine has drawn increasing attention. Mongolian medicine, as an important component of traditional Chinese medicine, possesses a complete theoretical system and rich clinical experience, with a long history in the diagnosis and treatment of insomnia. According to Mongolian medical theory, the pathogenesis of insomnia mainly involves excessive Khii interacting with blood, and the therapeutic principle is to calm Khii and regulate the balance of the three humors. There are numerous treatment modalities for insomnia in Mongolian medicine, including Mongolian herbal formulas, moxibustion, warm needling, acupuncture, and herbal baths, all of which have demonstrated notable clinical efficacy. In recent years, clinical studies on Mongolian medicine for insomnia have gradually increased; however, systematic evidencebased evaluations and clear future directions remain insufficient. This paper aims to integrate the clinical evidence and modern mechanistic research findings on Mongolian compound prescriptions and distinctive therapies, analyze the major bottlenecks currently faced in research, and propose subsequent research directions, with the goal of providing a reference for the development of Mongolian medical sleep medicine.

2. Mongolian medical understanding of the etiology and pathogenesis of insomnia

In Mongolian medical classics, insomnia has not been recorded as an independent disease entity, but rather as symptoms such as “insomnia,” “easy awakening,” “poor sleep,” “inability to fall asleep,” and “reduced sleep”, which are sporadically documented under categories such as “Khii disorders” and “heart disorders” [3]. For instance, The Spring of Sweet Dew states: “The manifestations of excessive Khii include emaciation, preference for warmth, shivering, abdominal distension, constipation, dizziness, talkativeness, feeling powerless, restless sleep, and dull senses” [4]. Blue Lapis Lazuli mentions that “Khii disorders generally present with sleeplessness at night, yawning accompanied by shivering; if the disease is located in the heart, there may also be generalized trembling, chest tightness, dizziness, reduced night sleep, and sighing” [5]. In addition, ancient texts such as Zhe Dui Ning Nuo Er, Lan Ta Bu, Mongolian Medical Golden Cabinet, and Golden Light Annotations also contain relevant records. In the 1980s, Teacher Ce. Sürenzhabu, in his Mongolian Internal Medicine, for the first time established insomnia as an independent disease entity. According to Mongolian medical theory, insomnia results from imbalances in the three bodily humors (Khii, Shara, Badagan) caused by disturbances in “body, mind, and speech” functions, thereby giving rise to “Khii disorders” characterized by an imbalance among the three humors and predominance of Khii [6]. When Khii becomes excessively predominant and disturbed, the balance of the three humors is disrupted, leading not only to elevation of Khii but also to dysfunction in the interrelationships, pathways, and functions of the five subtypes of Khii [3].

Based on etiology, insomnia in Mongolian medicine can be classified into Khiipredominant type, Sharapredominant type, and Badaganpredominant type; according to the site of involvement, it can be classified into cardiac type, renal type, and whitechannel type [7].

3. Current status of clinical research on Mongolian medicine for insomnia

3.1. Mongolian herbal medicine for insomnia

Aochier randomly divided 88 insomnia patients into a treatment group and a control group, with 44 cases in each [8] . Both groups received basic medications: oryzanol 20 mg, vitamin B1 20 mg, and doxepin 25 mg, taken orally three times daily. The treatment group additionally received a Mongolian herbal compound consisting of Gaoyou13 Pills, Amin Erdun, and Chenxiang35 as core components. The treatment course was 10 days per cycle, for a total of 3 cycles. The total effective rate in the treatment group was 93.18%, significantly higher than the 72.73% in the control group. Deng Siqin et al. divided 60 patients with Khiitype insomnia equally into two groups [9]. The treatment group received 3 g of Sugmel3 Decoction boiled in 100 mL of pure milk taken orally before bedtime, while the control group received the same dose of Sugmel3 Decoction boiled in 100 mL of water, once nightly for 10 consecutive days. After treatment, the total effective rate was 93.3% in the treatment group and 83.3% in the control group. Mu Ren et al. enrolled 56 insomnia patients and treated them with Mongolian medicine primarily containing Chenxiang37, achieving a total effective rate of 94.6% [10]. Bao Gerile et al. divided 60 patients with cardiactype insomnia into an experimental group and a control group, with 30 cases each [11]. The experimental group received Shunqi Buxin11 Pills orally daily, while the control group received Tianmeng Oral Liquid. Both groups were treated for 21 days. After treatment, the Athens Insomnia Scale scores decreased in both groups compared with baseline; the total effective rate was 76.7% in the experimental group, slightly higher than 73.3% in the control group. Sa Riga studied 224 insomnia patients, divided into an observation group and a control group [12]. The control group received Western medications, while the observation group received formulas such as Amin Erdun, Sugmel3 Decoction, and Chenxiang35. Comparison of sleep quality scores between the two groups showed that the observation group had significantly better efficacy than the control group ($p < 0.05$). Bai Bisina enrolled 80 insomnia patients and randomly assigned them to a treatment group and a control group. The treatment group received oral Mongolian medicines (Wuwei Qingzhuo Pills, JiruhenAgaru8, Shunqi Anshen Pills, Sugmel3 Decoction), while the control group received zopiclone tablets, both for 4 weeks [13] . The total clinical effective rate was 85% in the treatment group and 87.5% in the control group. Wu Rihan selected 64 insomnia patients and divided them into an observation group and a control group, with 32 patients each [14] . The control group received a Western medication regimen, while the observation group received Amin Erdun, 3 g each time, twice daily (upon waking and before bedtime), for 28 consecutive days. The total effective rate was 87.5% in the observation group and 78% in the control group.

3.2. Traditional Mongolian external therapies for insomnia

Wu Hongying conducted a randomized study of 116 insomnia patients, in which the control group received routine Western medication, and the treatment group received Mongolian herbal foot baths; the nursing outcomes were compared between the two groups [15]. The study showed that the PSQI score in the treatment group was significantly lower than that in the control group, with statistically significant differences ($p < 0.05$); intergroup comparison of efficacy also showed statistical significance ($p < 0.05$). Mongolian herbal foot baths had a definite effect on improving insomnia symptoms and enhancing patients' sleep quality. Jin Qiu et al. studied 80 patients with Khiipredominant insomnia, dividing them into a treatment group and a control group with 40 cases each [16] . The treatment group received Mongolian warm needling, while the control group received placebo acupuncture. The Insomnia Severity Index (ISI) scores and sleep electroencephalogram parameters were recorded before and after treatment. Results showed that after treatment, the treatment group

had increased total sleep time, shortened sleep latency, improved sleep efficiency, and altered sleep structure, namely a decreased proportion of N1 sleep and an increased proportion of REM sleep (all $p < 0.05$). Sa Chula selected 60 insomnia patients and divided them into a treatment group and a control group, with 30 cases each. The control group received 3 mg of eszopiclone orally before bedtime each night, while the treatment group received Mongolian hot oil therapy at the Khii acupoint, Dinghui acupoint, Heibaiji acupoint, and Heart acupoint (or Kidney acupoint), once every other day. Both groups were treated for 4 consecutive weeks [17]. The total effective rate was 83.33% in the treatment group and 26.67% in the control group, with a highly statistically significant difference between the groups ($p < 0.01$).

3.3. Mongolian herbal medicine combined with traditional external therapies for insomnia

Te Rigèle selected 82 insomnia patients and treated them with moxibustion combined with Mongolian medicines, including Tonglaga5, Gaoyou13, Amin Erdun, Sugmel3 Decoction, Zadi5, Yihehari12, and Yihe Decoction, achieving a total effective rate of 98.78% [18]. Ao Fu used Mongolian herbal compounds and acupuncture to treat insomnia. The Mongolian herbal compounds included ErdunWurile, Chenxiang15, and Amin Erdun; acupuncture was applied to the Dinghui acupoint with warm needling [19]. The total effective rate was 98.78%, indicating significant efficacy. Li Xia studied 248 patients with Khiipredominant insomnia, randomly divided into an observation group (134 cases) and a control group (114 cases) [20]. The observation group received Mongolian warm needling combined with oral Mongolian medicines, mainly including Tonglaga5, Amibaqir11, Gaoyou13, and Sugmel3 Decoction. The total effective rate in the observation group reached 100%. Chen Pingping treated insomnia patients with moxibustion alone or Mongolian herbal compounds (ErdunWurile, Gaoyou13, Shunqi Buxin ElevenIngredient Pills, Amin Erdun, Sugmel3, etc.) combined with moxibustion [21]. The results showed that the combination group had a significantly higher total effective rate than the moxibustionalone group, indicating that Mongolian herbal compounds combined with moxibustion exerted a synergistic therapeutic effect and improved clinical outcomes. Bao Liming selected 120 insomnia patients, of whom 60 received oral Mongolian medicines combined with warm needling [22]. The Mongolian medicines included Sugmel3 Decoction, Chenxiang35 Decoction, ErdunWurile, and Yihe25 Decoction. The total effective rate in the observation group was 98.33%. Dao Rina divided 88 patients with clearly diagnosed Khiipredominant insomnia into a treatment group and a control group according to randomization principles. The treatment group received Mongolian moxibustion combined with oral Sugmel3 Decoction and Gaoyou13 Pills, while the control group received the same Mongolian medicines orally only. Both groups took the medicines once daily, and the treatment group received moxibustion once every 2 days, for a treatment course of 20 days. The Pittsburgh Sleep Quality Index (PSQI) and Mongolian medical symptom scores were used as the primary outcome measures. Results showed that, based on Mongolian medical symptom criteria, the total effective rate was 87.8% in the treatment group and 76.2% in the control group; after 20 days of treatment, improvements in symptoms such as insomnia, fatigue, dizziness, blurred vision, yawning, and dreaminess were superior in the treatment group compared with the control group.

4. Problems and prospects

4.1. Existing problems

Although Mongolian medicine has accumulated considerable clinical practice in the treatment of insomnia,

its clinical research still has numerous methodological deficiencies. The overall sample sizes in clinical studies are relatively small, and there is a shortage of multicenter, largesample randomized controlled trials, which limits the level of evidencebased medicine. The efficacy evaluation criteria for Mongolian medicine in treating insomnia are not yet unified; most studies rely primarily on scales such as the Pittsburgh Sleep Quality Index, lacking objective laboratory indicators and standardized assessment systems. Existing research has explored the molecular mechanisms of certain herbal medicines and warm needling, but the integrated regulatory mechanisms of multicomponent, multitarget, and multipathway actions of Mongolian herbal compound formulas remain poorly understood, and the doseresponse relationship between active substance bases and pharmacological effects has not been fully elucidated. The standardization and normalization of Mongolian medicine treatment protocols are insufficient, and the criteria for syndrome differentiation are not uniform, which hinders clinical promotion and academic exchange.

4.2. Prospects

Future research on Mongolian medicine interventions for insomnia should be advanced in several key directions. First, highquality multicenter, largesample, randomized doubleblind controlled clinical trials should be conducted, incorporating a variety of sleep assessment tools into the comprehensive efficacy evaluation system to enhance the level of clinical evidence. The construction of an evidencebased Mongolian medicine database, the development of clinical guidelines, and the translation of research findings into practice are important pathways for the internationalization of Mongolian medicine. Systematic collation of ancient texts and existing clinical literature should be undertaken to build a sharedresource evidencebased database. With reference to international evidence evaluation standards, clinical guidelines and diagnostictreatment protocols for Mongolian medical treatment of insomnia should be formulated. The development of new Mongolian medicines and the standardization of traditional therapies should be advanced, and industryuniversityresearch collaborative innovation should be leveraged to promote the translation of achievements, thereby facilitating the internationalization of Mongolian medicine.

5. Conclusion

Mongolian medicine treats insomnia based on the theory of “threehumor balance,” with the core pathogenesis being excessive Khii and dysregulation of the seven constituents and three wastes. It emphasizes holistic regulation and individualized syndromebased treatment. Current evidence indicates that oral Mongolian medicines, warm needling, and moxibustion can all improve sleep, with overall effective rates mostly exceeding 90%. These modalities are characterized by rapid onset, few adverse reactions, and low dependence liability, and combined use of multiple methods yields even better outcomes. However, most current studies are singlecenter with small sample sizes, and deficiencies remain in randomization, blinding, diagnostic and evaluation criteria, and longterm followup, which constrain the improvement of evidence quality and clinical dissemination.

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Effect of Prefabricated Fiber Posts in Oral Prosthetic Restoration and Analysis of Treatment Success Rate

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Abstract: *Objective:* To investigate the actual effects of prefabricated fiber posts on masticatory function, restoration success rate, and postoperative adverse events in patients with tooth defects undergoing oral prosthetic restoration. *Methods:* From January 1, 2023 to December 30, 2024, 100 patients diagnosed with tooth defects and scheduled for postandcore crown restoration in our hospital were selected. After screening, 86 cases meeting the inclusion criteria were enrolled in this study. They were divided into two groups using a random number table: the control group (43 cases) received traditional cast metal posts, and the observation group (43 cases) received prefabricated fiber posts. All subjects completed a 12month followup. Bite force and masticatory efficiency before and after restoration were compared between the two groups; the time required for restoration, clinical success rate, and postoperative complications were also recorded. Results: Before restoration, there were no statistically significant differences in bite force and masticatory efficiency between the two groups ($p > 0.05$). After 12 months of restoration, both groups showed improvement in masticatory efficiency and bite force, with the observation group demonstrating significantly greater improvement than the control group ($p < 0.05$). The observation group had shorter operative time per treated tooth and a higher success rate ($p < 0.05$). The overall incidence of various complications during the followup period was lower in the observation group than in the control group ($p < 0.05$). *Conclusion*: For patients with extensive tooth defects after root canal therapy, using prefabricated fiber posts for postandcore crown restoration can effectively improve masticatory function, shorten chairside operation time, increase the overall success rate, and reduce problems such as root fracture and post loosening. With strict adherence to indications, this approach is suitable for clinical application in prosthetic dentistry.

Keywords: Oral restoration; Prefabricated fiber post; Cast metal post; Bite force; Masticatory efficiency; Restoration success rate

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1. Introduction

Tooth defects are a common condition in dentistry, with caries, external trauma, and longterm attrition being frequent causes. For teeth with extensive defects, after adequate root canal therapy, the dental hard tissue loses pulp supply and overall tooth strength decreases. A simple full crown restoration often fails to achieve satisfactory retention; thus, a postandcore system is needed to establish retention, rebuild tooth morphology, and restore masticatory function [1]. Cast metal posts have been a commonly used restorative method in the past, offering high mechanical strength. However, the elastic modulus of metal differs significantly from that of natural dentin. Under occlusal loading, stress concentration tends to occur locally in the root canal, increasing the risk of root fracture. Moreover, metal materials can interfere with magnetic resonance imaging, and in anterior teeth, the metallic color may show through the crown, resulting in obvious aesthetic shortcomings [2]. Prefabricated fiber posts, as a gradually popularized postandcore material in recent years, have an elastic modulus closer to that of human dentin, which helps dissipate occlusal stresses and reduces the risk of root damage. Their color is similar to natural teeth, and they exhibit good bonding performance with a relatively simple clinical procedure. They are increasingly being used for the restoration of tooth defects after root canal therapy [3]. Against this background, the present controlled trial was conducted to observe the actual restorative effect of prefabricated fiber posts. The detailed report is as follows.

2. Materials and methods

2.1. Clinical data

A total of 100 patients with tooth defects requiring postandcore crown restoration admitted to our hospital from January 1, 2023 to December 30, 2024 were initially selected. After screening with inclusion and exclusion criteria, 86 subjects were enrolled and divided into a control group and an observation group using a random number table, with 43 cases in each group. Baseline data including gender composition, age range, distribution of defective tooth positions, and etiological factors were compared between the two groups, and no statistically significant differences were found ($p > 0.05$), indicating comparability between groups (see **Table 1**).

Table 1. Comparison of clinical data between the two groups

Clinical data	Control group (n = 43)	Observation group (n = 43)	χ^2/t	p
Gender (n, %)			0.186	0.666
Male	23 (53.49)	21 (48.84)		
Female	20 (46.51)	22 (51.16)		
Age ($\bar{x} \pm s$, years)	46.37 ± 7.41	45.94 ± 7.28	0.272	0.786
Tooth defect position (n, %)			0.317	0.573
Anterior teeth	16 (37.21)	19 (44.19)		
Posterior teeth	27 (62.79)	24 (55.81)		
Etiology of defect (n, %)			0.441	0.802
Caries	26 (60.47)	24 (55.81)		
Dental trauma	12 (27.91)	14 (32.56)		
Wear and others	5 (11.63)	5 (11.63)		

2.1.1. Inclusion criteria

(1) The affected tooth had undergone adequate root canal therapy with dense obturation and no active inflammatory response in the periapical area [4];
(2) The coronal defect area was ≥ 1/2, with remaining tooth tissue sufficient to support postandcore restoration;
(3) Root length and root canal wall thickness were adequate for post retention;
(4) Occlusal relationship was generally normal without severe occlusal disturbances;
(5) Patients were fully informed of the study content, voluntarily participated, and were able to complete the entire followup.

2.1.2. Exclusion criteria

(1) The root had cracks or fractures, or extensive defects in the root canal wall;
(2) Severe parafunctional habits such as bruxism or clenching;
(3) Severe periodontal disease with tooth mobility of grade II or above [5];
(4) Severe systemic diseases precluding tolerance of prosthetic procedures;
(5) Pregnancy or lactation;
(6) Incomplete followup data preventing outcome assessment.

2.2. Treatment methods

2.2.1. Control group

For all affected teeth in the control group, periapical radiographs and oral CT were taken preoperatively. The root canal morphology, root wall thickness, and periapical tissue status were carefully evaluated to confirm that the quality of prior root canal treatment met the standards [6]. The control group received cast metal post restorations: post space preparation was performed, followed by root canal impression taking and gypsum cast pouring. The casts were sent to a dental laboratory for fabrication of cast metal post-and-core units. After the finished restorations were returned to the department, intraoral tryin was conducted to check seating and marginal adaptation, followed by adjustment and trimming; resin cement was used for luting and fixation. Subsequently, routine tooth preparation was performed, intraoral impressions were taken, and full crowns were fabricated. After tryin, occlusal adjustments were made and the crowns were cemented. Postoperative oral hygiene instructions were provided to the patients, and regular followup visits were scheduled.

2.2.2. Observation group

The observation group received prefabricated fiber post restorations: post space preparation was performed according to standard protocols, and glass fiber posts of appropriate specifications were selected based on the actual internal diameter of the root canal. Intraoral tryin was conducted to confirm smooth seating. The root canal was etched, rinsed, and dried evenly; adhesive was uniformly applied; and the prefabricated fiber post was luted and fixed within the root canal using resin cement, followed by lightcuring. Thereafter, composite resin was used to build up the core structure, and the core contour was trimmed. Tooth preparation, impression taking, full crown fabrication, tryin, occlusal adjustment, and cementation were then completed. Postoperative oral hygiene instructions and followup schedules were consistent with those of the control group. All fiber post luting procedures strictly followed the technical specifications for clinical luting of fiber posts, so as to minimize the risk of restoration failure due to improper cementation procedures [7].

2.3. Observation indicators

2.3.1. Occlusal force and masticatory efficiency

Measurements were performed before restoration and at 12 months after restoration completion. Masticatory efficiency was determined using a 2g peanut chewing test: the subjects chewed with bilateral target teeth for 20 strokes on each side; the peanut residues in the oral cavity were collected and weighed, and masticatory efficiency was calculated. For occlusal force measurement, a bite test sheet was placed on the target tooth, and the subject was asked to bite evenly for 20 seconds; the test was repeated 10 consecutive times, and the average of the three highest values was taken as the occlusal force result for that tooth [8].

2.3.2. Operation time for singletooth restoration

The time from the completion of post space preparation to the completion of postandcore luting and curing was recorded, in minutes.

2.3.3. Restoration success rate

Restoration outcomes were evaluated during a 12month followup. Success criteria included: stable restoration without loosening or detachment; stable occlusion with no masticatory pain; and no periapical abnormalities or root fracture on radiographic reexamination. Failure was defined as the occurrence of any of the following: postandcore loosening, crown detachment, root fracture, recurrent occlusal pain, or new periapical lesions [9].

2.3.4. Complication rate

The total incidence of complications, including postandcore loosening, root fracture, secondary periapical periodontitis, and gingival inflammation, was recorded during the 12month followup period.

2.4. Statistical methods

Data analysis was performed using SPSS 24.0 software. Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), and betweengroup comparisons were conducted using independentsamples *t* tests. Count data were expressed as n (%) and analyzed using the chisquare test. A p value of < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of occlusal force and masticatory efficiency between the two groups before and after treatment

Before restoration, there was no statistically significant difference in masticatory efficiency or occlusal force between the two groups ($p > 0.05$). At 12 months after restoration, both functional indicators improved compared with baseline in both groups, and the improvements in the observation group were significantly greater than those in the control group ($p < 0.05$), as shown in **Table 2**.

Table 2. Comparison of masticatory efficiency and occlusal force between the two groups before and after treatment ($\bar{x} \pm s$)

Group	Masticatory efficiency (%)		Bite force (kg)	
	Before treatment	After treatment	Before treatment	After treatment
Control group (n = 43)	52.41 ± 4.72	71.25 ± 5.84*	37.42 ± 4.83	48.71 ± 5.26*
Observation group (n = 43)	52.63 ± 4.58	79.64 ± 6.37*	37.16 ± 4.65	55.33 ± 5.74*
t value	0.219	6.418	0.254	5.581
p value	0.827	< 0.001	0.800	< 0.001

Note: Compared with the same group before treatment, *$p < 0.05$.

3.2. Comparison of restoration procedure time and success rate between the two groups

The mean time for postandcore restoration per affected tooth in the observation group was significantly shorter than that in the control group, and the proportion of successful restorations was higher in the observation group, with statistically significant differences between the groups ($P < 0.05$), as shown in **Table 3**.

Table 3. Comparison of restoration procedure time and success rate between the two groups

Group	Number of cases	Single tooth restoration time ($\bar{x}$, min)	Success n (%)	Failure n (%)
Control group	43	74.36 ± 8.42	34 (79.07)	9 (20.93)
Observation group	43	51.73 ± 6.25	41 (95.35)	2 (4.65)
t/χ^2 value		14.124	5.108	
p value		< 0.001	0.024	

3.3. Comparison of complication rates between the two groups

After 12 months of followup, the overall incidence of complications in the observation group was lower than that in the control group, and the difference was statistically significant ($p < 0.05$), as shown in **Table 4**.

Table 4. Comparison of complication rates between the two groups [n (%)]

Group	Postcore loosening or dislodgement	Root fracture	Apical periodontitis	Gingival inflammation	Total incidence rate
Control group (n = 43)	3 (6.98)	3 (6.98)	2 (4.65)	3 (6.98)	11 (25.58)
Observation group (n = 43)	1 (2.33)	0 (0.00)	1 (2.33)	1 (2.33)	3 (6.98)
χ^2					5.460
p					0.019

4. Discussion

After root canal treatment, the dental hard tissue loses the nutritional and metabolic support from the pulp, leading to increased tooth brittleness. When the crown defect is extensive and the remaining tooth structure is limited, direct fullcrown restoration often fails to achieve adequate retention, necessitating the use of a postandcore system to establish a foundation for retention, reconstruct the crown morphology, and restore the patient's daily masticatory function [10]. Cast metal postandcores have been used clinically for a long time and possess high mechanical strength; however, the elastic modulus of metal posts differs considerably from that of human dentin. When the tooth bears occlusal loads, stress concentration tends to occur at weak points

within the root canal, increasing the risk of root fracture. Additionally, metal materials interfere with the imaging quality of magnetic resonance examinations, and in anterior tooth restorations, the metallic shade is prone to show through the restoration crown, adversely affecting aesthetics, thus limiting their clinical application [11].

Prefabricated glass fiber posts are mainly composed of glass fiber and resin composite, with an elastic modulus closer to that of natural dentin. When the tooth bears occlusal forces, they can distribute stress within the root canal, thereby reducing the risk of root fracture [12]. As prefabricated products, these posts do not require impressiontaking or offsite processing; after root canal post space preparation, the appropriate post can be selected and bonded directly, and the post core can be built up onsite with composite resin, significantly reducing chairside time and alleviating the burden of multiple visits for the patient [13]. The resin matrix of fiber posts achieves favorable bonding with resin cement and resin core materials, providing good interfacial sealing, reducing microleakage, and lowering the risk of secondary periapical pathology. The material color closely resembles that of natural teeth, allowing for better aesthetic outcomes in anterior restorations. If failure occurs later, fiber posts are easier to remove from the root canal than metal posts, creating more opportunities for preserving the natural root [14].

The present data indicate that after 12 months of followup, the observation group showed greater improvement in bite force and masticatory efficiency than the control group; the restoration success rate in the observation group reached 95.35%, higher than the 79.07% in the control group, while chairside time was shorter and complication rates were lower. Analysis suggests that the biomechanical properties of prefabricated fiber posts are more compatible with the root dentin, allowing uniform distribution of occlusal stress, reducing localized stress damage to the root, and maintaining masticatory function. The elimination of casting and processing steps, along with direct intraoral fabrication of the postandcore, shortens the clinical operation time. The postcementresin core forms a continuous composite resin system, providing good interfacial sealing, reducing microleakageinduced gingival and periapical inflammation, and decreasing adverse events such as postandcore loosening and root fracture, thereby improving overall restorative prognosis [15].

Nevertheless, prefabricated fiber posts have certain limitations. In teeth with severely curved root canals or irregularly shaped wide root canals, prefabricated posts may not fully adapt to the root canal wall, compromising the bonding effect. In such cases, cautious use is advised, and clinicians should comprehensively assess root canal imaging and select the appropriate restorative approach [16]. In addition, the followup period of the present study was only 12 months, and longterm fracture resistance and aging performance over 5 years or more have not been observed. Future studies with larger sample sizes and extended followup are needed to further validate the longterm restorative effects of prefabricated fiber posts.

5. Conclusion

In conclusion, for cases of extensive tooth defects after root canal treatment, prefabricated fiber posts can improve bite force and masticatory efficiency, shorten chairside time, increase restoration success rates, and reduce various postoperative complications. Under strict control of indications, this restorative approach is worthy of clinical promotion in prosthodontic practice.

Disclosure statement

The authors declare no conflict of interest.

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Research on the Cultivation Path of Professional Literacy in Geriatric Nursing for Higher Vocational Nursing Students

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Abstract: With the rapid ageing of the population, the training of geriatric nursing staff has gradually been added to the list of problems in medical education. Higher vocational nursing education bears the main responsibility of cultivating geriatric nursing talents for the grassroots level, and the professional literacy of these students directly affects the quality of care and the sense of life among older adults. However, at present, the training for geriatric-nursing-related professional literacy among higher vocational nursing students generally lacks clear goals, fragmented systems, and insufficient practical experience; therefore, a systematic path needs to be designed. Based on the definition of the connotation of geriatric nursing professional literacy, this paper uses competency theory and situated learning theory to systematically analyze the structural dimensions and practical dilemmas in the professional literacy of higher vocational nursing students. It will also construct training paths from three aspects: curriculum system, practical teaching and humanistic literacy, and put forward a triple guarantee mechanism for faculty development, collaborative education and quality evaluation. The goal of this study is to offer an applicable practical model for geriatric nursing talent cultivation in higher vocational colleges and thus improve the quality and efficiency of elderly care services.

Keywords: Higher vocational nursing; Geriatric nursing; Professional literacy; Training pathways

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1. Introduction

The number of older people in China is rising, and thus the demand for specialized nursing services for disabled and semi-disabled older adults has been increasing steadily. For a long time, the two main problems facing the elderly-care industry have been a lack of staff and low levels of professional literacy among workers. As one of the main training bases for skill-oriented nursing talents, higher-vocational nursing colleges have produced a large number of graduates employed in grassroots elderly-care institutions. A person's professional literacy will directly affect the safety and quality of life for older adults. Unfortunately, higher-vocational colleges have not yet established a geriatric nursing training system suitable for an ageing

society. There are still some deficiencies, such as a gap between classroom teaching and real-life application, and a lack of deep-seated interest in learning. Therefore, exploring training paths for professional literacy that meet the characteristics of higher-vocational education and are tailored to the special needs of geriatric nursing carries real-world significance and academic value. Therefore, this paper hopes to provide some support for the above demands by establishing a training system.

2. Core concepts and theoretical foundations

2.1. Connotation definition of geriatricnursing professional literacy

Geriatric nursing professional literacy refers to the all-encompassing system of qualities and professional abilities that nursing staff should have in providing care services for older people. In addition to knowledge and skills, one should also know about the values of professionals, be aware of humanistic care, possess ethical judgment ability, and have practical wisdom for dealing with serious health issues in old age. At the bottom of this idea is general nursing literacy combined with the special demands of elderly care; it aims to provide all-around support for older adults' physical decline, psychological changes and social-role adaptation. The particularity of geriatric nursing professional literacy lies in an in-depth understanding of ageing and conscious protection of dignity at the end-of-life stage; therefore, it differs from the professional requirements for general clinical nursing in terms of stronger emotional engagement and ethical awareness [1].

2.2. Training orientation for students majoring in higher vocational nursing

Higher school nursing education aims to cultivate applied nursing talents for primary medical-health institutions and elderly-care facilities. The groups of students have different backgrounds for admission, varying levels of academic preparation, and unclear career plans. Undergraduate nursing education focuses more on research and management abilities; higher-vocational nursing, however, places more emphasis on the ability to perform post-operative practical skills and adaptability in a clinical setting. Therefore, the professional literacy training needs to meet the actual requirements of the front-line staff. With the deep-seated changes in the mode of nursing services due to an ageing population, the training focus for higher-education nursing students should shift from being solely about technical operators to becoming geriatric health managers, communicative coordinators and practitioners of humanistic care. A new goal for training has been set in recent years.

2.3. Theoretical basis for the study

Competency theory serves as the foundation for exploring the structure of geriatric nursing professional literacy. It shows the underlying reasons why high-performers are better than average performers, such as their motivations, traits, self-concept, knowledge and skills. It can help turn the abstract ideas of literacy into observable and learnable behaviors. Situated Learning Theory proposes that the process of acquiring professional literacy is inherently social; therefore, learners need to be immersed in actual or simulated work environments, and by participating in legitimate peripheral activities, they can gradually become proficient professionals. Lifelong learning theory also provides the theoretical basis for extending geriatric nursing literacy education. Therefore, it can be concluded that higher vocational education is merely the beginning of professional literacy, and the design of training paths should leave some space for further professional development of students [2].

3. Structure and requirements of geriatricnursing professional literacy

3.1. Dimensional composition of geriatricnursing professional literacy

The five interconnected components of geriatric nursing professionals' literacy can be divided into professional cognition, specialized knowledge, operational skills, humanistic sentiments and ethical literacy; together they constitute the whole picture of literacy training. Professional cognition provides the emotional basis for literacy development and includes the recognition of values and a sense of duty in geriatric nursing work. Specialized knowledge provides cognitive support for practice by introducing the physiological and psychological features of older adults, necessary care measures for common diseases, and rehabilitation and healthcare knowledge. Operational Skills refer to specific geriatric nursing techniques for fall prevention, dysphagia management and cognitive exercise. Humanistic Sentiment is shown in respect, empathy and patience for older people. Ethical Literacy refers to the ability to deal with difficult problems related to the rights of older people, informed consent and end-of-life decisions. The five factors are interconnected and promote each other's growth to foster all-around literacy among higher vocational nursing students in geriatric nursing.

3.2. Competency requirements for geriatric nursing positions

As the demands for services have risen, so too have the competency requirements for geriatric nurses; now they need to provide all-round support for older people's lives and health. Geriatric nursing staff should organize regular health check-ups for older adults in practice to find any problems early on and plan personalized nursing care. At the same time, older adults are more likely to have multiple diseases and take several medications; therefore, good knowledge of drug administration and awareness of cross-disciplinary cooperation are required. Good communication with older adult clients and their families is also considered one of the essential post-graduation competencies; this includes learning how older adults express themselves and reducing the stress of caregiving for family caregivers.

3.3. Particularities in cultivating professional literacy for higher vocational nursing students

First of all, there are specific reasons for this: most students are at the beginning of their professional identity formation stage and have little knowledge or are even prejudiced against geriatric nursing work; therefore, it is difficult to motivate them to learn internally. Another feature is that the length of study for higher vocational education is relatively short compared with the extended period required for literacy development. A main problem in teaching organization is how to combine knowledge transmission, skill cultivation and emotion cultivation within a short time frame. In addition, the actual training environment of higher vocational colleges does not fully align with real-life elderly care situations [3]. Operating norms learned at school may not meet the actual demands of older adults' lives after graduation, thus causing a gap between training and practice.

4. Analysis on the current situation of geriatricnursing professional literacy among higher-vocational nursing students

4.1. Investigation and analysis of professional cognition and attitudes

Based on many studies, most high school seniors studying for the college entrance examination have little

interest in geriatric nursing. Many people believe that geriatric nursing is only about daily living and manual labor; they do not know the technical aspects and professional values of geriatric nursing. Therefore, these people are less likely to choose a job in old-age care. Most students do not have a positive attitude towards older people's lives; they believe that such lives are uninteresting, lack social recognition, and are too busy. A relatively small number of students wish to study for a degree in geriatric nursing. This negative attitude is due to a lack of geriatric nursing content in previous courses and no positive interactive experiences with older adults. Cognitive Intervention and Emotional Guidance are urgently required at the beginning of training to correct this problem.

4.2. Evaluation of knowledge and skill maturity

Higher-education nursing students do not have good mastery of special geriatric nursing knowledge and skills. Most can carry out basic nursing operations, such as measuring vital signs and hygiene care, but they are lacking in standardization and proficiency for specialized skills, such as all-round geriatric assessment, dementia care and swallowing function training. Students have a weak understanding of the characteristics of older people's drugs, unusual diseases and nutrition support measures; therefore, they perform poorly in the special geriatric nursing section of the theory test. Observations from clinical internships also show that students are unable to apply the knowledge they have learned to solve real-life problems in a hospital setting, and frequently fail to provide timely and accurate nursing assessments for elderly patients with multiple health issues.

4.3. Main existing problems and cause analysis

The main problems in the current professional literacy training for geriatric nursing among higher vocational nursing students are vague training goals, outdated and fragmented curriculum content, misalignment between practical classes and post-service demands, and formalistic cultivation of professional sentiment. Several reasons account for the above problems. There are no unified institutional curriculum standards and quality requirements for higher vocational geriatric nursing education; thus, colleges have designed their own training programs independently. In terms of resources, there is a shortage of teachers with geriatric nursing experience, insufficient investment in age-appropriate practical training facilities, and a high demand that cannot be met by high-quality internship opportunities at elderly care institutions. Socially, the low public image and poor remuneration of the elderly-care industry have partially offset the benefits of college education, making it difficult to maintain the training effect [4].

5. Construction of training pathways for geriatricnursing professional literacy

5.1. Pathway for curriculumsystem optimization

Optimization of the curriculum system will help nurture geriatric nursing professionals. First, it should be integrated with the existing curriculum of general nursing classes to create a new model for teaching geriatric nursing, rather than being taught as a separate course. Specific measures include adding more case studies on geriatric pathophysiology in pre-clinical courses, organizing special topics on geriatric ethics and geriatric psychology in Introduction to Nursing, and rearranging teaching content according to common geriatric health problems in clinical-nursing courses. In addition, all-encompassing scenario-oriented practical training courses focusing on elderly care should be developed to break through traditional disciplinary boundaries,

integrate training in assessment, communication, operational skills and health education, and build closer links between curriculum content and future post-service work.

5.2. Pathway to strengthening practical teaching

Application of knowledge in actual teaching helps students develop abilities for professional literacy. Its improvement should follow a gradual path: from simulation to actual operation, and from isolated modules to full-process workflows. At the on-campus practical training stage, high-fidelity geriatric nursing training centers should be established, equipped with age-adapted facilities and ageing-simulation devices, and multiple-scenario practice environments covering home-based, community-based and institutional care should be created so that students can repeatedly exercise special geriatric nursing skills in a safe environment. For clinical internships, there should be sufficient rotation time in geriatric wards, rehabilitation departments and elderly-care institutions, and preceptors need to offer regular guidance and feedback on the students' professional behavior. Another new way is to integrate volunteer work with professional practice by having students take part in community-based elderly health services regularly; thus, they will be exposed to the lives of older people over time.

5.3. Pathway for humanistic-literacy cultivation

The Foundation of Geriatric Nursing Professional Literacy is Humanistic Literacy. Cultivation should move away from traditional lecture-based teaching and achieve deep-seated assimilation through experience and reflection. Geriatric simulation teaching has shown good results; students experience physical discomfort and emotional changes due to ageing by simulating the physical restrictions of older adults and feel a strong sense of empathy. Narrative education is also worth promoting: students read geriatric literature, listen to the life stories of older adults, and write reflective care journals to develop a sense of purpose for geriatric nursing work through emotional connection. Campus culture and social practice are also excellent places for nurturing humanistic literacy. Organize activities with themes of respect for the elderly, geriatric nursing skill competitions and hospice care volunteer services to inspire students' sense of responsibility gradually [5].

5.4. Pathway for professional identity and emotional construction

Professional Identity serves as the internal motivation for the development of professional literacy. The extent to which higher-vocational nursing students feel emotionally connected to geriatric nursing work will affect their enthusiasm for learning and future employment. Currently, there is no emotional education in the training system, so many students have acquired knowledge and skills but lack an inner sense of purpose for elderly care careers. Therefore, we need to adjust our professional cognition. Orientation programs at the time of admission should present the trends of an ageing society and career prospects in geriatric nursing systematically to help students develop reasonable career ideals by fully grasping the professional significance of their studies. More significantly, continuous positive professional experiences can foster emotional recognition; students should be exposed to excellent role models in geriatric nursing practice and hear about their career development stories to feel the dignity and value of geriatric nursing work through real-life professional narratives. Institutional follow-up support for emotional construction is also required, such as establishing a professional mentor system to promptly address students' career-related confusion and help turn temporary emotional inspiration into long-term, stable professional commitment.

6. Safeguards for the implementation of training pathways

6.1. Safeguard for faculty team building

The faculty will organize the training paths. There is a serious lack of dual-qualified teachers who have both theoretical knowledge and practical experience in geriatric nursing; thus, the quality of training cannot be improved. Therefore, high-level vocational colleges should strategically hire geriatric nursing experts with strong industrial experience to strengthen the teaching staff. At the same time, encourage in-house teachers to enhance their professional literacy in geriatric nursing by participating in clinical further studies, academic exchanges and special training. Another relatively feasible way is to set up a joint employment model between colleges and institutions to invite experienced nursing managers and technical backbone staff from elderly care institutions to take on some practical teaching work and keep classroom content in line with frontline practice. All nursing teachers need to learn about changes in society's ageing process and incorporate geriatric nursing ideas across all courses during their own learning and development.

6.2. Safeguards for collaborative education among colleges and institutions

Collaborative education among colleges and institutions can meet the demand for new-generation talents after graduation. High-quality vocational colleges need to establish stable and deep partnerships with medical and elderly-care institutions to take part in all stages of talent cultivation. Under this cooperation model, colleges and institutions will jointly develop talent-training courses, co-create curriculum materials and practical-training projects based on post-graduate work requirements, and ensure that the training goals align with those of the post-graduate program. The dual-preceptor system for clinical teaching serves as a necessary tool for cooperative education; college teachers and institutional preceptors take turns leading theoretical instruction and practical demonstrations, and regularly organize teaching seminars to coordinate training progress. In-depth cooperation models include order-oriented training and modern apprenticeship pilots, which embed professional literacy learning in real-world professional settings.

6.3. Safeguard for quality evaluation and continuous improvement

The purpose of quality assessment is to determine whether the training path has achieved its goals and needs to be optimized. Build a multi-faceted evaluation system for all stages of training and balance the assessment of knowledge-skill acquisition with emotional-attitudinal changes. Evaluators should not be restricted to college teachers; they can also include clinical preceptors, older adults and their families, students themselves, etc., to cover all aspects of students' professional literacy development. For the type of assessment, move away from a single final examination and use process-oriented evaluation instead. Clinical journals, case studies, scenario simulations, 360-degree evaluations, etc., can all be used to observe changes in students' cognition, skills and emotions over time. Based on the results of the evaluation, colleges should promptly address the weak links in the training program and establish a closed-loop system of evaluation, feedback and improvement to ensure that the training path can adapt to changes in elderly care practice continuously.

7. Conclusion

Based on professional literacy training for geriatric nursing among higher vocational nursing students, this study has built a relatively complete theoretical system and practical plan through concept definition,

structural analysis, current situation diagnosis, pathway construction and safeguard design. Based on the above research, geriatric nursing professional literacy is multi-dimensional and contextual. Cultivation refers to the cultivation of people's moral qualities and abilities, and it is not just about imparting knowledge and skills. Higher-vocational colleges need to address the structural contradictions in the current training system, take curriculum optimization as the foundation, strengthen practical training support, and promote humanistic cultivation at the same time. Several paths can be used to achieve joint effects via faculty development and institutional safeguards. It is understood that the proposed framework will require testing and adjustment in actual school-running circumstances. Different regions and types of higher education institutions should adapt to their own resource conditions and regional elderly care needs, and thus transform the theoretical framework into practical results effectively.

Disclosure statement

The author declares no conflict of interest.

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Effects of Family-participation-based Continuous Nursing Combined with Respiratory Function Training on Recurrence of Children with Wheezing Diseases

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Abstract: *Objective*: To explore the effects of family-participation-based continuous nursing combined with respiratory function training on family-management ability, training compliance and recurrence in children suffering from wheezing diseases. *Methods*: A total of 96 children with wheezing diseases admitted to the Department of Pediatrics of Yancheng Maternity and Child-Health Hospital from January 2025 to March 2026 were selected as research subjects. They were divided into control group and observation group by random-number-table method, with 48 cases in each group. The two groups were compared in terms of family-management-ability scores before and after intervention, training compliance, wheezing recurrence and medical-visit conditions within 3 months, and family-member nursing satisfaction. *Results*: Before intervention, there was no statistically significant difference in each-dimension scores and total scores of family-management ability between the two groups ($p > 0.05$). After 3-month intervention, the observation group obtained higher scores than the control group in disease cognition, medication management, respiratory-training implementation, environmental management, symptom monitoring and total score, with statistically significant differences ($p < 0.001$). The excellent-compliance rate of training in the observation group was 91.67 %, higher than 66.67 % in the control group ($p < 0.05$). During the 3-month follow-up, the wheezing-recurrence rate and emergency-visit rate of the observation group were 10.42 % and 8.33 % respectively, both lower than 31.25 % and 25.00 % of the control group, showing statistically significant differences ($p < 0.05$). The readmission rate of the observation group was lower than that of the control group, but the difference had no statistical significance ($p > 0.05$). The family-member nursing-satisfaction rate of the observation group was 95.83 %, higher than 79.17 % of the control group, with statistically significant difference ($p < 0.05$). *Conclusion*: Family-participation-based continuous nursing combined with respiratory function training can improve family-management ability and training compliance of children with wheezing diseases, reduce wheezing-recurrence rate and emergency-visit rate, and raise family-member nursing satisfaction. It possesses certain clinical-promotion value.

Keywords: Children's wheezing diseases; Family participation; Continuous nursing; Respiratory function training;

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1. Introduction

Children's wheezing diseases rank among the common chronic respiratory diseases in pediatrics, mainly manifested as repeated wheezing, cough, shortness of breath, dyspnea and other symptoms. They can be induced by multiple factors including respiratory-tract infection, allergen stimulation, environmental factors and airway hyperresponsiveness. Due to the relatively narrow airway lumen, immature development of respiratory muscles and imperfect immune-system function in children, problems such as airway obstruction, declined pulmonary-function and repeated disease attacks tend to occur during disease recovery. Researches indicate that recurrent wheezing in childhood not only affects normal growth-development and quality of life, but also may increase the risk of subsequent bronchial-asthma onset, bringing heavy economic burden and psychological pressure to children's families. At present, treatments for children's wheezing diseases mainly include pharmacotherapy such as anti-infection, anti-wheezing, expectorant therapy and atomization inhalation, as well as routine nursing care. Although the above-mentioned measures can effectively control acute symptoms, children after discharge often suffer from insufficient home-nursing knowledge, poor medication compliance, interrupted respiratory training and weak early-warning awareness of disease recurrence, which impair long-term disease-control effects. In recent years, with the development of chronic-disease-management concepts, nursing modes have gradually transformed from in-hospital nursing to continuous in-hospital and out-of-hospital management. Continuous nursing emphasizes improving disease-management capacity of patients and their family members and realizing long-term disease control through continuous post-discharge guidance, health education and follow-up management.

Family participation constitutes an important component of continuous nursing. For pediatric patients, parents are primary implementers of disease management. Their disease-cognition level, nursing skills and management capacity exert direct influences on therapeutic effects and disease prognosis. Studies hold that strengthening family participation can raise family members' disease-awareness level, enhance their capabilities in medication management, symptom monitoring and environmental control, so as to improve children's compliance and lower disease-recurrence risks. Meanwhile, as an important part of pulmonary rehabilitation, respiratory-function training features simple operation, high safety and good child acceptability. It can improve airway patency, strengthen respiratory-muscle function and promote sputum excretion. Combining respiratory-function training with family-participation-based continuous nursing is expected to further boost family-management capacity and disease-control outcomes.

2. Materials and methods

2.1. General data

A total of 96 children with wheezing diseases admitted to the Department of Pediatrics of Yancheng Maternity and Child-Health Hospital from January 2025 to March 2026 were enrolled. They were divided into control group and observation group via random-number-table method, with 48 cases in each group.

In the control group: 27 boys and 21 girls, aged 4–10 years, mean age (6.84 ± 1.42) years; disease course 2–6 days, mean (3.58 ± 0.91) days; 30 cases of mild wheezing, 18 cases of moderate wheezing; 14 cases with allergic history. In the observation group: 25 boys and 23 girls, aged 4–10 years, mean age (6.71 ± 1.36) years; disease course 2–6 days, mean (3.46 ± 0.87) days; 32 cases of mild wheezing, 16 cases of moderate wheezing; 16 cases with allergic history. There were no statistically-significant inter-group differences in general data including gender, age, disease course, wheezing severity and allergic history ($p > 0.05$), and the two groups were comparable.

2.1.1. Inclusion criteria

Conforming to relevant diagnostic criteria for children's wheezing diseases [1–5]; aged 4-10 years; relatively stable condition, capable of cooperating with intervention and follow-up; primary caregivers of children could receive follow-up via WeChat or telephone, and gave informed consent for participation in this study.

2.1.2. Exclusion criteria

Complicated with diseases impairing respiratory function such as congenital heart disease, foreign-body in airway, laryngomalacia and mediastinal neoplasm; complicated with severe nervous-system diseases, mental-behavioral disorders or cognitive impairment; condition deteriorated to require admission to intensive-care unit during treatment; incomplete data, case dropout or loss-to-follow-up.

This study was approved by the hospital ethics committee, and guardians of all children signed informed-consent forms.

2.2. Methods

2.2.1. Control group

The control group received routine nursing and discharge guidance. After admission, duty nurses assessed disease changes, closely monitored vital signs including body temperature, respiratory rate, heart rate, blood-oxygen saturation, as well as clinical symptoms such as cough and wheezing, and cooperated with physicians to complete anti-infection, anti-wheezing, expectorant, atomization-inhalation and other therapies. During nursing, children were guided to maintain comfortable body positions, encouraged to drink adequate water, and assisted with sputum excretion to keep respiratory tracts unobstructed. Meanwhile, health education was delivered to family members, explaining disease-related knowledge, medication administration methods, dietary management and daily-nursing precautions. Health-education pamphlets were distributed at discharge. Review-visit time and recurrence-prevention measures were informed, and family members were instructed to implement home-based nursing according to medical advice.

2.2.2. Observation group

On the basis of interventions for the control group, the observation group received family-participation-based continuous nursing combined with respiratory-function training. After enrolment, family-management files were established. Duty nurses recorded children's basic information, past medical history, allergic history, recurrence status, family-environment conditions and information of primary caregivers. One primary caregiver was designated as the person-in-charge of family management. Before discharge, duty nurses delivered systematic face-to-face training for primary caregivers, covering knowledge of wheezing diseases, identification of inducing factors, management of medication and atomization therapy,

respiratory-function-training methods, symptom monitoring and early-warning of recurrence, so that family members could master basic skills for long-term disease management.

In terms of respiratory-function training, duty nurses guided children and their family members to complete abdominal breathing, pursed-lip breathing, balloon-blowing training and effective-cough training together. For abdominal-breathing training, children maintained comfortable postures, inhaled slowly through nose to make abdomen bulge, then exhaled slowly through mouth to make abdomen fall back. For pursed-lip-breathing training, children inhaled through nose and then exhaled slowly with lips pursed as if whistling. Balloon-blowing training was performed progressively according to children's age and tolerance level. Effective-cough training required deep inspiration and brief breath-holding followed by active coughing to promote sputum discharge. The above-mentioned trainings were carried out twice a day, 15–20 minutes each time, lasting for 3 months. Duty nurses provided on-site guidance during hospitalization; after discharge, family members supervised training implementation.

2.3. Observation indicators

2.3.1. Family-management-ability score

Evaluated by self-developed evaluation scale for family-management ability of children with wheezing diseases of our hospital. It contained five dimensions: disease cognition, medication management, respiratory-training implementation, environmental management and symptom monitoring. Each dimension accounted for 20 points, with a total score of 100 points. Higher scores represented stronger family-management ability.

2.3.2. Training compliance

Evaluated according to the ratio of actual completed training times to planned training times. Completion rate ≥ 80 % was defined as good compliance; 60–79 % as fair; < 60 % as poor.

2.3.3. Recurrence status

Children were followed-up for 3 months after discharge. Conditions of wheezing recurrence, emergency-department visits and readmission were recorded. Wheezing recurrence was defined as re-occurrence of obvious wheezing symptoms requiring pharmacotherapy or medical intervention.

2.4. Statistical methods

SPSS 26.0 statistical software was adopted for data analysis. Measurement data passing normality test were expressed as mean ± standard deviation ($\overline{x} \pm s$). Independent-sample *t*-test was used for inter-group comparison, and paired *t*-test was adopted for intra-group pre-post-intervention comparison. Enumeration data were expressed as case number and percentage, and Chi-square test or Fisher's exact test was used for inter-group comparison. $p < 0.05$ was regarded as the threshold for statistically-significant difference.

3. Results

3.1. Comparison of general data between two groups

No statistically-significant differences were found between the two groups in general data such as gender, age, disease course, wheezing severity and allergic history ($p > 0.05$). The two groups were comparable, as shown in Table 1.

Table 1. Comparison of general data between two groups of children

Items	Control group (n = 48)	Observation group (n = 48)	t/χ^2 value	p value
Male/Female (cases)	27/21	25/23	0.168	0.682
Age (years)	6.84 ± 1.42	6.71 ± 1.36	0.458	0.648
Disease course (d)	3.58 ± 0.91	3.46 ± 0.87	0.660	0.511
Mild/Moderate wheezing (cases)	30/18	32/16	0.177	0.674
Allergic history (cases)	14 (29.17 %)	16 (33.33 %)	0.190	0.663

3.2. Comparison of family-management-ability scores between two groups

Before intervention, there existed no statistically-significant differences in dimensional scores and total scores of family-management-ability between the two groups ($p > 0.05$). After 3-month intervention, family-management-ability scores of both groups increased compared with pre-intervention levels. Scores of the observation group in disease cognition, medication management, respiratory-training implementation, environmental management, symptom monitoring and total score were obviously higher than those of the control group, with statistically-significant differences ($p < 0.001$), as shown in Table 2.

Table 2. Comparison of family-management-ability scores of two groups before and after intervention

Indicators	Time	Control group(n = 48)	Observation group(n = 48)	t value	p value
Disease cognition	Before intervention	11.42 ± 2.16	11.56 ± 2.21	0.314	0.754
	After intervention	14.83 ± 2.35	17.46 ± 2.08	5.799	< 0.001
Medication management	Before intervention	10.91 ± 2.24	11.13 ± 2.19	0.487	0.628
	After intervention	14.25 ± 2.31	17.21 ± 2.03	6.661	< 0.001
Respiratory-training implementation	Before intervention	9.78 ± 2.05	9.86 ± 2.12	0.188	0.851
	After intervention	13.58 ± 2.42	17.38 ± 2.06	8.283	< 0.001
Environmental management	Before intervention	12.04 ± 2.28	11.92 ± 2.25	0.260	0.795
	After intervention	15.12 ± 2.34	17.63 ± 2.01	5.634	< 0.001
Symptom monitoring	Before intervention	10.69 ± 2.17	10.81 ± 2.20	0.269	0.788
	After intervention	14.56 ± 2.39	17.25 ± 2.11	5.845	< 0.001
Total score	Before intervention	54.84 ± 7.26	55.28 ± 7.39	0.294	0.769
	After intervention	72.34 ± 8.18	86.93 ± 7.41	9.153	< 0.001

3.3. Comparison of training compliance between two groups

The excellent-compliance rate of training in the observation group was 91.67 %, markedly higher than 66.67 % in the control group ($\chi^2 = 9.560$, $p = 0.002$), as shown in Table 3.

Table 3. Comparison of training compliance between two groups

Group	Cases	Good	Fair	Poor	Excellent-compliance rate	χ^2 value	p value
Control group	48	32	11	5	32 (66.67 %)	-	-
Observation group	48	44	3	1	44 (91.67 %)	9.560	0.002

3.4. Comparison of risks of major follow-up outcomes between two groups within 3 months

After 3-month follow-up, risks of wheezing recurrence, emergency-department visits and readmission in the

observation group were all lower than those in the control group. Statistically-significant differences were observed in wheezing recurrence and emergency-department visits ($p < 0.05$), while no statistical difference was found in readmission rate ($p > 0.05$), as shown in Table 4.

Table 4. Comparison of risks of major follow-up outcomes of two groups within 3 months

Follow-up outcome	Control group (n = 48)	Observation group (n = 48)	RR (95 %CI)	*p* value
Wheezing recurrence	15/48 (31.25 %)	5/48 (10.42 %)	0.33 (0.13–0.84)	0.011
Emergency-department visit	12/48 (25.00 %)	4/48 (8.33 %)	0.33 (0.12–0.96)	0.028
Readmission	7/48 (14.58 %)	2/48 (4.17 %)	0.29 (0.06–1.31)	0.076

Note: RR means relative risk of observation group compared with control group; 95 % CI stands for 95 % confidence interval.

3.5. Comparison of family-member nursing satisfaction between two groups

Total nursing-satisfaction rate of family members in the observation group was 95.83 %, higher than 79.17 % of the control group ($\chi^2 = 6.095$, $p = 0.014$), as shown in Table 5.

Table 5. Comparison of family-member satisfaction between two groups

Group	Cases	Very satisfied	Satisfied	Dissatisfied	Total satisfaction rate	χ^2 value	*p* value
Control group	48	20	18	10	38 (79.17 %)	-	-
Observation group	48	31	15	2	46 (95.83 %)	6.095	0.014

4. Discussion

The results of this study indicated that there existed no statistically-significant differences in dimensional scores and total scores of family-management-ability between the two groups before intervention ($p > 0.05$), which suggested comparability of baseline data. After 3-month intervention, scores of the observation group in disease cognition, medication management, respiratory-training implementation, environmental management, symptom monitoring and total score were obviously higher than those of the control group ($p < 0.001$). The total score of the observation group reached (86.93 ± 7.41) points versus (72.34 ± 8.18) points of the control group, showing statistically-significant difference. It demonstrated that family-participation-based continuous nursing combined with respiratory-function training could effectively improve children's family-management ability. Possible reasons may lie in that the family-participation mode highlights family-members' principal role in disease management. Through establishment of family-management files, individualized health education and skill training, family members can systematically master disease-related knowledge and nursing skills. Meanwhile, continuous guidance and supervision via WeChat platforms and telephone follow-up further strengthen family members' comprehension and application of disease-management contents, so as to improve family-management ability.

Compliance serves as a vital factor affecting long-term management outcomes of chronic diseases. As an important component of rehabilitation management for wheezing diseases, respiratory-function training requires long-term standardized implementation to exert effects. Nevertheless, young children lack the initiative to persist in training, and ideal outcomes can hardly be achieved merely relying on children themselves. This study showed that the excellent-compliance rate of training in the observation group was 91.67 %, significantly higher than 66.67 % in the control group (P=0.002), which was basically consistent

with findings of previous researches on family management and rehabilitation training. It indicated that the family-participation mode helped improve children's training compliance. The underlying reason may be that the family-participation mode clarifies primary caregivers' responsibilities and makes parents direct participants in training execution and supervision.

Disease recurrence is an important indicator for evaluating long-term management outcomes of children's wheezing diseases. Three-month follow-up in this study found that the wheezing-recurrence rate and emergency-visit rate of the observation group were 10.42 % and 8.33 % respectively, both lower than 31.25 % and 25.00 % of the control group, with statistically-significant differences ($p < 0.05$). It suggested that family-participation-based continuous nursing combined with respiratory-function training contributed to lowering disease-recurrence risks. Possible explanations are as follows: firstly, improved disease-cognition level of family members enables standardized implementation of medication and respiratory training; secondly, guidance on family-environment management reduces exposure to allergens and other inducing factors; thirdly, symptom-monitoring and recurrence-early-warning education allow family members to detect disease changes timely and take corresponding measures to prevent further deterioration. In addition, although the readmission rate of the observation group was lower, no statistical significance was obtained ($p = 0.076$). This may result from relatively small sample size, short follow-up duration and low incidence of readmission events. Further researches with expanded sample size are required for subsequent verification.

5. Conclusion

Family-participation-based continuous nursing combined with respiratory function training can improve family-management ability and training compliance in children with wheezing diseases, reduce wheezing recurrence and emergency visits, and increase family-member nursing satisfaction, showing certain clinical-promotion value.

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Pharmacodynamic Study of *Abrus Cantoniensis* Polysaccharides in Alleviating Hepatic Steatosis in Laying Hens

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Abstract: Fatty Liver Hemorrhagic Syndrome (FLHS) is a common nutritional-metabolic disease in laying hens and constitutes a major factor causing decreased egg production and even death of laying hens. At present, prevention and treatment of this disease mostly rely on measures such as feed replacement or reduction of energy-yielding substances in diets. Nevertheless, such approaches not only require long therapeutic cycles, but also tend to impair the stability of laying-hen productive performance due to dietary adjustment, and can hardly satisfy the efficient prevention-and-treatment demands of breeding industries. *Abrus cantoniensis* polysaccharides possess unique advantages in regulating lipid metabolism and preventing-treating Fatty Liver Hemorrhagic Syndrome in laying hens. This paper discusses research advances of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens from aspects including extraction technology and pharmacological basis of *Abrus cantoniensis* polysaccharides, pathogenesis of FLHS and its correlation with intestinal microbiota, as well as action mechanisms of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens. It aims to provide objective references for clinical application of *Abrus cantoniensis* polysaccharides to relieve hepatic steatosis in laying hens.

Keywords: *Abrus cantoniensis* polysaccharides; Fatty liver hemorrhagic syndrome (FLHS) in laying hens; Intestinal microbiota; Gut-liver axis; Chinese veterinary materia medica

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1. Introduction

Fatty Liver Hemorrhagic Syndrome (FLHS) in laying hens is a prevalent metabolic disorder in laying-hen breeding. It originates from excessive hepatic lipid deposition associated with high-energy low-protein feed, genetic susceptibility, defects in caged-rearing management and abnormal hormonal regulation, which results in hepatocyte degeneration, fragile blood vessels, hemorrhage and death [1]. This disease was first discovered in the United States and initially named Fatty Liver Syndrome. It was renamed after the core pathological

feature of hepatic hemorrhage was identified. Shortly afterwards, scholars systematically reported this disease for the first time and clarified its correlation with high-energy feed and abnormal estrogen metabolism. Subsequent researches further revealed mechanisms whereby high estrogen levels in high-yield laying hens promote hepatic lipogenesis. Meanwhile, intestinal microbiota dysbiosis, mycotoxins and stress also participate in disease onset. Clinical manifestations include sharp decline in egg-laying rate, pale combs, pendulous abdomen and sudden death. Necropsy shows enlarged and fragile liver with hemorrhagic spots, and massive fat accumulation around abdominal cavity and internal organs, which causes remarkable economic losses to the laying-hen industry [2]. Conventional prevention-and-treatment measures mainly consist of adjusting dietary nutrient ratios, supplementing anti-lipid factors, optimizing feeding management and breeding low-susceptibility varieties. Traditional modes relying on nutritional regulation and pharmaceutical intervention suffer from drawbacks such as drug residues. As a characteristic Lingnan Chinese herbal medicine, *Abrus cantoniensis* exerts anti-inflammatory and hepatoprotective activities. Its polysaccharide fraction boasts advantages of immunomodulation and anti-oxidation and holds broad application prospects in the field of healthy animal breeding [3]. *Abrus cantoniensis*, also known as yellow-head grass, is one of the characteristic Lingnan Chinese medicinal herbs. *Chinese Pharmacopoeia* records that *Abrus cantoniensis* possesses effects of clearing heat-toxin and anti-inflammation. In recent years, numerous studies have demonstrated that *Abrus cantoniensis* can clinically treat various hepatic diseases such as acute and chronic infectious hepatitis and liver cirrhosis. Thanks to favorable immunomodulatory and anti-oxidant activities, abrus cantoniensis polysaccharides exhibit promising application prospects in healthy animal breeding [4].

2. Extraction technology and pharmacological basis of *Abrus cantoniensis* polysaccharides

2.1. Extraction procedure *of Abrus cantoniensis* polysaccharides

Dried decoction pieces of *Abrus cantoniensis* after sun-drying are crushed and sieved, followed by degreasing with petroleum ether to remove lip-soluble impurities. Then the ultrasonic-assisted enzymatic extraction process is adopted. Under suitable environmental conditions, synergistic reactions proceed for sufficient duration. After centrifugation, supernatant liquid is diluted to appropriate concentration. The phenol-sulfuric acid method is used to determine absorbance at specified wavelength. Crude-polysaccharide extraction rate is calculated according to corresponding regression equation, and ideal measured extraction effects can be achieved [5]. The extract is de-proteinized with Sevag reagent and decolorized by activated carbon. Multiple volumes of absolute ethanol are added for ethanol precipitation. Precipitates are sequentially washed with absolute ethanol and acetone to eliminate residual impurities. After precipitate collection by centrifugation, freeze-dryer is used for drying under low-temperature vacuum conditions to obtain finished *Abrus cantoniensis* polysaccharides. Through response-surface optimization design, multiple experimental points are set with parallel replicates for each point to establish optimal parameter combination. The model presents favorable fitting degree. The whole extraction strictly complies with laboratory operating specifications to guarantee polysaccharide purity and bioactivity.

2.2. Immunomodulatory effects of *Abrus cantoniensis* polysaccharides

Multiple animal experiments and cell assays have verified that *Abrus cantoniensis* polysaccharides can significantly enhance organismal immune functions. Its mechanism mainly lies in activating proliferation and

differentiation of T-lymphocytes and B-lymphocytes, promoting synthesis and secretion of immunoglobulins, and up-regulating expression of cytokines such as interleukin-2, so as to strengthen anti-inflammatory and anti-oxidant capacities of organisms. It can restrain excessive release of inflammatory factors, elevate activities of anti-oxidant enzymes including superoxide dismutase (SOD), and reduce levels of oxidative products such as malondialdehyde (MDA). In laying-hen production, such immunomodulatory effects can effectively boost disease-resistant capacity of laying hens, lower incidence of common diseases such as Newcastle disease and avian influenza. Meanwhile, immune-response modulation alleviates hepatic metabolic burden, improves liver functions, and ultimately raises egg-laying rate and egg quality, providing important support for sound and efficient development of laying-hen breeding [6].

2.3. Anti-oxidant effects of *Abrus cantoniensis* polysaccharides

Oxidative stress constitutes one of the critical mechanisms for occurrence and progression of FLHS. *Abrus cantoniensis* polysaccharides exert remarkable anti-oxidant activity, scavenge free radicals *in vivo*, mitigate hepatocyte injury induced by oxidative stress and protect hepatic functions. Its specific anti-oxidant mechanism is closely related to activation of key intracellular anti-oxidant signaling pathways, for instance the ARE pathway — the core regulatory network for cellular response to oxidative stress. When *Abrus cantoniensis* polysaccharides act on hepatocytes, they promote translocation of Nrf2 from cytoplasm into cell nucleus for binding with anti-oxidant-response elements, and further induce expression of downstream anti-oxidant enzymes including superoxide dismutase. Synergistically, these enzymes can directly scavenge free radicals such as superoxide anions and enhance cellular resistance against oxidative damage. In addition, they suppress oxidative-stress-triggered inflammatory responses and mitigate hepatocyte damage from oxidative stress at multiple levels [7].

Researches show that in FLHS animal models induced by high-fat diets, after intervention with *Abrus cantoniensis* polysaccharides, the level of malondialdehyde (MDA), a marker product of oxidative stress in hepatic tissues, drops significantly, while activities of anti-oxidant enzymes such as SOD rise markedly. Accumulation of reactive oxygen species within hepatocytes is effectively controlled, and pathological changes including hepatocyte steatosis and inflammatory infiltration are alleviated accordingly, which directly proves hepatoprotective effects derived from its anti-oxidant property [8]. Moreover, anti-oxidant effects of *Abrus cantoniensis* polysaccharides can indirectly ameliorate lipid metabolism closely associated with oxidative stress. Oxidative-stress disturbs activities of key lipid-metabolizing enzymes and gives rise to excessive hepatic lipid deposition. By relieving oxidative stress, *Abrus cantoniensis* polysaccharides restore normal functions of such enzymes, accelerate lipolysis and lipid transport, thereby reducing hepatic lipid content and ameliorating disorders of lipid metabolism, and further retard FLHS progression. Such multi-faceted effects of “anti-oxidation-hepatocyte-protection-lipid-metabolism-improvement” make it a promising natural active ingredient for FLHS prevention and treatment.

2.4. Lipid-metabolism regulation by *Abrus cantoniensis* polysaccharides

Studies indicate that polysaccharide ingredients can realize precise balanced regulation of lipogenesis and lipolysis by modulating expression of key lipid-metabolism genes and core signaling pathways. On the one hand, they inhibit activity of sterol regulatory-element-binding protein 1c (SREBP-1c), the master transcription factor for lipogenesis, and further down-regulate expression of its downstream target genes acetyl-CoA carboxylase and fatty-acid synthase, so as to directly suppress rate-limiting steps of lipogenesis.

On the other hand, they promote gene expression of key lipolytic enzymes: adipose triglyceride lipase and hormone-sensitive lipase, accelerating hydrolysis and decomposition of hepatic triglycerides [9]. These synergistic actions reduce total-cholesterol deposition in liver. The core pathological mechanism of Fatty Liver Hemorrhagic Syndrome is hepatocyte degeneration, necrosis and hemorrhagic injury induced by excessive hepatic lipid accumulation. Hence, *Abrus cantoniensis* polysaccharides lay solid theoretical foundation for its application in FLHS alleviation via balancing lipid metabolism and mitigating hepatic fat deposition.

3. Pathogenesis of FLHS and its relationship with intestinal microbiota

3.1. Pathogenesis of FLHS

The pathogenesis of FLHS is complex and involves multiple factors including heredity and nutrition. Essentially, it results from synergistic effects of "production overload" and "transport paralysis" triggered by nutritional imbalance. To sustain continuous egg-laying, high-yield laying hens force their livers to overwork for synthesizing massive lipids required for yolk development, which represents the physiological state of "production overload". When excessive high-energy substances are supplied by feeds, liver converts them into fats. Nevertheless, if key raw materials for lipoprotein synthesis — proteins, essential amino acids, vitamin B12 and choline — are insufficient, "transport paralysis" occurs: large quantities of fats are synthesized yet cannot be exported out of hepatocytes due to lack of "transport carriers". Consequently, fats keep accumulating inside hepatocytes and fatty liver develops. Such accumulated fats are not inert; they are oxidized to generate large quantities of harmful substances. On the one hand, they directly attack and injure hepatocytes and result in hepatocyte degeneration and necrosis. On the other hand, they impair hepatic synthesis of coagulation factors and induce abnormal blood-clotting mechanisms [10]. Ultimately, the liver becomes enlarged and extremely fragile due to massive fat accumulation. Sharp rise in intra-abdominal pressure during egg-laying in laying hens readily causes hepatic rupture, massive hemorrhage and even sudden death. In addition, insufficient physical activity of laying hens lowers lipid-metabolizing rates, while intestinal-microbiota dysbiosis may affect lipid absorption and metabolism. Both factors further facilitate onset and progression of FLHS via disturbing lipid metabolism and intestinal-barrier functions.

3.2. Relationship between intestinal microbiota and FLHS

As the largest microbial community of host organisms, intestinal microbiota exerts great influences over host nutrient absorption, immunomodulation and metabolic homeostasis. Studies reveal that when intestinal-microbiota dysbiosis occurs in laying hens, especially with proliferation of harmful bacteria and decline of beneficial bacteria, hepatic burdens are aggravated from multiple perspectives. For one thing, dysbiotic microbiota disrupts intestinal-mucosa barrier, rendering harmful substances such as endotoxins more liable to enter blood circulation and reach liver directly, which triggers hepatic inflammation and injury. For another, disturbed microbiota interferes with normal metabolism of nutrients. It may produce more lipogenic substances while reducing components facilitating lipid metabolism. Such dual effects jointly exacerbate hepatic fat deposition, oxidative stress and inflammatory responses, render liver more vulnerable, and accelerate and deteriorate progression from simple fatty liver to hemorrhagic syndrome [11]. Therefore, maintaining healthy intestinal microbiota is critical for FLHS prevention.

4. Action mechanisms of *Abrus cantoniensis* polysaccharides for alleviating hepatic steatosis in laying hens

4.1. Modulating homeostasis of intestinal microbiota

Findings from project-based researches demonstrate that *Abrus cantoniensis* polysaccharides can markedly modify intestinal-microbiota composition of FLHS-affected laying hens, raise proportions of beneficial bacteria, reduce counts of harmful bacteria, restore intestinal-barrier functions, decrease endotoxin translocation toward liver, so as to mitigate hepatic inflammation and fat deposition. High-throughput sequencing technology was adopted to successfully screen key bacterial strains sensitive to *Abrus cantoniensis* polysaccharides, and further researches were conducted to investigate roles of such strains in lipid-metabolism regulation [12].

4.2. Exerting effects through the gut-liver axis

The "gut-liver axis" refers to bidirectional communication between intestine and liver through portal-vein system, biliary tract system and other pathways. By regulating homeostasis of intestinal microbiota, *Abrus cantoniensis* polysaccharides change categories and quantities of intestinal metabolites, and further influence hepatic lipid metabolism and inflammatory responses via the gut-liver axis [13]. Metabolomics technology was utilized in this project to detect metabolite variations in serum and liver of FLHS laying hens before and after *Abrus cantoniensis*-polysaccharide intervention. Metabolomics analysis indicates that pathways including glycerophospholipid metabolism, arachidonic-acid metabolism and biosynthesis of unsaturated fatty acids are significantly altered in polysaccharide-treated groups [14]. Lipogenic metabolites decrease while anti-lipogenic metabolites increase. Bile-acid metabolism modulates lipid metabolism via FXR receptors, inhibits VLDL secretion and accelerates fatty-acid oxidation.

5. Application prospects and challenges

5.1. Application prospects

Against the background of large-scale breeding of poultry and livestock, non-standard antibiotic usage brings severe drug residues in livestock products and increased organismal drug resistance. Announcement No. 194 issued by Ministry of Agriculture and Rural Affairs of China stipulates that production, import and operation of partial feed-use medicinal additives except Chinese herbal medicines shall be terminated. Since then, "antibiotic prohibition" and "antibiotic-replacement" have become hot topics in animal-husbandry industry. Among numerous antibiotic-replacement schemes, Chinese veterinary materia medica serves as the mainstay for antibiotic substitution. Polysaccharide-based immunostimulants can trigger immune responses and relieve oxidative damage, and enhance animal resistance against infectious diseases and adverse environments [15]. As natural active ingredients with merits of safety and absence of drug resistance, *Abrus cantoniensis* polysaccharides display promising application prospects in alleviating hepatic steatosis in laying hens. In the future, *Abrus cantoniensis* polysaccharides are expected to be widely applied in laying-hen breeding as Chinese veterinary drugs or feed additives, improve productive performance and health status of laying hens, and promote sustainable development of breeding industry.

5.2. Existing challenges

Despite remarkable effects of *Abrus cantoniensis* polysaccharides on alleviating hepatic steatosis in

laying hens, its large-scale application still confronts several challenges. First, extraction and purification technologies for *Abrus cantoniensis* polysaccharides need further optimization to improve its purity and bioactivity. Second, its concrete action mechanisms have not been fully clarified, and in-depth studies on its molecular-biological mechanisms are required. Third, clinical application effects of *Abrus cantoniensis* polysaccharides need further verification to guarantee its safety and effectiveness.

6. Conclusion

This paper comprehensively reviews research advances of *Abrus cantoniensis* polysaccharides in alleviating hepatic steatosis in laying hens. *Abrus cantoniensis* polysaccharides significantly mitigate hepatic fat deposition and inflammatory responses in FLHS-affected laying hens via regulating intestinal-microbiota homeostasis, exerting functions through gut-liver axis and modulating expression of lipid-metabolism-related genes. In the future, along with further researches and technological progress, *Abrus cantoniensis* polysaccharides are expected to play vital roles in laying-hen breeding and boost green and sustainable development of animal-husbandry industry.

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A Qualitative Study on the Real-life Experience of Junior-College Midwifery Interns Participating in Delivery Assistance

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Abstract: *Objective*: To gain an in-depth understanding of the real-life experience of junior-college midwifery students participating in delivery assistance during their internship. *Methods*: Purposive sampling was adopted. From July 2021 to March 2022, 11 junior-college midwifery interns from a Grade-A tertiary specialized hospital in Guangzhou were selected for semi-structured in-depth interviews. The Colaizzi seven-step analysis method was used to analyze interview data and extract themes. *Results*: The experiences of junior-college midwifery students in participating in delivery assistance during internship could be summarized into three themes: strong professional identity (joy and moving feelings; sense of achievement; willingness to become midwives); coexistence of pressure and difficulties in internship (heavy work pressure on midwives; massive learning content for midwives); and expectations for diversified teaching support (expectation of diversified teaching methods; expectation of teaching tool support). *Conclusion*: It is recommended to provide emotional support for midwifery interns. Meanwhile, teaching models shall be provided and practical teaching methods shall be further explored so as to deliver diversified teaching support for midwifery interns.

Keywords: Junior college; Midwifery interns; Delivery assistance; Real-life experience

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1. Introduction

Academically, midwives are generally defined as professionals who provide physical support, psychological comfort, health-knowledge popularization and other services throughout pregnancy, childbirth and the postpartum period [1]. Midwives are guardians of maternal-infant safety. The most intuitive criterion for judging professional competence lies in whether it affects the life quality and health level of perinatal infants. Therefore, strengthening the construction of the midwife workforce and improving their professional competence constitute the top priority for safeguarding maternal and infant health. According to the *Healthy*

China 2030 Outline, the National Health Promotion Project calls for strengthening the construction of the maternal-child health-care system and sets raising maternal and infant survival rates as a major objective [2]. Afterwards, the fertility policy was adjusted to the three-child policy. The expected number of newborns will rise substantially, and the demand for high-quality midwifery services will increase accordingly. Although midwifery manpower allocation in China has been improved in recent years, supply shortage still exists on the whole. Documents issued by the National Health Commission point out that it is necessary to further improve the training mechanism for midwifery talents to meet the growing service demands [3,4]. Among them, the *National Report on the Reform and Development of the Health Service System (2018)* explicitly puts forward the strategic arrangement for perfecting the midwifery-skill training system, which is still under gradual improvement. Clinical internship is a vital link in higher midwifery education. It plays an irreplaceable role between theoretical knowledge and practical skills, helps learners transform book knowledge into practical performance, exerts a long-term influence on learners' professional competence, and provides a platform for translating medical-scientific-research achievements into practical products [5]. Studies show that midwifery-education models worldwide still have certain deficiencies and cannot cope with new challenges brought by the rapid development of the industry [6]. Observations from practical teaching activities indicate that some intern students have sound theoretical foundations yet encounter numerous problems in delivery-assistance practice, which is related to their insufficient hands-on experience. For beginners, the absence of systematic standardized training will exert negative impacts on their future development. Hence, it is of great importance to analyze difficulties and their causes encountered by midwifery students in delivery-assistance training. Against the above-mentioned background, this study investigates the current status of internship-teaching modes, puts forward corresponding improvement measures, and aims to enhance talent-training outcomes of the whole industry.

2. Subjects and methods

2.1. Research subjects

From July 2021 to March 2022, purposive sampling was adopted to select junior-college midwifery interns from a Grade-A tertiary hospital in Guangzhou as research subjects.

2.1.1. Inclusion criteria

(1) Majoring in midwifery at junior-college level;
(2) Having participated in delivery assistance during obstetric-ward internship;
(3) Good verbal-expression ability;
(4) Informed consent and voluntary participation in this study.

Sample size was determined by information saturation, namely when no new viewpoints or themes emerged.

A total of 11 midwifery interns were enrolled, and all of them gave informed consent. General information of respondents is shown in **Table 1**.

Table 1. General information of respondents

No.	Age (Years) / major	Adjusted-major admission	Time of entering department	Time of first delivery assistance	Times of delivery assistance
N1	22 / Midwifery	No	At the beginning of internship	4th week	4
N2	20 / Midwifery	No	At the beginning of internship	5th week	4
N3	21 / Midwifery	No	At the beginning of internship	4th week	3
N4	21 / Midwifery	No	2nd month of internship	5th week	6
N5	21 / Midwifery	No	2nd month of internship	3rd week	4
N6	21 / Midwifery	No	2nd month of internship	4th week	3
N7	20 / Midwifery	No	5th month of internship	3rd week	5
N8	22 / Midwifery	No	5th month of internship	3rd week	12
N9	20 / Midwifery	No	8th month of internship	3rd week	6
N10	23 / Midwifery	No	8th month of internship	4th week	7
N11	21 / Midwifery	No	8th month of internship	3rd week	5

2.2. Research methods

2.2.1. Development of interview outline

Combining clinical teaching experience and literature-analysis results according to research objectives, a preliminary interview outline was formulated. Three rounds of pre-investigations were conducted on 3 midwifery interns, and then the interview outline was revised. The interview mainly covered the following aspects:

(1) What are your feelings after participating in delivery assistance?

(2) How do you deal with difficulties encountered in delivery assistance?

(3) What do you think can help you perform delivery assistance better?

(4) How has your perception of the midwifery major changed after participating in delivery assistance?

(5) Do you want to become a midwife after taking part in delivery-assistance practice in obstetric-ward internship?

(6) Please put forward suggestions on arranging interns to participate in delivery assistance in the department.

2.2.2. Data collection

This study adopted a phenomenological research paradigm and collected data from 11 midwifery interns via semi-structured in-depth interviews [5]. Before formal interviews, the research group agreed on time and place with each respondent. Two interns took face-to-face interviews in the hospital-department meeting room, while the other nine were interviewed in quiet dessert shops or cafés. To guarantee participants' rights and research standardization, researchers elaborately explained research objectives, methods and procedures to all participants before audio-recording started. Audio-recording began only after written consent was obtained. During interviews, researchers observed and recorded respondents' non-verbal behaviors and allowed them to freely express inner true feelings. Each interview lasted for 30–90 minutes. Interviews were terminated when no new information appeared, which meant data saturation was reached. All audio records were transcribed into texts and proofread by respondents to ensure authenticity and completeness of data.

2.2.3. Data analysis

The Colaizzi seven-step analysis method was adopted for systematic sorting and in-depth analysis of transcribed audio data. Text materials were coded in the order N1–N11 and digitally stored with Nvivo 11.0 software. The research procedures included reading original transcripts to grasp key points of respondents' answers, extracting statements relevant to research themes, assigning meaning labels to high-frequency viewpoints, aggregating related elements to form an initial thematic-structure model, interpreting connotations of each theme, conducting multiple checks to ensure consistency and accuracy of categorized information, and finally submitting research results to respondents for review so as to confirm authenticity and scientific validity of conclusions [6].

2.2.4. Quality control

Pre-tests were carried out on three midwifery interns before formal investigation, and the interview outline was revised according to pre-test data. A total of 11 respondents with different rotation phases and clinical-experience levels participated in formal interviews. The average interview duration exceeded 30 minutes, ensuring good sample representativeness. All research-team members received systematic training on qualitative-research methods and passed assessment. After multiple group discussions and in-depth analyses, a coding framework was formed and major research themes were extracted.

3. Results

3.1. Theme 1: Strong professional identity

3.1.1. Joy and moving feelings

During obstetric-ward internship, midwifery interns all experienced their first delivery-assistance practice. They felt both moved by witnessing new-life birth and joyful for welcoming newborns.

N3: "I admire every mother for their greatness. Witnessing the birth of new life together with family members is really an interesting moment in delivery assistance. When hearing babies' loud cries and seeing exhausted smiles on mothers' faces, indescribable joy fills my heart".

N10: "The moment the baby is delivered with our efforts touches me deeply and will stay in my memory forever. I instantly feel that every midwife is so great, an angel welcoming new lives".

3.1.2. Sense of achievement

During internship, midwifery interns practiced midwives' daily work, including maternal labor-progress observation, nursing care, delivery assistance and postpartum care, and gained a sense of achievement from midwifery work.

N1: "It feels magical when the fetal head gets closer to the vaginal orifice during delivery assistance. Successful delivery assistance brings a strong sense of achievement".

N9: "I gain a great sense of achievement from welcoming newborn babies".

N7: "After assisting in delivery, I think midwives are extraordinary. Assisting the arrival of new life is both magical and rewarding".

3.1.3. Willingness to become midwives

All midwifery interns recognized the role of midwives and expressed their willingness to become midwives

safeguarding maternal-infant safety in the future.

N2: “Taking part in delivery assistance strengthens my aspiration to be a midwife. I want to relieve women’s labor pain and make childbirth a happy experience for them”.

N6: “I hope to become a midwife because I can welcome new lives”.

N8: “Participation in delivery assistance consolidates my career choice. I want to work as a midwife”.

3.2. Coexistence of pressure and difficulties in internship

3.2.1. Heavy work pressure on midwives

Midwifery interns perceived that midwives in obstetric wards are burdened with heavy workload and great pressure, as each maternal safety is related to two lives.

N4: “It is tougher and more difficult than I imagined, with more difficulties and uncertain factors”.

N11: “Midwives are busy and exhausted, and they suffer great pressure when facing rescue cases”.

3.2.2. Massive learning content for midwives

Respondents held that obstetric-ward practice requires more knowledge and skills compared with other clinical departments.

N3: “As a midwife, we need to fully master specialized obstetric-ward knowledge, and there is a huge amount of content to learn”.

N6: “We have to learn more theoretical knowledge as well as emergency-response measures for unexpected incidents”.

N10: “Midwives need sufficient carefulness and experience to judge various possible conditions during childbirth and make predictive interventions”.

3.3. Expectations for diversified teaching support

3.3.1. Expectation of diversified teaching methods

During obstetric-ward internship, respondents expected diversified teaching methods to integrate practice with theory, serve pregnant and lying-in women and guarantee maternal-infant safety.

N2: “I hope supervisors can adopt the ‘hands-off but eyes-on’ principle, allowing interns to operate more independently. We should start practicing delivery assistance from the 3rd week, with more than 10 delivery-assistance experiences”.

N5: “We can practice suturing with discarded placentas first. More delivery-assistance practices are always better”.

3.3.2. Expectation of teaching tool support

Interviewee midwifery interns hoped for corresponding teaching tools for specialized-skill training in clinical teaching. Most of them wanted mannequins to simulate delivery-assistance procedures.

N3: “I hope some mannequins can be used to clearly demonstrate anatomical structures and operating procedures for better understanding and practice”.

N9: “I wish we could practice simulated delivery-assistance operations with mannequins”.

4. Discussion

4.1. Attach importance to pressures and difficulties of students in learning delivery assistance, introduce positive midwifery values and reinforce professional identity

This paper conducts a detailed analysis on characteristics of junior-college midwifery interns' cognition of midwife professional roles when learning delivery-assistance techniques, and identifies two-fold factors. On the one hand, they generally gain profound sense of achievement from midwifery work, have deep experience of new-life birth, and possess strong willingness to engage in this occupation. On the other hand, midwives have to master extensive medical knowledge and complicated technical operations, so interns feel psychological pressure, together with practical challenges such as high-intensity workload, high-risk operations and frequent night shifts. The above-mentioned results are consistent with existing academic findings reported by Wu Dandan et al., Huang Shurong et al. [7–9]. Due to the special service nature and generally insufficient manpower in midwifery industry, midwives often undertake heavy-duty tasks and emergency treatments. They need to guarantee maternal-infant safety in obstetric emergencies and face high occupational-exposure risks. In such context, internship experience becomes a decisive factor for students' career planning and development. At the school-education stage, ideological-and-political guidance shall be strengthened. Positive publicity shall be adopted to help students fully understand professional values of midwives and cultivate their dedication-oriented professional spirit. Furthermore, clinical-teaching methods shall be improved. While practical-ability training is emphasized, mental-health support shall also be valued, and a tutorial-supervision system shall be implemented to provide personalized care. Besides, innovative practical-training forms and various online-learning activities shall be developed to deliver targeted and interesting tutoring for midwifery learners.

4.2. Meet students' learning demands for delivery assistance, adopt specialized teaching tools and implement diversified teaching methods

Research results show that midwifery interns expect to systematically master clinical delivery-assistance techniques via standardized teaching systems, and they attach great importance to supervisors' competence and guidance quality. These findings are roughly consistent with relevant domestic research outcomes [10]. Midwives are major practitioners of maternal-infant care. They are both service implementers and providers, and required to possess solid professional skills while facing high occupational risks. During internship, midwifery students usually encounter heavy learning burdens and complicated role transitions. To solve such problems, clinical departments shall be equipped with standard simulators first to increase interns' hands-on practice time [11]. In addition, clinical supervisors shall be encouraged to innovate teaching approaches and adopt personalized-guidance schemes. While strengthening supervision, excessive interference shall be reduced, so that interns can master core skills more rapidly and improve emergency-disposal capabilities, thus safeguarding maternal-infant safety and legitimate rights.

5. Conclusion

By summarizing simulated work experience of 11 midwifery interns, three major themes are extracted: strong professional identity, coexisting pressure and difficulties in internship, and expectations for diversified teaching support. The above points shall be emphasized in teaching practice. It is necessary to innovate midwifery teaching activities, increase mental-health support for prospective graduates and allocate

corresponding resources. The clinical-practice-teaching system shall be further optimized to strengthen students' competence from both theoretical and practical dimensions and enhance their professional self-confidence. Finally, a systematic and comprehensive teaching-support system shall be constructed to satisfy the growth demands of more midwifery students, which deserves further exploration and practice.

Disclosure statement

The authors declare no conflict of interest.

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The Impact of Real-Case Scenario Simulation Teaching on Nursing Students' Pediatric Emergency Response Competence

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Abstract: *Objective*: To investigate the actual results of applying real-life scenario simulation teaching in nurturing nursing students' pediatric emergency response ability. *Methods*: A total of 96 nursing interns from the pediatric department of a hospital were selected and randomly divided into a control group and an observation group, with 48 students in each group. The control group was taught by the traditional lecture method, and the observation group was taught using real-life case scenario simulations based on this method. Compare the scores of emergencies theoretical knowledge, operational skills and all-around emergency response ability for the two groups. *Results*: The observation group performed significantly better than the control group in emergency theoretical knowledge, operational skills and overall emergency response ability ($p < 0.05$). *Conclusion*: Real-life scenario simulation teaching can help nursing students develop their skills for responding to emergencies among children more effectively and is thus recommended.

Keywords: Scenario simulation; Real cases; Nursing students; Pediatrics; Emergency response

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1. Introduction

Pediatric emergencies are sudden-onset, rapidly progressing, and have a high mortality rate; therefore, they place very high demands on the emergency response ability of nursing staff. As the reserve force of the clinical nursing team, the cultivation of nursing students' pediatric emergency skills will directly affect the quality of future pediatric nursing care and the safety of children. Traditional teaching models focus on knowledge transmission, and nursing students may feel anxious, confused, disorganized in their work, and unable to cooperate effectively during a real emergency situation; thus, they cannot effectively apply what they have learned in class to practice. Real-case scenario simulation teaching takes actual clinical cases as its foundation, recreates the emergency process through high-fidelity scenarios, enables nursing students to practice multiple times and receive immediate feedback in a near-real-stressful environment, and helps

them bridge the gap between classroom learning and clinical application. Systematically assess the effect of this teaching model on nursing students' abilities in pediatric emergency response through a controlled experiment, and provide empirical support for nursing education reform [1].

2. Subjects and methods

2.1. Study subjects and grouping

From March 2024 to January 2025, 96 nursing students who had been rotated in the pediatric department of a tertiary Grade A hospital served as the study subjects. The inclusion criteria were: full-time undergraduate or associate degree students in nursing who had completed the theoretical course on pediatrics, provided informed consent, and volunteered to participate in this study. Exclusion criteria were: those with previous experience in pediatric emergency training and those who dropped out during the internship. Using a random number table, the nursing students were randomly assigned to a control group and an observation group, and there were 48 students in each group. There were no statistically significant differences in the baseline data of the two groups for age, gender, education level and pre-rotation theoretical examination scores ($p > 0.05$), so they could be compared; see **Table 1**. The study has been approved by the hospital's ethics committee, and all nursing students have signed informed consent forms.

Table 1. Comparison of general information between the two groups of nursing students

Item	Observation group (n = 48)	Control group (n = 48)	Statistical value	*p* value
Age (years, $\bar{x} \pm s$)	21.35 ± 1.42	21.48 ± 1.37	$t = 0.456$	0.649
Gender (male/female, n)	8/40	7/41	$\chi^2 = 0.079$	0.779
Education (undergraduate/associate, n)	19/29	21/27	$\chi^2 = 0.171$	0.679
Pre-rotation theoretical score (points, $\bar{x} \pm s$)	76.82 ± 6.54	77.15 ± 6.28	$t = 0.252$	0.801

2.2. Teaching methods and implementation

The control group used the old way of teaching; clinical instructors gave centralized theoretical lectures based on the pediatric internship syllabus, explained the rescue procedures and nursing key points for common pediatric emergencies, and then demonstrated operations in the demonstration room. Nursing students worked in groups, and the teachers moved around to guide them. The observation group received real-case scenario simulation teaching in addition to the traditional teaching method, and this was carried out in three steps. First, select a case and write a script. Four representative cases were selected from actual pediatric emergency situations for the teaching team's four typical scenarios: febrile convulsion, acute laryngeal obstruction, anaphylactic shock, and cardiac respiratory arrest. De-identify the data, standardize the scenario scripts, and specify when the condition changes and how it is assessed. Second, set up a scenario. A high-fidelity simulator and emergency equipment were employed to build a simulated scene. Nursing students formed groups of six and, under changing circumstances, carried out emergency operations such as assessment, judgment, calling for help, cardiopulmonary resuscitation (CPR), medication administration, and airway management, all of which were recorded on video. Thirdly, lead the debriefing. After the simulation, the instructor played back the recording and led the nursing students in a multi-dimensional reflective discussion about technical operation, clinical decision-making, teamwork and communication, etc., and then

provided item-by-item comments and summaries [2].

2.3. Evaluation indicators and tools

The three types of teaching effectiveness in this study are shown below. A self-developed test paper was used to assess the students' emergency theoretical knowledge, covering basic theory for children's emergencies, emergency medication dosage calculation, and key points of emergency procedures; a total of 100 points were available, and this test was given uniformly after the teaching period. Standardized operating assessment scales were used to evaluate emergency operational skills, and three main operations were selected: cardiopulmonary resuscitation (CPR), airway management, and intravenous access establishment. Each operation was graded out of 100 points, and then the mean of the three grades was taken as the operational skill score; independently, two uniformly trained graders rated these scores, and their average values were recorded. Five items were included in the self-developed rating scale for comprehensive emergency response ability: condition assessment and judgment, execution of emergency procedures, teamwork and coordination, nurse-patient communication, and emergency psychological quality. Each item was scored out of 20 points, and the total score of 100 points was obtained by combining the ratings from clinical instructors based on recordings of the simulation process and daily behavior. All three evaluation tools were validated by five nursing education and pediatric emergency experts, and all had content validity indices exceeding 0.85; they also passed pilot tests for good reliability.

3. Results

3.1. Comparison of emergency theoretical knowledge scores between the two groups

At the end of the teaching period, both groups of nursing students took the test for pediatric emergency theory. As shown in **Table 2**, the mean scores of the observation group and the control group were 88.42 ± 5.36 and 81.27 ± 6.18, respectively; the difference between them was statistically significant ($p < 0.001$), and thus the observation group performed better than the control group. Based on the further analysis of the scores by question type, it was found that the advantage of the observation group was relatively greater for case analysis questions and emergency procedure sequencing questions. Case analysis questions asked nursing students to determine whether there was a problem and suggest a solution based on the given situation for a child in an emergency; the average score of the observation group was 86.3%, and that of the control group was only 74.8%. Sequencing questions on emergency procedures tested how well nursing students could organize the steps of rescue logically, and the scoring rate for the observation group was also relatively high. Therefore, it can be seen that real-case scenario simulation teaching has strengthened the connection between theoretical knowledge and clinical practice by enabling nursing students to repeatedly experience the entire thought process of "assessment-judgment-management" in simulated environments, thus promoting the transition from rote memorization to the construction of an organized system of emergency thinking, and demonstrating a clear advantage in theoretical tests requiring all-around application[3].

3.2. Comparison of emergency operating skill scores for the two groups

Based on the results of the emergency operating skill assessment, the mean operation skill scores for the observation group were (90.15 ± 4.82) points, and those for the control group were (83.76 ± 5.94) points; the observation group had a higher score than the control group and was statistically significantly different ($p <$

0.001), as shown in **Table 2**. In item-by-item comparisons, for cardiopulmonary resuscitation, the observation group had significantly better standardization than the control group in all key indicators, including compression depth, rate and adequate recoil. In the operations of airway management, the observation group showed superior proficiency and fluency in bag-valve-mask ventilation techniques, timing of oropharyngeal airway insertion, and suctioning procedures. For intravenous access construction, the observation group had a shorter operation time, showed good asepsis awareness, and achieved a high first-attempt success rate. Based on the above results, it can be seen that real-life scenario simulations gave nursing students multiple chances to practice emergency operations under stress. Each simulation exercise was a full-featured and well-coordinated practical training session, requiring nursing students to quickly and accurately perform various emergency techniques under dynamic circumstances, rather than practicing isolated individual operations. This way of training for "operating in context" helped the nursing students learn how to apply their knowledge in practice and thus improve the quality and efficiency of their work during exams.

Table 2. Comparison of emergency theoretical knowledge and operational skill scores between the two groups (points, $\bar{x} \pm s$)

Item	Observation group (n = 48)	Control group (n = 48)	*t* value	*p* value
Emergency theoretical knowledge	88.42 ± 5.36	81.27 ± 6.18	6.055	< 0.001
Operational skill total score	90.15 ± 4.82	83.76 ± 5.94	5.786	< 0.001
Cardiopulmonary resuscitation	91.23 ± 5.14	84.38 ± 6.27	5.854	< 0.001
Airway management	89.76 ± 5.42	83.52 ± 6.15	5.274	< 0.001
Intravenous access establishment	89.46 ± 5.08	83.38 ± 5.86	5.431	< 0.001

3.3. Comparison of comprehensive emergency response competence scores between the two groups

The overall scores of the comprehensive emergency response competence tests for both groups are shown in **Table 3**; the observation group achieved a higher total score of (86.73 ± 5.21) points compared to the control group at (78.64 ± 6.35) points, and this difference was statistically significant ($p < 0.001$). Among the sub-item scores, the observation group showed the largest improvement in the three areas: condition assessment and judgment, teamwork and coordination, and emergency psychological quality. In the course of the scenario simulation, the nursing students in the observation group could promptly recognize signs of danger based on changes in vital signs and other clinical manifestations of the simulated children, and thus made reasonable prioritization judgments. In a group emergency response, the members had clearly divided labor and worked together well, carrying out their own responsibilities conscientiously. In the face of unexpected circumstances, the observation group had better self-regulation ability and was able to handle problems more proactively. On the other hand, although the control group of nursing students had learned some basic emergency knowledge and operation skills, they were still relatively disorganized, lacked coordination in teamwork, and were not emotionally ready to deal with complex emergencies. Therefore, it can be concluded that real-life case study simulation teaching promotes all-around and multi-faceted development of nursing students' general emergency response abilities [4].

Table 3. Comparison of comprehensive emergency response competence scores between the two groups (points, $\bar{x} \pm s$)

Evaluation item	Observation group (n = 48)	Control group (n = 48)	*t* value	*p* value
Condition assessment and judgment	17.86 ± 1.42	15.32 ± 1.78	7.729	< 0.001
Emergency procedure execution	17.42 ± 1.36	16.18 ± 1.52	4.212	< 0.001
Teamwork and coordination	17.65 ± 1.28	15.08 ± 1.86	7.885	< 0.001
Nurse-patient communication	16.92 ± 1.45	15.74 ± 1.63	3.747	< 0.001
Emergency psychological quality	16.88 ± 1.53	15.32 ± 1.72	4.694	< 0.001
Total score	86.73 ± 5.21	78.64 ± 6.35	6.782	< 0.001

4. Discussion

4.1. Impact of scenario simulation teaching on nursing students' emergency theoretical level

Real-case scenario simulation teaching can help nursing students learn more about the theoretical knowledge of pediatric emergency care better. Traditional theoretical teaching presents knowledge in an isolated and abstract manner; therefore, nursing students need to rely on rote memorization for exams and cannot apply what they have learned to actual clinical situations effectively. Scenario simulation teaching can address this problem by placing emergency theoretical knowledge in a real-life situation under time pressure and changing circumstances, prompting nursing students to actively recall, organize and apply what they have learned in the process of solving specific problems. This "learning by doing" method is in line with the first idea of constructivist learning theory; that is, people do not acquire knowledge passively but create it themselves in real life. A leader of the simulation will also conduct a group discussion later. Teachers guide the nursing students to reflect on their own judgments and decisions during the simulation, compare their actual performance with theoretical knowledge, identify deficiencies in their studies, and correct misunderstandings to deepen their understanding of the theory. Therefore, the increase in the theoretical level achieved by scenario simulation teaching is not merely the repetition of knowledge but also deep processing and meaning construction of that knowledge.

4.2. Effects of scenario simulation teaching on nursing students' emergency operating skills

The promotion effect of real-case scenario simulation teaching for emergency operation skills is also relatively strong. Given the high degree of proceduralism and time pressure in emergency operating skills, they cannot be taught by gradual decomposition; rather, all-encompassing training under near-real-life stress needs to be employed. In scenario simulation teaching, nursing students do not perform isolated single-operation tasks but a whole emergency process with continuously changing circumstances. A sequence of operations needs to be completed within a short period of time, such as assessment, calling for help, chest compressions, airway opening and intravenous access establishment; these operations have strict logical sequences and mutual constraints. Thus, this way of training can repeatedly activate and strengthen the operating skills of nursing students in real-world task chains, forming stable motor programs. At the same time, the repeatability of the simulation environment can be used to repeat practice safely several times before taking care of actual patients in a real emergency. Promptly correct errors and provide feedback during

the simulation to help nursing students learn about the standardized operation details more intuitively and improve the quality of their test results.

4.3. Impact of scenario simulation teaching on the all-round clinical competence of nursing students

Essentially, emergency response ability refers to all-around clinical practice skills that include both knowledge and operational skills, as well as other types of competencies such as clinical judgment, teamwork, communication, and stress management. The overall emergency response capability score of the observation group increased significantly in this study; thus, it can be concluded that the special value of real-case scenario simulation teaching lies in its all-encompassing cultivation of nursing students' all-round abilities. Nursing students need to work together to handle sudden changes in health during high-fidelity emergency training. Collaborative learning activities require students to learn how to divide roles, share information and cooperate mutually; these skills cannot be taught effectively in a traditional classroom setting. At the same time, the relatively mild psychological stress caused by the simulated scenarios can also serve as a form of "stress inoculation" for nursing students; through repeated exposure to tense simulated emergency situations, their emotional regulation and stress response abilities will gradually improve, and anxiety and panic in the face of actual emergencies will be reduced. Real-life cases can help nursing students feel the urgency of paediatric emergencies and understand why good cooperation among medical staff is necessary; thus, they will be motivated to learn systematically and develop a sense of professional responsibility.

5. Conclusions and recommendations

5.1. Research conclusions

Based on the results of a controlled experiment, this study found that simulated case scenario-based teaching can help nursing students improve their theoretical knowledge of pediatrics and emergency care, as well as enhance their practical skills and all-around emergency response ability. Scenario simulation teaching is better than the old lecture-demonstration method in terms of helping students learn how to apply their knowledge in practice and develop all-round clinical literacy; thus, it is a good way to teach pediatric emergency nursing [5].

5.2. Teaching recommendations

According to the research results, it is proposed that nursing colleges and clinical teaching bases proactively adopt real-case scenario simulation teaching in pediatric internship education. First, a well-organized library of typical cases for children's emergencies should be built to cover all kinds and difficulties of emergency situations and meet the requirements for tiered teaching. Secondly, strengthen the training of simulation teaching faculty to improve the clinical instructors' abilities in script writing, scenario leading and feedback analysis. In addition, the ratio of simulation teaching, theoretical instruction and skill training should be reasonably set up to form a closed-loop teaching process of "theory-simulation-reflection-re-practice", and a scientific and standardized evaluation system needs to be established to comprehensively and objectively assess the emergency response ability of nursing students.

5.3. Research limitations and prospects

The Study has the following defects. First, the sample was obtained from a single center and had a small size; therefore, the results of this study need to be verified by multiple centers and large-scale samples before being applied externally. Second, the assessment indicators focused on the short-term teaching effect and did not include a follow-up evaluation of how well nursing students retained their emergency skills after leaving school. Thirdly, the overall emergency response capability scores were subjectively evaluated by clinical instructors, and although reliability and validity tests have been conducted, there may still be some bias. In the future, one can extend the follow-up time, add objective behavioral observation indicators and clinical performance assessments, and further explore the ideal implementation plan for scenario simulation teaching and its application across all levels of nursing students.

6. Conclusion

The training of children's emergency response ability is a relatively urgent and complex problem in nursing education. Real-case scenario simulation teaching has many strengths, such as context creation, interaction and reflection, which can help nursing students connect their classroom learning with actual practice. Based on the above analysis, it can be concluded that this way will help nursing students improve their emergency theory knowledge, operating skills and all-around response ability. With the continuous progress of simulation teaching technology and changes in teaching ideas over time, this teaching model will likely be applied more widely to nurture outstanding nursing talents who possess strong emergency skills and can protect the lives of young patients.

Disclosure statement

The authors declare no conflict of interest.

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Systematic Review of Delirium Risk Prediction Models in Adult ICU Patients

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Abstract: *Objective*: To systematically retrieve and evaluate delirium risk prediction models in adult intensive care unit (ICU) patients and provide evidence for model optimization and clinical practice. *Methods*: A systematic literature search was conducted in PubMed, Web of Science, Embase, Cochrane Library, CINAHL, CNKI, Wanfang Data, VIP, and CBM databases from inception to August 2025. Two independent researchers performed literature screening, data extraction, and quality assessment. *Results*: Seventeen studies involving 18 prediction models were included, with sample sizes ranging from 100 to 8,878 cases and outcome events from 21 to 4,431 cases. The area under curve (AUC) for model development ranged from 0.732 to 0.941. Twelve models reported calibration, 10 studies performed internal validation, and 6 studies conducted external validation. Overall applicability of the 17 studies was acceptable. The final models contained 3-15 predictors; however, all models exhibited high risk of bias. *Conclusion*: Existing models generally demonstrated acceptable discrimination, but were associated with high risk of bias, with insufficient evidence regarding external validation, calibration assessment, and clinical implementation. Future studies should strictly follow the PROBAST criteria, standardize procedures for model development and validation, improve model stability and clinical application value, and provide reliable evidence for clinical decision-making.

Keywords: Intensive care unit; Delirium; Prediction model; Systematic review

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1. Introduction

Delirium is an acute, reversible cognitive dysfunction syndrome characterized by fluctuating disturbance of consciousness, inattention, disorganized thinking, or altered level of consciousness [1]. It is the most common acute brain dysfunction complication in intensive care unit (ICU) patients, with an incidence rate as high as 20–80% [2]. Studies have indicated that delirium impairs patients' cognitive function, increases risk of complications, prolongs mechanical ventilation duration and overall hospital stay, and may lead to

disability or death in severe cases, affecting patient prognosis and increasing clinical burden [3]. Therefore, early identification of high-risk factors and targeted management are of great clinical significance for improving patients' delirium status. As a scientific and effective risk prediction tool, risk prediction models can integrate various independent risk factors, quantify individual disease probability, accurately screen high-risk populations, and provide theoretical support for clinical medical staff to implement personalized interventions [4]. Currently, scholars worldwide have constructed and validated prediction models for delirium risk in ICU patients; however, differences exist in predictors, modeling methods, and performance indicators, and systematic evaluation of related models is still lacking. Therefore, this study systematically reviews the current status of delirium risk prediction models in ICU patients and comprehensively evaluates the included studies to provide theoretical reference for clinical practice and related research.

2. Materials and methods

2.1. Literature search strategy

A systematic literature search was performed in PubMed, Web of Science, Embase, Cochrane Library, CINAHL, CNKI, Wanfang Data, VIP, and CBM databases for studies on delirium risk prediction models in ICU patients, from database inception to August 2025. The search combined subject terms and free-text words. For Chinese databases, taking CNKI as an example, the search strategy was: Subject = (critical care OR intensive care unit OR ICU) AND Subject = (delirium syndrome OR clinical delirium OR delirium) AND Subject = (early warning OR risk prediction OR prediction model OR diagnostic model OR risk score OR risk assessment OR risk factors OR nomogram). For English databases, taking PubMed as an example, the search strategy was: (((“critical illness”[MeSH]) OR (“intensive care units”[MeSH])) AND ((“delirium”[MeSH Terms]) OR (“delirium”[Title/Abstract])) AND (((((((“risk assessment”[MeSH]) OR (“risk prediction”[Title/Abstract])) OR (“risk forecast model”[Title/Abstract])) OR (“risk score”[Title/Abstract])) OR (“prediction model”[Title/Abstract])) OR (“prediction tool”[Title/Abstract])) OR (“nomograms”[MeSH])) OR (“diagnostic model”[Title/Abstract])) OR (“risk factors”[MeSH])))). This study was registered on the PROSPERO platform (Registration No. CRD42024602398).

2.2. Inclusion and exclusion criteria

2.2.1. Inclusion criteria

(1) Study subjects were adult ICU patients;

(2) Study content was construction or validation of delirium risk prediction models in adult ICU patients;

(3) Study type was cohort study (prospective or retrospective) or cross-sectional study; (4) Outcome indicator was delirium.

2.2.2. Exclusion criteria

(1) No clear model reported;

(2) Conference abstracts, grey literature, and other informally published literature;

(3) Complete model information unavailable, such as only mentioning model name without providing formula or regression coefficients.

2.3. Literature screening and data extraction

Two researchers independently completed literature screening according to preset inclusion and exclusion criteria. In case of disagreement, a third researcher was consulted. After removing duplicate literature using NoteExpress software, titles and full texts were read to exclude irrelevant literature before inclusion. Two researchers independently extracted the following information using a unified form: basic study characteristics, outcome definition, candidate predictors, modeling methods, sample size and number of events, variable processing methods, validation methods, discrimination indicators, and calibration indicators.

2.4. Risk of bias and applicability assessment

2.4.1. Risk of bias assessment

This study used the Prediction model Risk of Bias ASsessment Tool (PROBAST) to conduct quality evaluation from four domains: participants, predictors, outcome, and analysis, covering 20 items. Each domain included 2-9 questions, judged as "yes/probably yes," "no/probably no," or "no information." Each dimension was individually rated as low risk, high risk, or unclear. A single domain was rated as low risk if all key questions were met, high risk if any key question was not met, and unclear if key information was missing but other items were met. Overall risk of bias was determined by combining results from the four domains: low risk if all domains were low risk, high risk if any domain was high risk, and unclear if only unclear domains existed with others being low risk [5,6].

2.4.2. Applicability assessment

The evaluation logic for applicability risk was parallel to that of bias risk, but based on evaluation results from three domains: participants, predictors, and outcome [6]. If applicability risk results for all three domains were "low," overall applicability risk was rated as "low." If at least one domain had "high" applicability risk, overall applicability risk was rated as "high." If at least one domain had "unclear" applicability risk and other domains were "low," overall applicability risk was rated as "unclear."

3. Results

3.1. Literature search process and results

A total of 3,037 relevant articles were retrieved through the search. After removing duplicates, 2,542 articles were obtained. After screening, 17 articles were finally included. The literature screening process is shown in **Figure 1**.

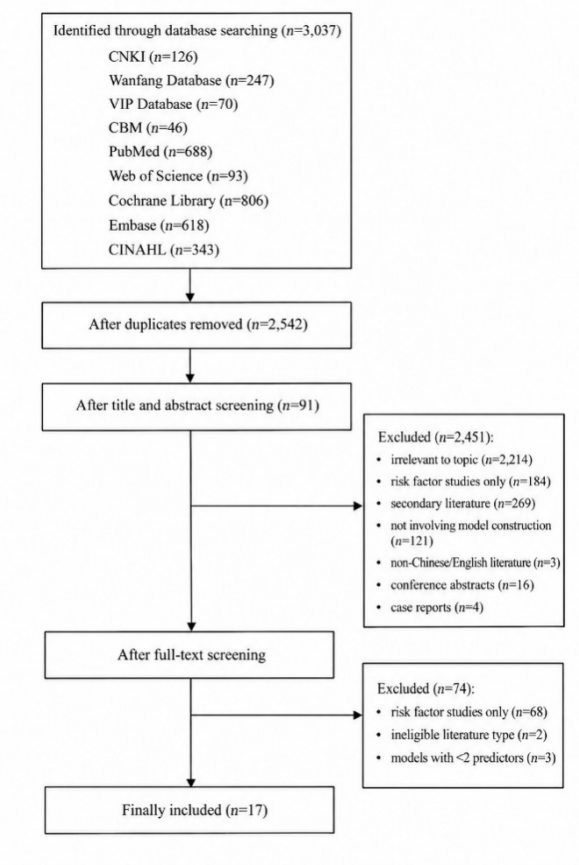


Figure 1. Flow chart of literature search.

3.2. Basic characteristics of included studies

Seventeen studies were finally included, published as follows: 12 from China, 1 from the Netherlands, 1 from South Korea, 1 from Canada, 1 from Argentina, and 1 joint study from 7 countries (Australia, Belgium, United Kingdom, Germany, Spain, Sweden, Netherlands) [7–23]. Among them, 8 were Chinese-language articles and 9 were English-language articles[7-18, 19–23]; of the 17 studies, 8 were retrospective studies and 9 were prospective studies [8–23]. Basic characteristics of included studies are shown in **Table 1**.

Table 1. Basic characteristics of the included studies (n = 17)

Study	Publication year	Country	Study design	Study population	Delirium assessment criteria
Huang et al. [23]	2023	China	Retrospective	ICU patients	CAM-ICU (criterion b)
Chang et al. [22]	2024	China	Retrospective	Elderly patients with severe pneumonia on mechanical ventilation	CAM-ICU (criterion a)
Zhang et al. [21]	2025	China	Prospective	ICU patients	CAM-ICU (criterion a)
Cao et al. [20]	2023	China	Prospective	ICU patients	CAM-ICU, ICDSC
Wassenaar et al. [19]	2015	Multi-country (7 countries)	Prospective	ICU patients	CAM-ICU positive
Shen et al. [18]	2023	China	Retrospective	ICU patients	CAM-ICU (criterion a)
Zhu [17]	2017	China	Retrospective	ICU patients	CAM-ICU positive

Dai et al. [15]	2024	China	Retrospective	ICU patients with respiratory failure on mechanical ventilation	CAM-ICU (criterion a)
Zhang et al. [16]	2024	China	Prospective	ICU patients	CAM-ICU (criterion a) combined with RASS classification
Wang et al. [14]	2023	China	Retrospective	ICU patients	ICDSC score ≥ 4
Chen et al. [13]	2017	China	Prospective	ICU patients	CAM-ICU (criterion c)
Boogaard et al. [12]	2012	Netherlands	Prospective	ICU patients	CAM-ICU (criterion c)
Moon et al. [10]	2018	South Korea	Prospective	ICU patients	CAM-ICU (criterion a)
Chen et al. [8]	2025	China	Retrospective	ICU patients	CAM-ICU positive
Cherak et al. [11]	2020	Canada	Retrospective	ICU patients	ICDSC score ≥ 4
Fan et al. [9]	2019	China	Prospective	ICU patients	CAM-ICU (criterion a)
Sosa et al. [7]	2018	Argentina	Prospective	ICU patients	CAM-ICU positive

Note: ICDSC: Intensive Care Delirium Screening Checklist; CAM-ICU: Confusion Assessment Method for the ICU; Criterion a: CAM-ICU positive when meeting criteria (1)+(2)+(3) or (4) among four criteria; Criterion b: CAM-ICU single positive when only one positive symptom present; Criterion c: CAM-ICU screening positive when at least one positive screening result during observation period.

3.3. Model development

The included studies had 7 to 4,211 candidate predictors, sample sizes of 100 to 8,878 cases, and outcome events of 21 to 4,431 cases. Regarding modeling methods, 14 studies used logistic regression as the primary modeling method, 1 study combined logistic regression with random forest algorithm, and 1 study applied machine learning (GBT, LR, DL) [7–23]. The 17 included studies involved 18 prediction models, of which 13 models constructed risk assessment formulas based on logistic regression coefficients, 2 studies presented prediction models in nomogram form, 1 study presented machine learning models (including models at admission and 24 hours), and 1 study combined logistic regression with random forest algorithm to construct models [7–23].

3.4. Model performance and predictors

All included studies reported discrimination assessment indicators during model development or validation, with area under the curve (AUC) ranging from 0.732 to 0.941, indicating overall good model discrimination. Regarding model validation, 10 studies performed internal validation (including cross-validation, Bootstrap method, and random split validation), and 6 studies conducted external validation [7,8–14,16,18,19,21,23]. Final models contained 3–15 predictors, with frequently appearing predictors including age, APACHE II score, GCS score, blood urea nitrogen (BUN), mechanical ventilation, hypertension history, diabetes history, and infection. See **Table 2**.

Table 2. Establishment of delirium risk prediction models for adult ICU patients (n = 17)

Study	Candidate Variables (n)	Continuous Variable Processing	Modeling Sample Size (n)	Outcome Events (n)	Primary Modeling Method	Model Validation Method	Calibration Method	Development AUC	Validation AUC	Predictors
Huang et al. [23]	28	Partially converted to categorical	247	73	Logistic regression	Ten-fold cross-validation	Calibration curve	0.799	—	Age, hypertension history, APACHE II score, benzodiazepine sedatives, mechanical ventilation
Chang et al. [22]	—	Kept continuous	397	80	Logistic regression	—	H-L goodness-of-fit test	0.929	—	Critical condition, cerebrovascular disease, diabetes, prolonged mechanical ventilation, prolonged awakening time after drug withdrawal, elevated blood lactate, elevated CRP, elevated PCT
Zhang et al. [21]	—	Partially converted to categorical	436	59	Logistic regression, Random forest	Ten-fold cross-validation	Calibration curve	0.832 /0.871	0.849	Age, APACHE-II, BMI, Barthel index, sleep, combined medication, emergency admission, etc.
Cao et al. [20]	9	Kept continuous	212	37	Logistic regression	—	—	0.882	0.882	Age, cognitive impairment history, alcohol abuse history, treatment experience, MAP, respiratory failure, BUN
Wassenaar et al. [19]	18	Kept continuous	1,962	481	Logistic regression	Ten-fold cross-validation	Calibration curve	0.76	0.75	Age, cognitive impairment history, alcohol abuse history, BUN level, admission category, emergency admission, MAP, glucocorticoid use, respiratory failure
Shen et al. [18]	—	Partially categorical	100	21	Logistic regression	External validation	H-L goodness-of-fit test	0.891	0.838	Age, hypertension history, invasive mechanical ventilation, hospital stay, APACHE II score, acid-base imbalance

Study	Candidate Variables (n)	Continuous Variable Processing	Modeling Sample Size (n)	Outcome Events (n)	Primary Modeling Method	Model Validation Method	Calibration Method	Development AUC	Validation AUC	Predictors
Zhu [17]	—	Partially categorical	147	36	Logistic regression	Random split internal validation	H-L goodness-of-fit test	—	0.749	BUN level, GCS score, infection
Dai et al. [15]	—	Converted to categorical	140	62	Logistic regression	External validation	—	0.764	—	Age ≥65 years, pain ≥4, APACHE II score >13, ICU environmental stressor score >72, ICU stay >1 week, diabetes, hypertension
Zhang et al. [16]	30	Partially converted to categorical	300	93	Logistic regression	Bootstrap internal validation, External validation	H-L goodness-of-fit test	0.941	0.897	Electrolyte imbalance, catheters ≥2, diuretic use, GCS score, CRP concentration, BUN concentration
Wang et al. [14]	ADM-8, 24H-15	Kept continuous	ADM-4,999, 24H-2,773	ADM-1,624, 24H-881	Machine learning (GBT, LR, DL)	External validation	Calibration curve	0.858 (ADM), 0.931 (24H)	—	Age, BMI, dementia history, postoperative monitoring, elective surgery, pre-ICU hospital days, GCS score, initial respiratory rate
Chen et al. [13]	11	—	620	160	Logistic regression	Random split internal validation	—	0.78	—	Age, APACHE-II score, coma, emergency surgery, mechanical ventilation, multiple trauma, metabolic acidosis, hypertension history, delirium history, dementia history, dexmedetomidine use
Boogaard et al. [12]	25	Partially categorical	1,613	411	Logistic regression	External validation	Calibration curve	0.87	0.84	Age, APACHE-II score, coma, admission category, infection, metabolic acidosis, morphine use, sedative use, urea concentration, emergency admission

Study	Candidate Variables (n)	Continuous Variable Processing	Modeling Sample Size (n)	Outcome Events (n)	Primary Modeling Method	Model Validation Method	Calibration Method	Development AUC	Validation AUC	Predictors
Moon et al. [10]	4,211	Kept continuous	3,284	688	Logistic regression	Random split internal validation, External validation	—	0.89	0.72	Age, education years, LOC score, pulse, activity level, internal medicine, BUN, infection, number of catheters, restraint, psychotropic drugs
Chen et al. [8]	—	Partially continuous	964	186	Logistic regression	Random split internal validation	Calibration curve	0.732	—	Drug abuse, alcohol abuse, male, maximum potassium, minimum chloride, hospital days, maximum BUN, minimum hematocrit
Cherak et al. [11]	10	Partially converted to categorical	8,878	4,431	Logistic regression	Ten-fold cross-validation	—	0.76	0.67-0.78	Age, sex, APACHE II, GCS, SOFA, Charlson index, vasoactive drugs, neuropsychiatric history, CRRT, mechanical ventilation
Fan et al. [9]	7	Partially converted to categorical	336	68	Logistic regression	Bootstrap internal validation, Random split internal validation	H-L goodness-of-fit test	0.907	0.9	Chronic disease history, hearing impairment, infection, APACHE II >7.5, sedation/analgesia, catheterization, sleep disorder
Sosa et al. [7]	10	Kept continuous	178	49	Logistic regression	External validation	—	—	0.83	Age, APACHE II score, coma, emergency admission, admission category, infection, sedative use, morphine use, urea level, metabolic acidosis

3.5. Model quality assessment

PROBAST was used to evaluate prediction model studies. Regarding participants, 8 studies were rated as "high risk" because 2 studies excluded patients with "Mini-Mental State Examination (MMSE) score < 10 at admission", preventing the study population from representing the target population and causing model prediction performance to be overestimated [8,11,14,15,17,18,22,23]. One study excluded participants with competing

events such as "postoperative death", reducing model prediction performance [17]. The remaining 5 studies' main risk source was retrospective study design, which is more prone to selection bias and information bias during modeling and validation phases [8,11,15,18,22]. Regarding predictors, 1 study's bias risk was rated as "unclear" because the article did not clearly state whether predictor assessors were blinded to the outcome (delirium) [16]. Regarding outcome, 2 studies' bias risk was rated as "unclear", and 10 studies were rated as "high risk" [7,8–13,15–18,22]. The main reason for high risk in most studies was using predictor information when determining outcomes; 2 studies did not report whether outcome definitions were consistent across all patients [7,18]; outcome definition standards and measurement methods were unclear in 5 studies [7,9,11,17,18]; 2 studies did not report whether outcome definition excluded predictor information [7,18]; and unreasonable time intervals existed between predictor and outcome assessment in 5 studies [7,9,11,17,18]. See **Table 3**.

Table 3. Quality assessment for risk of bias and applicability concern of the models (n = 17)

Study	Risk of Bias				Applicability			Overall Assessment	
	Partici pants	Predictors	Outcome	Analysis	Partic ipants	Predictors	Outcome	Risk of Bias	Applic ability
Huang et al. [23]	High risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Chang et al. [22]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Zhang et al. [21]	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Cao et al. [20]	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Wassenaar et al. [19]	Low risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Shen et al. [18]	High risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Zhu [17]	High risk	High risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Dai et al. [15]	High risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Zhang et al. [16]	Low risk	Unclear	Unclear	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Wang et al. [14]	High risk	Low risk	Low risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Chen et al. [13]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Boogaard et al. [12]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Moon et al. [10]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Chen et al. [8]	High risk	High risk	Unclear	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Cherak et al. [11]	High risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Fan et al. [9]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk
Sosa et al. [7]	Low risk	Low risk	High risk	High risk	Low risk	Low risk	Low risk	High risk	Low risk

4. Discussion

4.1. Overall high risk of bias in delirium risk prediction models for ICU patients, with methodological quality needing improvement

Among the 17 included studies, model discrimination was generally good, with all reported development or validation AUC > 0.7; however, overall methodological quality was low, with all identified as high bias risk due to deficiencies in statistical analysis, manifested as insufficient events per variable (EPV), improper continuous variable processing, insufficient explanation or handling of missing data, and lack of external validation. Systematic evaluation of included studies using PROBAST tool revealed bias risk mainly concentrated in the following aspects: ① Regarding participants: most studies used retrospective design,

and some excluded high-risk populations such as those with cognitive impairment, prone to selection bias; ② Regarding predictors: most data came from retrospective medical records, with inconsistent definitions and measurement methods, and some factors had timing bias; ③ Regarding outcome: predictor information was used in outcome determination, with unreasonable assessment time intervals; ④ Regarding analysis: insufficient sample size (most EPV < 20), improper continuous variable processing, unclear missing data handling, variable selection involving only univariate analysis, and insufficient model validation (lack of internal validation or only random split processing). This greatly reduced reliability of model performance assessment and generalization performance. Therefore, future studies should strictly follow PROBAST specifications, adopt prospective multicenter design, ensure EPV ≥ 20, implement scientific and effective variable selection methods, and prioritize Bootstrap method or cross-validation for internal validation while conducting multicenter external validation to construct more reliable ICU delirium risk prediction models.

4.2. Certain commonalities exist among predictors across different delirium risk prediction models

Results showed that although variables included in each model had different emphases, they showed obvious commonalities in predictors. Age, APACHE II score, infection/sepsis, metabolic acidosis, and sedative use were common and stable core prediction indicators across multiple model types. Reasons are as follows: with increasing age, elderly patients experience decreased brain reserve function and increased susceptibility to inflammation and metabolic disorders [25]; higher APACHE II scores indicate more severe physiological disorders and systemic inflammatory responses, potentially triggering central nervous system inflammatory responses, disrupting neurotransmitter balance, and ultimately causing delirium [26]; infection or sepsis can induce delirium by promoting inflammatory responses that damage the blood-brain barrier, activate microglia, induce neuroinflammation, and interfere with neurotransmitter metabolism; metabolic acidosis affects neuronal function and energy metabolism by reducing pH, exacerbating internal environment disorders and promoting delirium occurrence [27]; sedative use (especially benzodiazepines) inhibits the central cholinergic system, disrupts sleep cycles, and increases delirium risk [28]. Notably, some factors such as GCS score and mechanical ventilation had relatively lower consensus but still held important value in specific clinical contexts. For example, GCS score can reflect consciousness level and has important value for assessing consciousness state in postoperative patients with traumatic brain injury [29]; prolonged mechanical ventilation duration can cause acute changes in patients' cognitive and consciousness states [30]; cardiopulmonary bypass time has critical value in application to post-cardiac surgery patients. Based on this, during clinical practice, stratified screening strategies combining core factors with scenario-specific factors should be appropriately implemented: for modifiable factors such as sedative use and mechanical ventilation, dynamic dose adjustment and daily spontaneous breathing trials should be managed proactively; for high-risk populations such as elderly patients and those with high APACHE II scores, early warning stratified monitoring programs should be established. Additionally, medical-nursing communication and handover systems should be strengthened to ensure effective transmission of high-risk patient information across shifts; at the nursing level, early mobilization interventions, sensory stimulation regulation, and sleep protection measures should be implemented to achieve organic combination of risk identification and preventive intervention.

4.3. Clinical screening pathways for ICU delirium risk prediction models and future prospects

Currently, the number of ICU delirium risk prediction models is increasing, but clinical generalizability still requires verification. Reasons include: model generalization ability is generally insufficient, most are constructed based on specific subpopulations, and performance significantly decreases when applied to general ICU patients, such as E-PRE-DELIRIC showing AUC of only 0.54 in cardiac surgery validation [24,31]; differences exist among delirium assessment tools (CAM-ICU, ICDSC, etc.) used in different studies, limiting comparability between models. Additionally, methodologically, 82.4% of studies relied on logistic regression, making it difficult to capture nonlinear relationships, coupled with problems such as insufficient sample size (EPV < 20), improper continuous variable processing, and lack of external validation, leading to high bias risk in studies. Therefore, establishing a stratified screening mechanism is recommended: first evaluate compatibility between model and target population, reviewing whether inclusion criteria, assessment tools, and outcome definitions are consistent; second, assess methodological quality according to PROBAST evaluation, prioritizing models with prospective design, sufficient sample size (EPV ≥ 20), reasonable variable processing, and multicenter validation; finally, balance prediction performance with clinical operability, focusing on calibration and accessibility of predictors in routine monitoring. Future study design should prioritize prospective multicenter large-sample cohorts and follow reporting standards such as TRIPOD and CHARMS; modeling can introduce machine learning algorithms to explore complex associations. Meanwhile, urgent need exists to unify delirium assessment standards and core variable definitions, promote database sharing, and enhance comparability. Ultimately, validated models should be embedded in electronic medical records or mobile nursing systems to achieve real-time dynamic assessment and interface with ABCDEF bundle care, constructing a decision-making closed loop from early warning to intervention to effectively reduce delirium incidence.

5. Conclusion

This study included 17 studies involving 18 prediction models for adult ICU delirium risk, systematically evaluating participants, predictors, outcomes, and analysis aspects of each model. Results showed that existing adult ICU delirium risk prediction models generally demonstrated good discrimination (AUC range 0.732–0.941), but most studies had high bias risk due to: incomplete model validation system, inconsistent validation methods, improper continuous variable processing, and lack of multicenter large-sample data. Therefore, in future research, referring to PROBAST guidelines, procedures for prediction model construction and validation should be standardized, using combined internal-external validation, cross-validation, and other methods to improve model validation system. Meanwhile, multicenter, large-sample prospective studies should be conducted to enhance model stability and clinical application value. Moreover, during clinical nursing application, models should be carefully selected based on target population, delirium assessment tools, prediction time points, and variable availability, and risk warning should be linked with standardized delirium screening and ABCDEF bundle care interventions to promote translation of prediction models into clinical practice.

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Disclosure statement

The authors declare no conflict of interest.

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Knowledge on and Understanding of Preventive Measures on Gestational Hypertension: Basis for a Health Education Model

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Abstract: *Background*: Gestational hypertension is a significant contributor to maternal and perinatal morbidity and mortality. Improving pregnant women's knowledge of the condition and its preventive measures is essential to promote early recognition, effective disease management, and better pregnancy outcomes. *Objectives*: This study examined pregnant women's knowledge of gestational hypertension, assessed their understanding of preventive measures, and developed a health education model based on the survey findings. *Methods*: A quantitative descriptive-correlational design was adopted. A total of 84 pregnant women diagnosed with gestational hypertension from Shucheng People's Hospital in Anhui Province were recruited by purposive sampling. Validated self-developed questionnaires were used for data collection, with Cronbach's α coefficients ranging from 0.961 to 0.989. Descriptive statistics, Pearson correlation and multiple linear regression analyses were applied for data processing. *Results*: Participants possessed moderate overall knowledge of gestational hypertension regarding its causes, clinical manifestations and treatment. Obvious knowledge gaps existed in clinical features related to multiple pregnancies and chronic kidney disease. Among preventive-measure dimensions, items about prenatal check-ups and nutrition obtained the highest scores, while travel safety and gestational sexual activity had relatively lower scores. Knowledge level of gestational hypertension was positively and significantly correlated with understanding of preventive measures ($\beta = 0.720$, $*p* < 0.01$). Family history of hypertension and gravida were significant influencing factors for knowledge level. Advanced age, higher education background, employment status and regular attendance at Hypertensive Disorders of Pregnancy (HDP) clinics were predictive of higher scores for preventive-measure comprehension. *Conclusion*: Better knowledge and preventive awareness of gestational hypertension facilitate disease management and optimize maternal-infant outcomes. A four-dimensional integrated health education model focusing on risk stratification, multimodal education, interdisciplinary-family joint support and continuous dynamic monitoring is proposed. It is recommended to optimize clinical nursing practice, embed maternal health education into nursing education curricula, and carry out large-sample multi-center studies to improve care quality for patients with gestational hypertension.

Keywords: Gestational hypertension; Hypertensive disorders of pregnancy (HDP); Knowledge level; Preventive measures; Health education model; Pregnant women

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1. Introduction

1.1. Background of the study

Improving maternal health remains a core global public-health priority and an important target of United Nations Sustainable Development Goal (SDG) 3, which aims to cut preventable maternal mortality and guarantee healthy life for mothers and newborns. Even with continuous progress in obstetric care worldwide, numerous pregnant women still suffer from avoidable pregnancy-related complications each year. Timely prenatal surveillance can identify and intervene in most of these adverse conditions. Pregnancy-related complications not only raise the risk of maternal illness and death, but also trigger a series of unfavorable fetal-neonatal consequences including preterm birth, fetal growth restriction and perinatal death, bringing long-term health burden and socioeconomic loss to families and communities [1].

Gestational hypertension ranks among the top leading causes of maternal and perinatal morbidity and mortality across the globe [1]. According to WHO statistics, gestational hypertension results in roughly 42 000 preventable maternal deaths annually, accounting for 14–16% of global pregnancy-associated mortality [2]. In China, the prevalence of gestational hypertension has climbed from 4.57% in 2018 to 7.04% in 2023. Advanced maternal age, pre-pregnancy overweight and insufficient prenatal health education contribute to higher incidence in western inland regions. In accordance with 2022 diagnostic criteria released by the International Society for the Study of Hypertension in Pregnancy (ISSHP), gestational hypertension refers to newly-occurring systolic blood pressure ≥ 140 mmHg and/or diastolic blood pressure ≥ 90 mmHg after 20 weeks of gestation among previously normotensive women, without proteinuria or end-organ damage evidence [3]. Distinct from more serious hypertensive disorders in pregnancy, gestational hypertension can be largely prevented or well-controlled by early risk screening, regular prenatal monitoring and standardized prenatal health education [2].

Existing evidence confirms that maternal health cognition exerts critical effects on gestational hypertension prevention and pregnancy prognosis [4]. Insufficient awareness of risk factors, warning signs and self-protective behaviors acts as a modifiable risk factor for disease onset. Targeted prenatal health education represents a cost-effective strategy for lowering incidence of gestational hypertension [5]. The exact pathogenesis of gestational hypertension has not been fully clarified [6]. Considering fetal safety limits pharmacological options during gestation, clinical guidelines universally stress prevention and early intervention [7]. Therefore, enhancing pregnant women's knowledge about gestational hypertension and corresponding preventive measures is of great value for early case detection, promotion of healthy behaviors and individualized antenatal care.

Current domestic and international studies mostly focus on patients already diagnosed with gestational hypertension, attaching more importance to pharmacotherapy and inpatient nursing rather than preventive education for high-risk populations [5]. Few research teams simultaneously compare knowledge status between undiagnosed high-risk pregnant women and women living with gestational hypertension, which creates barriers to identifying differentiated educational demands. Moreover, evidence-based structured health-education models built upon real-world maternal questionnaire data are scarce [8]. Such models are urgently needed to support primary prevention for high-risk groups as well as secondary clinical management for confirmed patients. Filling these research gaps will greatly promote preventive maternal healthcare and clinical nursing practice.

For the above reasons, this research investigates knowledge level and preventive-measure understanding among high-risk pregnant women and patients diagnosed with gestational hypertension. On the basis of

empirical survey data, this study constructs a stratified evidence-based health education model, helping obstetric nurses deliver patient-centered individualized prenatal education, improve preventive maternal health service quality and achieve better maternal-neonatal outcomes.

1.2. Statement of the problem

Gestational hypertension severely threatens maternal and fetal safety and contributes greatly to maternal-perinatal adverse events [1]. Its etiology is multifactorial, jointly influenced by diverse maternal and environmental elements. Exploring pregnant women's mastery of gestational-hypertension-related knowledge and standardized preventive measures can produce empirical foundations for targeted nursing interventions and reduce disease occurrence. This study evaluates participants' knowledge and preventive cognition. Survey findings serve as empirical basis for developing a stratified health-education model. It should be noted that the health-education model is the final output of this project instead of a statistical hypothesis waiting for testing.

Six concrete research questions are put forward as follows:

(1) What is the demographic profile of participants in terms of:
   ①㊀maternal age
   ②㊀current gestational age
   ③㊀gravida (total lifetime pregnancies) and parity (number of live births)
   ④㊀educational attainment
   ⑤㊀monthly household income
   ⑥㊀occupation
   ⑦㊀familial history of hypertensive disorders in pregnancy

(2) What is the level of knowledge of pregnant women on gestational hypertension as to:
   ①㊀the causes
   ②㊀signs and symptoms
   ③㊀identification of severe maternal-fetal complications
   ④㊀fundamental principles of gestational hypertension prevention

(3) What is the participants' level of understanding of preventive measures for gestational hypertension in terms of:
   ①㊀regular prenatal check-up compliance
   ②㊀balanced gestational nutrition management
   ③㊀safe gestational physical exercise
   ④㊀scientific sleep schedule
   ⑤㊀safe gestational sexual activity guidance
   ⑥㊀reasonable pregnancy travel arrangements
   ⑦㊀appropriate occupational adjustments during pregnancy
   ⑧㊀standardized medication guidance and drug safety precautions

(4) Is there a significant relationship between the participants' level of knowledge and level of understanding of preventive measures for gestational hypertension?

(5) Is there a significant difference in the level of knowledge on gestational hypertension when the participants are grouped according to:

①㊀their demographic profile

②㊀the associated clinical characteristics of gestational hypertension

(6) Is there a significant difference in the level of understanding of preventive measures for gestational hypertension when subjects are grouped according to:

①㊀their demographic profile

②㊀the associated clinical characteristics of gestational hypertension

1.3. Significance of the study

The findings of this research help improve pregnant women's awareness of gestational hypertension and standardize their preventive behaviors during early gestation. The study yields theoretical and practical value for clinical nursing service, nursing education, and nursing research as follows:

1.3.1. Nursing service

This study enables obstetric nurses to formulate individualized, evidence-based care plans tailored to participants' clinical manifestations and cognitive levels of gestational hypertension prevention. The stratified health education model developed in this research can act as a standardized clinical guide for managing pregnant women with gestational hypertension. Furthermore, the research results can comprehensively elevate overall obstetric care quality, reduce maternal-fetal adverse events, and strengthen patient safety and long-term gestational health outcomes. The model can be embedded into hospital routine obstetric workflows to update clinical prenatal education protocols and build standardized training materials for frontline nurses, providing reliable evidence to support hospital obstetric risk management policies and regular vocational training. All survey data provides localized real-world evidence to advance evidence-based nursing interventions for gestational hypertension prevention.

1.3.2. Nursing education

The findings of this study can be integrated into the Maternal and Child Health Nursing curriculum, particularly in prenatal and high-risk pregnancy care. Nursing educators may use the results to develop innovative teaching strategies, such as simulation, case-based learning, and technology-enhanced education. These approaches can strengthen nursing students' clinical skills, critical thinking, patient education, and evidence-based practice while reinforcing patient-centered professional values. The proposed health education model also serves as a practical framework for teaching effective maternal health education. Furthermore, the study supports competency-based nursing education and aligns with national and international standards for preparing nurses to provide safe, high-quality care for women with gestational hypertension.

1.3.3. Nursing research

The findings of this study provide baseline data for future local and international research on gestational hypertension prevention. The researcher-developed questionnaire and health education framework offer

useful tools for future nursing studies and may guide the development of evidence-based clinical guidelines and maternal health policies. Furthermore, the study promotes research engagement among nurses by encouraging participation in preventive nursing research and supports their continuous professional development through the application of evidence-based practice.

1.4. Scope and limitations of the study

This study employed a cross-sectional quantitative design to assess pregnant women's knowledge of gestational hypertension and their understanding of standardized preventive measures [9]. Based on the findings, a stratified health education model was developed to provide differentiated educational guidance for two groups:

(1) high-risk pregnant women without gestational hypertension
(2) women diagnosed with gestational hypertension.

The study was conducted at Shucheng People's Hospital, a tertiary hospital in Anhui Province, China, over a four-week period in November 2025. Participants were recruited through purposive sampling and selected according to the established inclusion and exclusion criteria. Data were collected using a validated researcher-developed questionnaire to determine participants' knowledge of gestational hypertension, understanding of preventive measures, and the demographic and obstetric factors associated with these variables.

Several limitations should be considered when interpreting the findings. First, the use of a cross-sectional design limited the study to assessing participants' knowledge and understanding at a single point during pregnancy. Consequently, causal relationships could not be established, changes in knowledge and self-management behaviors over time could not be examined, and the effectiveness of the proposed health education model could not be evaluated because it was developed from survey findings rather than tested through clinical intervention.

Second, the use of purposive sampling from a single tertiary hospital may have introduced selection bias and limited the representativeness of the sample. Variations in outpatient attendance and participants' willingness to complete the questionnaire may have further influenced participant recruitment. As a result, the findings may not be generalizable to pregnant women receiving care in community health centers, rural healthcare facilities, or institutions with different healthcare systems and patient populations.

Third, data were obtained through a self-administered questionnaire, making the study susceptible to recall bias, social desirability bias, and inaccurate self-reporting. Although the questionnaire demonstrated excellent reliability, participants' educational backgrounds, literacy levels, and interpretation of survey items may have influenced response accuracy [10]. Environmental distractions during data collection, despite the use of a quiet room, and practical constraints within the clinical setting may also have affected questionnaire completion.

Finally, time, resource, ethical, and methodological constraints influenced the scope of the investigation. Data collection was completed within a four-week period using available personnel and resources, limiting sample expansion and long-term follow-up. To protect participants' privacy and minimize respondent burden, sensitive personal information was not comprehensively explored. Moreover, the study examined only selected demographic and obstetric variables. Other factors, such as health literacy, socioeconomic status, cultural beliefs, family and social support, previous health education, and access to healthcare resources,

were beyond the researcher's control and may have influenced participants' knowledge and understanding of gestational hypertension.

Despite these limitations, the study provides valuable baseline evidence on pregnant women's knowledge of gestational hypertension and preventive measures. The findings offer an evidence-based foundation for the proposed stratified health education model and contribute to future nursing research, maternal health education, clinical practice, and policy initiatives aimed at improving the prevention and management of gestational hypertension.

1.5. Clear research gap clarification

Three prominent gaps in existing domestic and international research are addressed in this study:

(1) Most prior studies only recruit patients diagnosed with gestational hypertension and exclude undiagnosed high-risk pregnant women, lacking comparative analysis of prevention knowledge between the two populations [4].

(2) Existing literature largely focuses on post-onset treatment and inpatient nursing interventions, with insufficient systematic investigation into maternal baseline knowledge and understanding of prenatal preventive strategies [5].

(3) Few localized stratified health education frameworks are developed based on real maternal cognitive survey data to provide differentiated primary prevention for high-risk women and secondary clinical management for diagnosed patients [8].

1.6. Definition of independent and dependent variables

1.6.1. Independent variables

(1) Demographic characteristics: maternal age, gestational age, gravida, parity, educational attainment, monthly household income, occupation.

(2) Clinical associated characteristics: family hypertension history, gestational weight, negative prenatal mood, prenatal check-up compliance.

1.6.2. Dependent variables

(1) Level of knowledge about gestational hypertension

(2) Level of comprehension of gestational hypertension preventive measures

1.6.3. Adaptability explanation of the proposed health education model

Although data are collected from both high-risk undiagnosed participants and diagnosed patients, the stratified health education model contains two differentiated modules to cover the research goal of primary prevention:

(1) Primary prevention module for high-risk pregnant women without gestational hypertension: focusing on early risk screening, lifestyle adjustment and regular prenatal monitoring to avoid disease onset.

(2) Secondary management module for diagnosed gestational hypertension patients: focusing on symptom monitoring, complication prevention and safe daily self-management. The dual-module design ensures the model can be applied to all target groups rather than only women with confirmed gestational hypertension.

2. Review of related literature

2.1. Knowledge on gestational hypertension

Gestational hypertension remains one of the most severe pregnancy-related complications worldwide, contributing to high maternal-neonatal morbidity and mortality [1]. Digital-health-education modes have proven effective for improving maternal awareness [11]. Mobile health applications and online prenatal courses can enhance pregnant women's mastery of blood-pressure monitoring, warning-sign recognition and preventive interventions, which brings special benefits for residents of remote areas with scarce medical resources.

Domestic and foreign scholars have launched abundant Knowledge-Attitude-Practice (KAP) cross-sectional surveys targeting gestational-hypertension awareness among gravidas [12]. International research demonstrates that most childbearing-age women hold incomplete cognition of disease warning manifestations and daily preventive behaviors; insufficient knowledge directly reduces self-management compliance [4]. Domestic cohort surveys also report that Chinese pregnant women generally obtain moderate scores on gestational-hypertension knowledge, and disease cognition is positively correlated with mastery of preventive measures [8]. Nevertheless, most domestic studies test knowledge or practice dimension separately. Investigations that simultaneously measure and analyze both disease knowledge and preventive-measure comprehension are relatively rare, forming the core research gap this study intends to fill.

2.2. Treatment of hypertension in pregnancy

Therapy for gestational hypertension is not limited to blood-pressure control; comprehensive multidisciplinary care is required to prevent maternal-fetal severe complications such as severe preeclampsia, eclampsia and placental abruption. Current clinical interventions consist of antihypertensive medication, intensive maternal-fetal monitoring, lifestyle modification, psychological support and timely delivery when necessary [7].

Growing research evidence reveals the connection between psychological stress and hypertensive disorders in pregnancy [13]. Anxiety, depression and emotional stress activate neuroendocrine responses and cause vasoconstriction and blood-pressure elevation. Patients suffering from gestational hypertension often experience fear for fetal safety and delivery risks. Unrelieved negative emotion will deteriorate physical condition. Compared with normotensive pregnant women, women with gestational hypertension exhibit significantly higher prenatal-anxiety level [13]. Hence psychological counseling and mental-health intervention constitute indispensable segments of obstetric care.

Patient-centered individualized nursing interventions produce favorable maternal outcomes [14]. Health education, emotional counseling, dietary guidance and continuous monitoring can elevate pregnant women's gestational-hypertension knowledge and relieve maternal anxiety. Subjects receiving regular nursing support achieve better treatment adherence and self-care performance. Health-education interventions improve gravidas' understanding of medication compliance, dietary management, warning-sign identification and blood-pressure surveillance. Sufficient disease knowledge enables pregnant women to participate actively in self-care and make informed health-related decisions.

Multidisciplinary teamwork involving obstetricians, nurses, dietitians and mental-health professionals optimizes management effects for hypertensive disorders in pregnancy, covering both physiological and psychological needs of patients. Lifestyle modification acts as fundamental therapeutic component: healthy dietary pattern with low sodium and sufficient high-quality protein, moderate physical activity and

adequate rest contribute to stable blood-pressure control and lower complication risk [7]. WHO highlights the importance of regular prenatal surveillance, timely referral of high-risk pregnancies and continuous maternal education for reducing mortality caused by gestational hypertension [2]. Pregnant women ought to receive systematic popularization of danger signs, medication requirements and the significance of routine antenatal visits.

2.3. Prevention of hypertension in pregnancy

Multimodal preventive strategies for hypertensive disorders of pregnancy cover routine antenatal surveillance, standardized blood-pressure screening, individualized nutrition guidance, structured physical activity, psychological-stress regulation and systematic risk stratification [15]. WHO recommends no less than eight scheduled antenatal visits throughout gestation to detect abnormal blood pressure early and mitigate severe maternal-fetal adverse events [2]. Targeted prenatal health education is recognized as cost-effective primary-prevention measure across global maternity-care research [5]. Pregnant women receiving integrated education about modifiable risk factors, warning manifestations and evidence-based self-management show better adherence to gestational-hypertension prevention protocols. Clinicians should deliver priority-tailored counseling for advanced-age, obese and multiparous patients to strengthen their awareness of early preventive care.

In accordance with updated ACOG clinical guidance, scheduled blood-pressure monitoring commencing from early pregnancy serves as core screening measure [16]. Pregnant individuals with positive family history of hypertension, pre-pregnancy obesity, multiple gestation or persistent prenatal anxiety need intensified antenatal assessment frequency to capture emerging gestational-hypertension signals timely. Nutritional adjustment occupies foundational preventive status. Calcium, magnesium and potassium supplementation together with low-sodium high-protein dietary pattern can regulate vascular endothelial function and decrease risk of gestational blood-pressure rise [15]. Reasonable gestational-weight control is vital for patients with pre-pregnancy overweight. Moderate standardized physical exercise improves peripheral vascular compliance during pregnancy [17]; sedentary lifestyle correlates with higher incidence of hypertensive disorders. Individualized low-intensity exercise schemes are advised for low-risk pregnant populations without contraindications.

Numerous cross-sectional and cohort studies confirm demographic, physiological and psychological predictive factors for gestational hypertension: maternal age $\geq$ 35 years old, pre-pregnancy BMI $\geq$ 24 kg/m^2, multiparity, inadequate prenatal nutrition, sedentary habit, poor sleep quality, sustained prenatal anxiety and irregular antenatal attendance [4]. Though risk-screening workflows have been widely applied in prenatal settings, existing literature puts excessive emphasis on pathological-mechanism exploration. Research treating maternal subjective health cognition as mediating variable linking risk exposure and disease onset remains insufficient. Few domestic KAP surveys quantitatively measure disease knowledge together with multi-dimensional preventive cognition so as to support stratified prenatal-education design [8].

2.4. Synthesis of literature review

Three major research streams about gestational-hypertension are summarized: pathological-risk-factor exploration, clinical therapeutic regimen research and population-oriented preventive-intervention studies. By comparing domestic and international literature, four key research gaps are identified. First, research-content bias: most existing publications explore pathogenesis and post-diagnosis treatment, while quantitative

research focusing on pre-disease knowledge and preventive cognition among high-risk pregnant women is scarce [5]. Second, insufficient integrated-variable analysis: unified analytical frameworks incorporating demographic background, disease knowledge, preventive cognition and self-management behavior are rarely constructed; internal correlation among core variables remains underexplored. Third, shortage of localized intervention models: traditional health education follows one-size-fits-all popularization mode, lacking risk-stratified educational schemes matching cognitive characteristics of Chinese pregnant women [8]. Fourth, inadequate subgroup-comparison research: domestic studies seldom contrast knowledge and preventive-cognition differences across subgroups divided by age, education and parity, failing to supply targeted nursing references for clinical practitioners.

Guided by these four gaps, this study selects Nola Pender's Health Promotion Model as theoretical basis [18]. Through questionnaire-based quantitative survey and inter-group statistical comparison, this paper evaluates pregnant women's gestational-hypertension knowledge and preventive cognition, analyzes subgroup differences of core cognitive indicators, and finally develops a risk-stratified health-education model suitable for grassroots obstetric nursing in China.

2.5. Theoretical framework

Nola J. Pender's Health Promotion Model (HPM) is adopted as exclusive theoretical framework for this investigation [18]. The HPM explains influencing factors of health-promoting behaviors and fits well for studying pregnant women's knowledge and preventive practice concerning gestational hypertension. Distinct from general psychological-motivation theories, HPM focuses on formation process of clinical population's health-promotion behaviors. Its multi-layer logical structure matches variable setting of this gestational-hypertension-prevention research perfectly. Several recent obstetric-nursing studies targeting gestational-hypertension have verified such theoretical-matching relationship.

The core logical chain of Pender's HPM includes three layers: individual characteristic and risk-background factors; behavior-specific cognition and self-efficacy; health-promotion behaviors driven by intervention measures. Adapted for gestational-hypertension-prevention scenario, the transmission path is "demographic background factors → gestational-hypertension knowledge level → gestational-hypertension preventive cognition → nursing stratified-health-education intervention → maternal self-management behaviors → final research and clinical outcomes". Each layer corresponds exactly to research variables in this survey.

Individual & Risk Background Factors represent exogenous independent variables, covering maternal age, gestational age, parity, education level, family income, pre-pregnancy BMI, family hypertension genetic history, prenatal psychological stress and adverse obstetric history. These demographic and risk characteristics produce baseline divergence in pregnant women's acquisition of gestational-hypertension knowledge and formation of preventive cognition.

Behavior-Specific Cognitions & Self-Efficacy constitute core research variables measured by questionnaires, containing two dimensions: gestational-hypertension knowledge level (19-item scale covering etiology, clinical signs, hazards and treatment); gestational-hypertension preventive-cognition level (61-item multi-dimensional scale involving prenatal examination, diet, exercise, sleep and other preventive behaviors). Auxiliary cognitive variables include perceived disease risk, perceived preventive benefits-barriers, family support and accessibility of medical resources, which reflect maternal self-efficacy. Interactive correlation

between knowledge level and preventive cognition serves as central research hypothesis of this study.

Modifiable Nursing Intervention is intervening variable. Based on cognitive defects and risk stratification identified from questionnaire data, nurses implement targeted measures: risk-stratified classified health education, one-on-one personalized prenatal counseling, multidisciplinary joint guidance of obstetrics-nutrition-psychological team, and digital-oriented maternal-health popularization.

Intermediate Behavioral Outcomes stand for dependent behavioral variables. Driven by sufficient gestational-hypertension knowledge and positive preventive cognition, pregnant women form standardized self-management behaviors: active home blood-pressure self-monitoring, long-term normalized daily-lifestyle management, and timely medical consultation once warning symptoms emerge.

Final Research & Clinical Outcomes are expected results. Theoretically, this research constructs localized risk-stratified gestational-hypertension health-education model adapted for Chinese pregnant women. Clinically, the model can lower overall gestational-hypertension incidence, reduce severe maternal-fetal complication risks and improve standardized perinatal-nursing quality in primary-level medical institutions.

All questionnaire indicators of this survey conform to adapted HPM logic, linking maternal background, cognitive level and stratified-nursing-intervention into one integrated analytical system. Three null hypotheses are derived from layered logic of HPM:

H_{01}: There is no significant relationship between subjects' knowledge level and their understanding of preventive measures for gestational hypertension.

H_{02}: There is no significant difference in gestational-hypertension knowledge level when subjects are grouped by profile variables.

H_{03}: There is no significant difference in comprehension level of preventive measures for gestational hypertension when subjects are grouped by profile variables.

3. Research methodology

3.1. Research design

This study applies quantitative descriptive-correlational research design [9]. Descriptive quantitative research is suitable for systematically measuring and describing knowledge level and preventive-measure understanding of pregnant women via numerical data and statistical inference. Correlational design explores relationships among variables without manual manipulation, which helps judge whether higher knowledge level correlates with better mastery of preventive measures. Meanwhile, it identifies demographic and clinical factors influencing cognition status, providing empirical basis for constructing gestational-hypertensi on-oriented health-education model.

3.2. Population and sample

Research subjects are pregnant women clinically diagnosed with gestational hypertension, recruited by purposive sampling. A-priori power analysis was finished before subject enrollment. Preset parameters: medium effect size = 0.4, $\alpha = 0.05$, statistical power = 0.80. Calculation output shows minimum required sample size = 84 participants. Eighty-four valid questionnaires were collected after eliminating incomplete and invalid copies, satisfying pre-calculated sample requirement.

3.2.1. Inclusion criteria

(1) Aged ≥ 18 years old;
(2) Gestational age ≥ 20 weeks;
(3) Clinically diagnosed with gestational hypertension by obstetric physicians;
(4) Possess basic literacy to independently finish self-administered questionnaire;
(5) Voluntarily sign written informed consent for participation.

3.2.2. Exclusion criteria

(1) Suffering from essential hypertension or diabetes mellitus;
(2) Combined with heart, liver, kidney and other vital-organ diseases;
(3) Visual-auditory impairment or intellectual disorder;
(4) Mental-illness history;
(5) Unable to cooperate with nursing work effectively;
(6) Having other pregnancy-related complications besides gestational hypertension;
(7) Recurrent-abortion, premature-delivery or drug-abuse history;
(8) Exposure to hazardous substances or viral infection during pregnancy.

3.3. Research locale

Investigation took place in Shucheng People's Hospital, a tertiary-level general hospital located in Anhui Province. Its Department of Obstetrics and Gynecology is key clinical department, and the hospital is the unique national high-risk-maternal-monitoring unit within Lu'an city. It supplies comprehensive maternal-health services including prenatal education, prenatal screening, mother-infant school programs, prenatal diagnosis and high-risk-pregnancy management.

3.4. Research instrument

Self-designed four-point Likert-style questionnaire serves as main data-collecting tool, consisting of three sections. Section 1 collects participants' demographic profile. Section 2 is 19-item knowledge scale for gestational hypertension, investigating etiology, clinical signs, medication and treatment, with scoring from 1(low knowledge) to 4(high knowledge). Section 3 is 61-item scale assessing comprehension of preventive measures, covering regular prenatal check-ups, nutrition, physical exercise, sleep, sexual activity, travel and occupational adjustment; scoring ranges from 1(low understanding) to 4(high understanding).

Three experts conducted content validation: one senior obstetrics-gynecology chief physician, one maternal-child-nursing associate professor (master supervisor), and one obstetric-ward head nurse with rich clinical health-education experience. Experts scored each item on relevance, clarity and rationality, raised revision suggestions for ambiguous statements concerning sexual activity, travel and occupational-prevention items. Questionnaire was revised twice according to expert feedback before formal pilot test. Pilot test was performed on 12 eligible gestational-hypertension pregnant women; pilot-sample data were not incorporated into formal analysis dataset. Four ambiguous items in preventive-practice scale were rephrased after pilot-test feedback. Patient medical-chart documentary analysis was also conducted to obtain obstetric-history, blood-test and vital-sign clinical information.

Reliability test: Cronbach's α of preventive-measure dimension = 0.989; Cronbach's α of knowledge dimension = 0.961. Both values far exceed acceptable threshold 0.7, indicating excellent internal consistency

[10]. Validity test: preventive-measure scale KMO = 0.878, Bartlett sphericity test $\chi^2 = 5552.555$, df = 1953, $*p* < 0.001$; knowledge-level scale KMO = 0.945, Bartlett sphericity test $\chi^2 = 1188.538$, df = 171, $*p* < 0.001$. KMO values above 0.8 prove good suitability for factor analysis; significant Bartlett test results confirm correlation among items and satisfactory construct validity [12].

3.5. Data-gathering procedure

Firstly, obtain academic-ethical approval from Far Eastern University Institute of Nursing and administrative permission from Shucheng People's Hospital. Secondly, outpatient-clinic nurses screen eligible pregnant women according to inclusion-exclusion criteria with non-probabilistic purposive sampling. Thirdly, fully inform participants of research purpose, procedure, benefit and safety guarantee. Subjects sign written informed consent under the premise of knowing that they have a right to withdraw at any time without damaging routine medical service. Fourthly, four-week on-site questionnaire distribution is carried out after prenatal consultation. Filling time is controlled within 30 minutes. Invalid incomplete questionnaires are eliminated. All data are anonymized with coding and kept strictly confidential only for academic research. Fifthly, valid data are imported into Microsoft Excel for sorting and preliminary cleaning. Finally, processed dataset is imported into IBM SPSS Statistics for statistical analysis.

3.6. Statistical treatment of data

Descriptive statistics (frequency, percentage, mean, standard deviation) are used to describe demographic-clinical profile, knowledge level and preventive-measure comprehension level. Pearson-correlation test is adopted to examine correlation between knowledge score and preventive-meas ure-understanding score. One-way ANOVA and independent-samples *t*-test are utilized to compare score differences among subgroups divided by demographic and clinical-associated characteristics. Multiple linear regression is performed to screen independent influencing factors for knowledge level. Pre-designed statistical-analysis templates are completed before data collection to avoid missing key indicators [9].

3.7. Ethical considerations

This study possesses obvious social value by generating evidence for gestational-hypertension-oriented health-education model and improving obstetric-nursing quality. Pregnant women are classified as vulnerable research subjects for medical, cognitive, socioeconomic and power-imbalance reasons. The research only uses paper self-administered questionnaires, without invasive examination or clinical intervention. Physical risk for participants is extremely low. Participation is completely voluntary. No monetary reward is provided for enrollment. Small practical pregnancy-care gifts are offered merely as gratitude for subjects' time.

All identifying information such as name and contact details is not recorded on questionnaires. Subjects are distinguished by unique coding to guarantee anonymity. Researcher treats every participant equally and fairly without discrimination. Full-procedure informed consent is implemented. Conflict-of-interest self-disclosure is completed: this cross-sectional survey receives no external commercial funding, pharmaceutical-enterprise sponsorship or special hospital research grant. Questionnaire design, data collection and statistical analysis are independently finished without third-party interference.

Data security management: identifying personal information is stored in separate AES-256-encrypted database, physically isolated from de-identified research data. Grade-authorization access-control mechanism is executed. All researchers sign confidentiality agreement. Research data will be preserved for

five years after study completion and destroyed via physical shredding and secure digital overwriting upon retention-period expiration under ethics-committee supervision.

4. Results and discussion

4.1. Results

Eighty-four participants clinically diagnosed with gestational hypertension finished valid questionnaires. Thirty-three subjects were older than 35 years old, accounting for 39.29% of total sample. Nearly 45.24% respondents held bachelor's degree or above. Diversified distribution existed in occupation, household monthly income, parity and fetal quantity.

Participants obtained moderate-to-high scores on gestational-hypertension knowledge. Highest-scoring risk-factor item was autoimmune-disease-related risk (M = 3.631, SD = 1.159). Multiple-pregnancy-related risk acquired lowest mean value (M = 3.417, SD = 1.273); chronic-kidney-disease-related characteristic had maximum standard deviation (SD = 1.427), reflecting huge individual cognitive divergence. For symptom-identification dimension, high-blood-pressure indicator gained highest score (M = 3.726, SD = 1.320), while visual-abnormality warning sign got relatively low score (M = 3.476, SD = 1.256). Concerning treatment-care measures, subjects understood the necessity of drug therapy well (M = 3.690, SD = 1.251), but cognition about monitoring frequency was insufficient (M = 3.536, SD = 1.330).

In preventive-measure dimension, prenatal-check-up and nutrition-management items achieved higher scores. In contrast, travel-safety and gestational-sexual-activity-guidance items had lower comprehension scores. There existed obvious cognitive blind spots: Valsalva-maneuver risk during physical exercise, pre-exercise fluid-replenishment requirement, travel-emergency-medical-resource preparation and supine-hypotensive-syndrome risk during rest.

Pearson correlation test rejects H_{01}: significant strong positive correlation between gestational-hype rtension-knowledge total score and preventive-measure-understanding total score ($r= 0.720$, $p < 0.001$). Multiple-linear-regression model was statistically significant ($F = 4.508$, $p < 0.001$, adjusted $R^2 = 0.388$). Number of fetuses presented significant negative predictive effect for knowledge level ($B = -0.296$, $p = 0.046$). One-way ANOVA partially rejects H_{02} and H_{03}: significant score differences among subgroups divided by age, education, employment status, household income, parity, hypertension-family-history and clinical-intervention-receiving status ($p < 0.05$). No statistically-significant inter-group difference was found according to fetal quantity ($p > 0.05$). Subjects with advanced age, higher education background, employment experience, positive hypertension-family-history and receiving specialized HDP-clinic service obtained significantly higher knowledge and preventive-cognition scores.

4.2. Discussion

Participants' overall knowledge and preventive-cognition remained at moderate level, with prominent cognitive weak points in multiple-pregnancy risk, atypical preeclampsia ocular warning signs and partial exercise-safety specifications. The strong positive correlation between disease knowledge and preventive-measure understanding is consistent with core proposition of Nola Pender's Health Promotion Model, which states behavior-specific cognition serves as prerequisite for health-promotion behaviors [18]. Multiple-fetus pregnancy predicts lower knowledge score possibly because antenatal care for multiple-gestation patients focuses heavily on fetal-growth surveillance while ignoring

gestational-hypertension-risk popularization.

Obvious subgroup cognitive stratification was observed. Advanced-age, well-educated, employed and high-income pregnant women owned better cognitive performance, which can be explained by richer pregnancy-related experience, stronger health-information-acquisition capacity and more adequate health-resource access. Subjects who received complication-related health education, owned home blood-pressure monitor and attended HDP specialized outpatient clinic achieved higher cognition scores, which directly proves the effectiveness of clinical prenatal-education intervention. It is worth noticing that participants with adverse obstetric-history showed relatively low cognition scores, possibly resulting from psychological avoidance coping toward pregnancy-complication-related information [13].

Based on empirical survey outcomes, this study constructs four-dimensional integrated health-education model for gestational-hypertension:

(1) Risk-stratified individualized baseline assessment: classify pregnant women into high-risk, intermediate-risk and low-risk groups according to age, education, obstetric-history, family-disease-history and fetal quantity, so as to deliver differentiated educational content;
(2) Precise modular phased health-education system: set up basic-disease-cognition module, self-management-skill module and emergency-warning-identification module, adjust educational emphasis following different gestational stages;
(3) Multi-dimensional social-technical-support system: build interdisciplinary-cooperation team consisting of obstetricians, specialized nurses, dietitians and psychological counselors; develop digital maternal-health tools; promote family-member joint-participation mode;
(4) Dynamic-monitoring closed-loop quality-improvement mechanism: construct home-community-hospital three-tier monitoring network, adopt knowledge-behavior-clinical-outcome three-dimensional evaluation system and form “assessment-intervention-reassessment” closed-loop management [15].

4.3. Limitations

This investigation has several methodological shortcomings. First, single-center purposive-sampling limits external validity of research outcomes. Second, cross-sectional design cannot demonstrate causal relationships among variables [9]. Third, sample size of multiple-pregnancy subgroup is small, reducing statistical stability of subgroup-comparison results. Fourth, prenatal-anxiety and psychological-stress indicators are not incorporated into analytical framework. Fifth, the four-dimensional health-education model is built from cross-sectional questionnaire data, without prospective-intervention verification of actual clinical effect. Future multi-center large-sample longitudinal research, psychological-variable-involved comprehensive investigation and randomized-controlled-trial verification for intervention-model effect are urgently needed [5].

5. Summary, conclusions, and recommendations

5.1. Summary

This descriptive-correlational cross-sectional study adopted purposive sampling to recruit 84 gestational-hyper tension-diagnosed outpatients from one Anhui tertiary-level hospital. Self-compiled 19-item knowledge scale (Cronbach’s $\alpha = 0.961$) and 61-item preventive-measure-comprehension scale (Cronbach’s $\alpha = 0.989$) with satisfactory construct validity were used for data collection [10,12]. Descriptive statistics, Pearson correlation,

multiple linear regression and one-way ANOVA were applied for hypothesis testing. A four-dimensional stratified health-education framework was established on the basis of inter-group cognitive-difference statistics.

Hypothesis testing results: H_{01} was rejected (strong positive correlation existed between knowledge and preventive-measure-understanding, $r = 0.720$, $p < 0.001$). H_{02} and H_{03} were partially rejected: most demographic-clinical subgroups displayed significant score differences, while fetal quantity did not produce statistically-significant score variance.

5.2. Conclusions

(1) The sample covered diversified distribution in age, education, household income, parity and clinical-risk indicators. Different subgroups possessed differentiated baseline background features relevant to gestational hypertension.

(2) Participants' overall knowledge of gestational hypertension stayed at moderate level. Distinct knowledge gaps existed in risks of multiple gestation, chronic-kidney-disease-related risk factors and atypical ocular warning signs of severe preeclampsia [4].

(3) Participants' mastery of seven categories of preventive behaviors was uneven. Cognitive deficiencies concentrated in exercise-safety knowledge, travel-emergency preparation and standardized rest-posture requirements [17].

(4) Significant strong positive linear statistical association existed between gestational-hypertension-knowle dge total score and preventive-measure-comprehension total score within this sample.

(5) Statistically-significant knowledge-score differences existed among subgroups divided by age, education, occupation, household income, parity and hypertension-family-history; fetal quantity showed no significant inter-group difference [4].

(6) Preventive-measure-comprehension scores presented remarkable disparities across most demographic-clinical subgroups; fetal grouping brought no statistical difference.

(7) Variable-correlation relationships observed in this sample conform to core logical path of Nola Pender's Health Promotion Model, supplying localized cross-sectional evidence for model application in Chinese gestational-hypertension-oriented obstetric-nursing research [18].

5.3. Implications

5.3.1. Clinical nursing

The four-dimensional stratified-education framework summarized from sample cognitive characteristics can provide reference for obstetric-nursing staff to design prenatal-guidance content [14]. Special attention should be paid to low-cognition subgroups: young gravidas, low-educational-level patients, unemployed pregnant women and primiparas. Common cognitive blind-spots discovered in this survey ought to be supplemented into routine prenatal-popularization content [5].

5.3.2. Nursing teaching

Cognitive-gap data obtained from this research can serve as supplementary teaching material for Maternal-Child-Health-Nursing curriculum. Teachers may organize scenario-simulation training aiming at diversified cognitive demands of high-risk-pregnancy subgroups.

5.3.3. Nursing research

Two validated self-developed measurement scales can be reused for future domestic cross-sectional surveys on maternal gestational-hypertension-health-literacy [8]. Correlation and subgroup-difference statistics offer baseline descriptive data for subsequent observational studies.

5.4. Recommendations

5.4.1. For clinical-nursing settings

Clinicians may carry out targeted supplementary prenatal counseling for low-cognition subgroups according to sample-summarized cognitive characteristics. Cognitive blind-spots including multiple-gestation risk, exercise safety and travel-emergency management can be added into regular health-education content [2]. Medical institutions may choose to pilot-apply the four-dimensional health-education framework under research-project arrangement instead of directly taking it as universal mandatory clinical protocol.

5.4.2. For nursing education

Nursing colleges can incorporate survey-derived cognitive-gap data into Maternal-Child-Health-Nursing teaching. Educators may flexibly use seven preventive-measure dimensions concluded in this paper for scenario-simulation-teaching design.

5.4.3. For future nursing research

Multi-center longitudinal surveys should be conducted to verify whether variable-correlation relationships discovered in this single-center sample exist in broader pregnant-woman populations [5]. Randomized-controlled trials are required to test real-intervention effectiveness of the proposed four-dimensional education model. Researchers can add prenatal-anxiety and other psychological variables into analytical framework [13]. Shortened screening versions of original multi-item scales can be developed to satisfy rapid-assessment demands in outpatient scenarios [12]. Regional comparative investigations across different-grade medical institutions are encouraged to enrich domestic baseline data of gestational-hypertensi on-related maternal cognition [8].

Disclosure statement

The authors declare no conflict of interest.

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Perioperative Nursing Care of a Patient with Severe Osteoporosis Undergoing Secondary Revision Hip Arthroplasty

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Abstract: To summarize the perioperative nursing experience of a patient with severe osteoporosis undergoing secondary revision hip arthroplasty. Nursing key points: multimodal analgesia management for complex pain; empowering psychological intervention and anxiety management; preventive nursing for high-risk prosthesis dislocation; prophylactic nursing for extremely high-risk thrombosis; multidisciplinary collaborative anti-infection nursing; and continuous rehabilitation nursing. After 3 weeks of systematic nursing, the patient's Numerical Rating Scale (NRS) pain score decreased from 6 at activity to 2, anxiety improved, and no complications such as dislocation, thrombosis, or wound infection occurred. The patient was discharged on schedule. Follow-up at 4 and 12 weeks after discharge showed stable mood and good rehabilitation compliance.

Keywords: Hip revision arthroplasty; Severe osteoporosis; Psychological nursing; Perioperative nursing; Case nursing

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1. Introduction

Secondary revision hip arthroplasty is indicated for patients with prosthesis failure after initial revision [1,2]. Patients with severe osteoporosis have poor bone quality, and the difficulty of secondary revision surgery and nursing care increases significantly. Current literature mostly focuses on surgical technique modification and complication prevention, with insufficient attention to patients' psychological health and holistic care [3–5]. Patients with severe osteoporosis undergoing secondary revision hip arthroplasty often experience complex pain resulting from the superposition of chronic bone pain and acute postoperative pain [6,7]; in addition, multiple surgical experiences can easily lead to severe anxiety, creating dual physical and psychological stress. This case involved a 60-year-old male patient who had previously undergone bilateral total hip arthroplasty and initial revision surgery, and was now scheduled for secondary revision of the right hip. The patient had comorbid severe osteoporosis, rheumatoid arthritis, and gout. Intraoperative exploration revealed multiple fractures of the right femoral shaft. The operation lasted 9 h with 1200 mL blood loss. The

perioperative Caprini thrombosis score was 11 (extremely high risk), and there were also risks of prosthesis dislocation and infection, presenting prominent nursing challenges. In response, the department implemented integrated "body-mind" nursing under multidisciplinary collaboration. This study achieved closed-loop perioperative risk prevention and control through multidisciplinary collaboration, adopted individualized multimodal analgesia to ensure safe early rehabilitation, and combined positive psychology intervention to relieve postoperative anxiety, achieving holistic body-mind nursing. This article summarizes the perioperative nursing experience of this case to provide reference for nursing care of similar complex revision cases.

2. Clinical data

2.1. General data

The patient, male, 60 years old, was admitted due to "pain and limping for more than 2 years after right hip revision arthroplasty". Past surgical history: bilateral total hip arthroplasty in 2002, initial revision of bilateral hip prostheses in 2013; secondary revision of the left hip in December 2025; this admission was planned for secondary revision of the right hip. Comorbidities included severe osteoporosis, rheumatoid arthritis, and gout. No history of drug allergy.

Admission physical examination: vital signs stable; old surgical scar visible on the right hip, with no local redness, swelling, or sinus tract; positive tenderness in the groin area; active and passive movement of the right hip limited; right lower limb shortened by 3 cm compared with the healthy side; left hip incision healed well; muscle strength and peripheral blood circulation of both lower limbs normal. Numerical Rating Scale (NRS) pain score was 3 at rest and increased to 6 at activity.

2.2. Treatment and outcome

Preoperative auxiliary examinations indicated a hypercoagulable state: fibrinogen 7.15 g/L, D-dimer 1.93 mg/L, with sinus tachycardia, indicating a high risk of postoperative complications. On January 14, 2026, secondary revision of the right hip prosthesis was performed under spinal anesthesia. Intraoperative exploration revealed multiple fractures of the right femoral shaft. The operation lasted 9 h with 1200 ml blood loss, and the patient was transferred to the intensive care unit for 24 h postoperatively.

In the early postoperative period (days 1–2), vital signs were stable, with an indwelling urinary catheter and double incision drainage tubes, and the patient was severely dependent in activities of daily living. On postoperative day 2, pain worsened (NRS score 6) with severe anxiety; the patient was restless and repeatedly asked about the surgical prognosis, fearing prosthesis dislocation. In the intermediate postoperative period (days 3–8), sleep deteriorated. Psychiatric consultation diagnosed postoperative anxiety state, and zaleplon dispersible tablets were given to improve sleep, along with individualized psychological nursing. On postoperative day 8, fever occurred (body temperature 39 ℃), which returned to normal after symptomatic treatment.

Multidisciplinary collaborative intervention was immediately initiated: the pharmacy department adjusted the anti-infection regimen and added meropenem; the rheumatology and immunology department intervened to lower uric acid and prevent gout attacks; the nutrition department formulated a specialized nutritional plan to promote fracture healing. After 3 weeks of systematic nursing, the patient's pain and anxiety symptoms improved significantly, and the NRS score decreased to 2. Postoperative imaging re-examination showed good prosthesis position and satisfactory fracture alignment. During hospitalization,

no complications such as prosthesis dislocation, deep vein thrombosis, or incision infection occurred. The patient could independently turn to the healthy side and was discharged smoothly. Telephone follow-up at 4 weeks after discharge showed stable mood and good compliance with rehabilitation training.

3. Nursing

3.1. Multimodal analgesia management for complex pain

This patient had comorbid severe osteoporosis with chronic bone pain, superimposed on acute traumatic pain caused by secondary revision surgery. The pain mechanism was complex and difficult to control. We implemented a multimodal analgesia regimen combining pharmacological, physical, and non-pharmacological interventions to achieve dynamic pain management throughout the perioperative period [8] . Within 72 h after surgery, a patient-controlled analgesia pump was used to control acute pain; on postoperative day 4, oral celecoxib (200 mg, twice daily) combined with sustained-release tramadol tablets (100 mg, twice daily) was administered for baseline analgesia. Meanwhile, targeting the underlying osteoporosis, alendronate sodium (70 mg, once weekly) and Caltrate D (600 mg, once daily) were regularly administered to improve bone quality and relieve intractable chronic pain. From 24 h after surgery, local ice application was performed (15 min per session, 3 times daily) to reduce incision swelling and inflammatory pain. During rehabilitation training, music therapy was used to divert attention and improve exercise tolerance. NRS scores were monitored daily. The patient's pain score steadily decreased from a peak of 6, and at discharge, only occasional mild pain (score 2) occurred after activity, with no adverse drug reactions throughout. For patients with fragile osteoporotic bones, stable pain control not only improves comfort but also serves as an important safeguard against falls and secondary fractures. In this case, multimodal analgesia effectively resolved the challenge of superimposed chronic and acute pain, creating safe conditions for early rehabilitation activities.

3.2. Empowering psychological intervention and anxiety management

The patient had undergone multiple hip surgeries and harbored fear of another revision. On postoperative day 2, when pain intensified, severe anxiety appeared, manifested as restlessness, repeated questioning about surgical prognosis, and fear of prosthesis dislocation. We recognized the shortcoming of missing psychological intervention in traditional orthopedic nursing, and therefore implemented individualized empowering psychological intervention based on the positive psychology PERMA model [9]. From postoperative day 2, the patient was guided to record "three grateful things" daily to help divert excessive attention from pain; during pain episodes, mindfulness breathing was guided, and by postoperative day 5, the patient could use it independently. Rehabilitation movements were designed as a "check-in challenge" game, and on postoperative day 7, the patient achieved a continuous accomplishment. Audiobooks were used to induce flow experiences, and the patient reported "forgetting the pain while listening to books". The primary nurse provided consistent explanation and feedback throughout to build a trusting relationship. Family members were instructed to "support without replacing", encouraging the patient to move independently. On postoperative day 6, the patient successfully turned over independently and received positive family reinforcement. We also guided the patient to visualize rehabilitation goals (e.g., walking in the park, picking up grandchildren), reconstructing the illness narrative from "bad luck" to "persisting despite difficulties". On postoperative day 8, the patient proactively comforted other patients with his own experience, marking a

transition from “patient” to “helper”. Rehabilitation micro-goals were broken down with specific feedback. On postoperative day 12, the patient actively shared his experience with fellow patients, and self-efficacy was significantly enhanced. On postoperative day 8, sleep declined; psychiatric consultation confirmed “postoperative anxiety state”, and zaleplon dispersible tablets were given to improve sleep, with simultaneous reinforcement of psychological nursing. At discharge, the patient’s anxiety improved and mood was stable. This body-mind psychological intervention effectively improved the specific anxiety of revision patients, corrected negative illness perceptions, and significantly enhanced treatment and rehabilitation initiative.

3.3. Preventive nursing for high-risk prosthesis dislocation

Patients with severe osteoporosis have insufficient bone reserve and poor prosthesis stability, and the risk of dislocation after secondary revision is significantly increased [10]. Therefore, we focused on position management and risk prevention. Postoperatively, the affected limb was strictly maintained in an abducted neutral position, with a “T”-shaped shoe and a trapezoid pillow placed between the legs. Double-person log-rolling was strictly performed to ensure hip stability. The head of the bed was elevated ≤ 30°, and straight leg raising was prohibited within 7 days after surgery. The hip flexion angle was strictly controlled at < 90° throughout. At the same time, health education was strengthened. The “three no’s” principle was explained and strictly implemented for the patient and family members: do not sit on low stools, do not cross the legs, and do not bend sideways, avoiding high-risk dislocation movements. This case was surgically complex, with multiple femoral shaft fractures observed intraoperatively, further increasing the hidden risk of dislocation. However, through standardized position management and continuous education, no prosthesis dislocation occurred during hospitalization, indicating that strict position protection is crucial for high-risk revision patients with extremely poor bone quality.

3.4. Prophylactic nursing for extremely high-risk thrombosis

The patient had major surgical trauma and a long postoperative bed rest period, with a Caprini thrombosis risk assessment score as high as 11 (extremely high risk). We initiated a thrombosis prevention program early postoperatively: from postoperative day 1, ankle pump exercises in bed were instructed, and the patient was encouraged to drink more water to dilute the blood. Because the patient had multiple surgical incisions, pressure-based antithrombotic devices were avoided, and gentle limb massage from distal to proximal was used to promote blood circulation. At 24 h after surgery, subcutaneous injection of low-molecular-weight heparin 5000 IU was started and continued for 3 weeks, with dynamic monitoring of coagulation function and D-dimer changes. During nursing, we closely observed lower limb circumference, skin color, and temperature, and remained alert to signs of thrombosis. The patient did not develop deep vein thrombosis throughout. For extremely high-risk patients, pharmacological prophylaxis combined with early passive activity is safe and effective, but attention must be paid to bleeding tendency. No bleeding complications occurred in this case, confirming the feasibility of this regimen.

3.5. Multidisciplinary collaborative anti-infection nursing

The patient’s operation lasted as long as 9 h and involved two incisions at the hip and femur, indicating an extremely high risk of infection. On postoperative day 8, the patient developed fever (39 ℃), with elevated blood routine and inflammatory markers. Multidisciplinary consultation considered infection risk, and the anti-infection regimen was promptly adjusted. Vancomycin was intravenously infused every 12 h strictly

according to medical orders to ensure blood drug concentration; meropenem was added after consultation with the pharmacy department. Incisions were observed daily for redness, swelling, heat, pain, and exudate, and dressings were kept dry. The urinary catheter and drainage tubes were removed on postoperative day 1, and body temperature and blood counts continued to be monitored after removal. Meanwhile, the rheumatology and immunology department assisted in controlling rheumatoid arthritis and gout, and the nutrition department formulated a specialized nutrition package to promote fracture healing. Through closed-loop risk prevention and control under multidisciplinary collaboration, the patient's body temperature gradually returned to normal, the incisions healed well, and no surgical site infection occurred. This case suggests that for complex revision surgery, integrating multidisciplinary resources such as pharmacy, nutrition, and rheumatology and immunology, and dynamically adjusting anti-infection strategies, can effectively address postoperative high fever and high infection risk.

3.6. Continuous rehabilitation nursing

Before discharge, we provided systematic guidance to the patient and family members: avoid lying on the affected side within 3 months after surgery, do not sit on low sofas, and do not bend over to pick up objects; within 6 weeks after surgery, mainly walk with partial weight-bearing, gradually transitioning, with the principle of not causing pain; emphasize the importance of regularly taking anti-osteoporosis drugs, and inform that non-compliance may lead to prosthesis loosening again; clarify the follow-up plan at 6 weeks, 3 months, 6 months, and 1 year after surgery. At the same time, family members were told to pay attention to the patient's emotional changes and seek medical attention promptly if anxiety worsened. Telephone follow-up at 4 weeks after discharge showed stable mood, NRS score 2, and good adherence to rehabilitation training. Continuous nursing maintained the continuity of rehabilitation intervention, effectively avoiding functional decline and emotional fluctuations after discharge, and is an indispensable part of holistic care for complex revision patients.

4. Summary

A 60-year-old male patient was admitted for a second revision of the right hip joint, with comorbid severe osteoporosis, rheumatoid arthritis, and gout. Intraoperatively, multiple femoral shaft fractures were observed, indicating substantial surgical trauma and high nursing complexity. During the perioperative period, we implemented an integrated "physical and psychological co-nursing" model supported by multidisciplinary collaboration. Through multimodal analgesic management for complex pain, empowering psychological intervention and anxiety management, prevention of high-risk prosthesis dislocation, prophylactic nursing for extremely high-risk thrombosis, multidisciplinary collaborative anti-infection nursing, and continuous rehabilitation nursing, multiple challenges including pain, anxiety, and complications were effectively addressed. The patient's postoperative pain and anxiety improved significantly, and no complications such as dislocation, thrombosis, or infection occurred. The patient was discharged smoothly with good rehabilitation adherence during follow-up. This case confirms that an individualized, multidisciplinary holistic nursing strategy is safe and effective for high-risk patients such as those with severe osteoporosis undergoing multiple hip revisions. However, as this is a single case report lacking controlled quantitative analysis, future large-sample prospective studies are still needed to verify its generalizability. This nursing experience may serve as a reference for similar complex orthopedic revision cases.

Disclosure statement

The authors declare no conflict of interest.

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Effects of Rehabilitation Training on Range of Motion after Total Knee Arthroplasty

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Abstract: Total knee arthroplasty (TKA) serves as an effective intervention for end-stage knee osteoarthritis and other related disorders. Postoperative recovery of knee range of motion (ROM) directly determines patients' daily functional performance and quality of life. By reviewing domestic and international recent literature, this paper summarizes functional requirements and influencing factors of postoperative ROM, early-stage rehabilitation training, continuous passive motion, muscle-strength and proprioception training, pain and swelling management, multi-modal rehabilitation strategies, and synergistic application of Mongolian traditional therapies. Available evidence demonstrates that systematic rehabilitation training following the principles of early intervention, gradual progression, active-exercise priority and individualization can significantly improve postoperative knee flexion-extension ROM, and reduce the incidence of joint stiffness and adhesion. Multi-modal rehabilitation guided by enhanced recovery after surgery (ERAS) as well as integrated Mongolian-Western medicine rehabilitation pathways exhibit promising clinical prospects.

Keywords: Total knee arthroplasty; Rehabilitation training; Range of motion; Functional exercise; Review

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1. Introduction

Total knee arthroplasty is an effective treatment modality for end-stage knee osteoarthritis, rheumatoid arthritis and other joint diseases, which can substantially relieve pain, correct deformity and reconstruct joint function, with long-term clinical excellent rate exceeding 90% [1]. Accelerated population aging in China has contributed to rising prevalence of knee osteoarthritis. According to the *Guidelines for the Diagnosis and Treatment of Osteoarthritis (2018 Edition)*, the prevalence of symptomatic knee osteoarthritis reaches approximately 8.1% in China, forming a large population of end-stage patients accompanied by annually increasing TKA surgical volume, and other joint diseases, which can substantially relieve pain, correct deformity, and reconstruct joint function, with a long-term clinical success [2].

Nevertheless, surgical success does not equal complete functional recovery. Satisfactory restoration of postoperative knee ROM, one of the core outcome indicators evaluating TKA efficacy, is decisive for patients' capacity to conduct daily activities including walking, stair ascending-descending, and sit-to-stand

transfers. Without systematic postoperative rehabilitation training, peri-articular soft tissues are prone to contracture and adhesion. Some patients suffer from limited flexion-extension; severe cases may develop fibrous joint adhesion that requires manipulation under anesthesia or even re-operation, thereby compromising surgical outcomes. Accordingly, it carries important clinical implications to systematically summarize the impacts and optimization strategies of rehabilitation training on ROM after TKA [3].

2. Functional significance and influencing factors of postoperative knee ROM

2.1. Functional requirements for range of motion

Normal knee joint flexion can achieve more than 135°, while full extension reaches 0°. Biomechanical studies reveal that level-ground walking demands roughly 65–70° knee flexion; stair climbing requires approximately 83°; stair descending needs 90–100°; sit-to-stand transfer from a chair consumes 95–110°; movements such as squatting and squat-to-defecate require flexion greater than 110° [4]. It is generally acknowledged that postoperative knee flexion ≥ 110° can meet most demands of activities of daily living. Meanwhile, complete knee extension without residual flexion contracture is a prerequisite for normal gait. Hence, rehabilitation training should address both flexion and extension dimensions.

2.2. Major factors affecting postoperative ROM recovery

Postoperative ROM restoration is affected by multifactorial variables.

(1) Preoperative factors

Baseline ROM, quadriceps strength, deformity severity, and comorbidities are powerful predictors of postoperative range-of-motion outcomes.

(2) Intra-operative factors

Prosthesis selection and placement, soft-tissue balancing, matching of flexion-extension gaps.

(3) Postoperative factors

Pain, swelling, intra-articular hematoma organization, adhesion formation, and patient rehabilitation compliance. Among these factors, scientific formulation and proper implementation of rehabilitation training constitute the most clinically modifiable component, which is the main focus of this review [5].

3. Effects of early-stage rehabilitation training on joint range of motion

3.1. Timing and contents of early rehabilitation

The concept of enhanced recovery after surgery advocates initiation of functional exercise at the earliest postoperative phase. The *Chinese Expert Consensus on Peri-operative Management for Enhanced Recovery after Hip and Knee Arthroplasty* recommends that ankle-pump exercise and isometric quadriceps contraction be commenced immediately after anesthesia emergence, and out-of-bed mobilization under walker protection within 24 hours post-surgery [6]. Early exercise facilitates venous and lymphatic return, mitigates swelling, prevents disuse atrophy of quadriceps and capsular contracture, and lays groundwork for subsequent range-of-motion training [7]. Research conducted by Bade et al. demonstrated that patients receiving high-intensity early rehabilitation obtained superior ROM and functional scores at 6-month follow-up compared with the conventional rehabilitation group [8]. Training during postoperative day 0–3 mainly consists of bed-based interventions: ankle-pump movement, isometric contraction of quadriceps and

hamstrings, straight-leg raise, as well as walker-assisted standing and partial-weight-bearing ambulation.

3.2. Continuous passive motion (CPM)

Continuous passive motion was first proposed by Salter in the 1970s [9]. Initially applied to experimental research on articular-cartilage repair, its theoretical basis lies in that continuous, pain-free and controllable passive movement can promote cartilage nutritional metabolism, inhibit adhesion formation and alleviate pain and swelling [10]. In clinical practice, CPM is usually initiated 24–48 hours post-operatively, with an initial motion arc set at 0–45°, increasing 5–10° daily, 30–60 minutes per session. A randomized controlled trial by Bruun-Olsen et al. reported superior improvement of postoperative flexion ROM in the CPM plus active-exercise group relative to the active-exercise-only group [11]. However, the Cochrane systematic review indicated that CPM combined with conventional physiotherapy only yields modest short-term ROM benefits without significant long-term functional improvement [12]. In recent years, deeper understandings have been gained regarding clinical indication and intensity regulation of CPM [13]. Therefore, CPM should be regarded as an adjunct to active training and implemented under pain-controllable conditions, and can never substitute active physical exercise.

3.3. Active joint range-of-motion training

Progressive active knee flexion-extension training is initiated 2–3 days after surgery, including bedside leg-dangle exercise, seated knee flexion, supine knee-hugging and wall-sliding training. Exercises should follow a step-wise principle, with knee flexion angle increased day-by-day within pain-free or mildly-tolerable pain thresholds. Meanwhile, extension-limitation correction can be achieved by placing a pillow beneath the heel for knee-pressing or prone suspension leg compression. Terminal-range extension training generates definite efficacy for mild extension lag within 10°. Violent passive manipulation must be avoided during training, for fear of soft-tissue injury, hematoma formation or even periprosthetic fracture. When ROM improvement plateaus, patellar mobilization together with stretching of quadriceps and hamstrings can be adopted as auxiliary interventions.

4. Roles of muscle-strength training and proprioceptive training

4.1. Quadriceps-strength training

Quadriceps strength is universally markedly diminished after TKA. Extensor-apparatus muscle strength is closely correlated with knee stability, flexion-extension coordination and maintenance of joint ROM. Mizner et al. verified that pre-operative quadriceps strength serves as an independent predictor of functional outcomes one-year post-operation [14]. Commonly adopted training modalities include isometric contraction, multi-directional straight-leg raise, terminal-range knee extension, and progressive resistance training (elastic bands, sandbags, isokinetic training). Adequate strength training for quadriceps and hamstrings can ameliorate extension limitation, mitigate quadriceps inhibition, supply dynamic support for flexion training, and facilitate conversion of passive range of motion into functionally-available active range of motion.

4.2. Proprioception, balance and gait training

During TKA, the anterior cruciate ligament is resected and proprioceptors embedded within joint capsule and surrounding soft tissues are disturbed, resulting in remarkable deterioration of knee position sense and

kinesthesia. Neuromuscular training consisting of balance-pad/balance-board exercises, single-leg stance, weight-shift drills and closed-chain exercises can enhance proprioception and dynamic balance capacity, rectify pathological gait, and improve functional utilization of acquired ROM [15]. Power cycling (gradually lowering saddle height), step ascending-descending and wall-squat exercises can be sequentially introduced at postoperative week 4-6, so as to achieve synchronized promotion of range of motion, muscle strength and motor coordination.

5. Impacts of pain management and swelling control on joint range of motion

Pain and swelling constitute primary obstacles restricting postoperative ROM training. Pain provokes protective muscle inhibition and joint immobilization, thus establishing a vicious cycle of "pain-immobilizat ion-adhesion-joint stiffness". Peri-operative multi-modal analgesia (stratified administration of paracetamol, non-steroidal anti-inflammatory drugs, opioids, together with peri-articular injection) combined with swelling-control measures such as post-incision ice-packing, limb elevation and elastic bandage compression can greatly boost patients' training tolerance and compliance [16]. ROM training can obtain effective angle increment only under sufficient analgesia. Blind pursuit of larger angles ignoring pain control frequently leads to training phobia and functional regression.

6. Synergistic application of Mongolian traditional therapies and modern rehabilitation training

In Mongolian medicine, knee osteoarthritis is categorized as "joint Shar-Us disease (Huang-Shui disease)". Its pathogenesis is attributed to disturbance of San-Gen (three fundamental body constituents), excessive Huang-Shui (yellow fluid) accumulation and impeded qi-blood circulation. Therapeutic principles include regulating body constitution, drying Huang-Shui, dredging Bai-Mai (white vessels), activating blood circulation and relieving pain [17]. After TKA, standardized rehabilitation training can be complemented by characteristic external Mongolian-medicine therapies:

(1) Five-Flavor-Nectar medicinal bath and topical Mongolian-medicine compress, to warm meridians, unblock collaterals, reduce swelling and alleviate pain;
(2) Mongolian moxibustion and Mongolian-medicine acupuncture, for relief of quadriceps spasm and per-incision pain [18];
(3) Cupping and blood-letting therapy, indicated for middle-late postoperative phase with local stasis, swelling and pain;
(4) Mongolian-medicine traditional massage and joint-mobilization manipulation, to improve soft-tissue extensibility and assist ROM recovery.

The above-mentioned therapies possess unique strengths in mitigating postoperative pain-swelling and improving rehabilitation compliance, serving as a complement to modern rehabilitation. Nevertheless, indications and intervention timing must be strictly controlled; blood-letting and deep massage with strong stimulation are contraindicated in early postoperative phase with bleeding tendency. Integrating Mongolian-medicine rehabilitation techniques into multi-modal TKA postoperative rehabilitation pathways represents a valuable exploration combining ethnic-medicine practice and modern rehabilitation medicine.

7. Problems and prospects

Although the clinical value of TKA postoperative rehabilitation is well-recognized, multiple challenges remain unsolved.

(1) Uniform standardized rehabilitation protocols are lacking; controversies persist concerning training timing, intensity and progression. Post-discharge rehabilitation organization and supervision remain insufficient; systematic reviews report limited evidence quality for post-discharge physiotherapy [19].

(2) Research focusing on individualized and telerehabilitation models for pastoral-area patients with scattered residence and difficult follow-up is inadequate.

(3) High-quality evidence-based research for Mongolian-medicine-based rehabilitation therapies is scarce.

Future research should carry out multi-center, large-sample randomized controlled trials, adopt wearable devices and digital platforms to realize objective quantitative monitoring of ROM and remote rehabilitation guidance, thoroughly evaluate clinical efficacy and health-economic value of integrated Mongolian-Western-medicine rehabilitation pathways, and gradually formulate TKA postoperative rehabilitation specifications suitable for national conditions in China.

8. Conclusions

Restoration of ROM after TKA results from combined effects of surgical technique, pain management, rehabilitation training and patient-related factors. Among these components, standardized systematic rehabilitation training delivers the most modifiable and direct clinical benefits. Rehabilitation regimens complying with principles of early intervention, gradual progression, active-exercise priority, passive-exercise supplementation, individualization and multi-modal intervention can effectively improve knee flexion-extension ROM, lower the incidence of joint stiffness and adhesion, and accelerate functional recovery. Clinicians should establish the conception of full-course peri-operative rehabilitation, attach importance to pre-operative pre-rehabilitation and patient health education, maximize synergistic advantages of modern rehabilitation techniques and characteristic ethnic-medical therapies, and ultimately maximize restoration of patients' joint function and quality of life [20].

Disclosure statement

The author declares no conflict of interest.

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A Study on the Construction and Implementation Effectiveness of a Higher Vocational Nursing Talent Development Model Based on the 1 + X Certificate System

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Abstract: *Objective*: To explore the methodology for constructing a talent development model integrating the 1 + X Certificate System into vocational nursing internship teaching, as well as to assess the effectiveness of this approach. *Methods*: A quasi-randomized controlled trial design was employed. A total of 280 vocational nursing students who were undertaking internships at a tertiary Grade-A hospital in Sichuan Province between May 2024 and March 2025 were recruited and randomly assigned, using a random number table, into an experimental group (n = 140) and a control group (n = 140). The control group received conventional internship teaching instruction, while the experimental group was taught using a curriculum-certificate integration training model based on the 1 + X Certificate System. The theoretical scores, clinical practical skills, clinical thinking abilities, and course evaluation outcomes were compared between the two groups. *Results*: The experimental group demonstrated significantly higher scores than the control group in theoretical knowledge, total clinical practical skills score, total clinical thinking ability score, and course evaluation score ($p < 0.05$). *Conclusion*: Integrating the 1 + X Certificate System into vocational nursing internship teaching can effectively enhance nursing students' theoretical knowledge, practical skills, and clinical thinking abilities, and thus holds potential for broader application.

Keywords: Higher vocational nursing program; 1 + X certificate system; Talent development model

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1.Introduction

Amid the accelerating aging of the population and the evolving demand structure for healthcare services, there is a growing societal need for highly skilled nursing professionals. In this context, to align nursing talent development models with the rapid developmental trends within the healthcare industry, it is essential

to reform and innovate traditional approaches to cultivating high-caliber nursing professionals [1,2]. The conventional higher vocational nursing education model primarily focuses on academic education, while practical skills and job-specific competency development remain relatively inadequate, making it difficult to fully meet the diverse demands of clinical practice [2]. The "1 + X Certificate System" implemented by the Chinese government for vocational education is designed precisely to enhance the quality of vocational education, thereby injecting new vitality into higher vocational education and creating favorable development opportunities. Under this system, the "1" represents an academic degree certificate—serving as proof of a student's completion of higher vocational nursing education and reflecting the fundamental standards for talent development; the "X" denotes various vocational skill level certificates, encouraging nursing professionals to enhance their multifaceted professional competencies beyond the completion of their academic studies; these certificates also serve as strong credentials of their diverse professional capabilities [3,4]. The effective implementation of this system aims to deepen school-enterprise collaboration and integrate industry with education. By facilitating the alignment of academic qualifications with vocational certifications, this approach equips nursing students with stronger employability, thereby meeting the high demands that contemporary society places on nursing professionals. During their clinical training at hospitals, nursing students should not only master their core professional knowledge and establish a solid theoretical foundation in nursing but also obtain various vocational qualification certificates—such as the Elderly Care Certificate, which is in increasing demand amid the aging population trend, as well as certificates in Health Management and Rehabilitation Nursing—thereby enhancing their professional competence and practical skills within the specific nursing fields to which these certificates apply. This approach enables them to better adapt to the complex and ever-changing demands of contemporary nursing practice [5,6]. Consequently, it is necessary to reform the current talent development model for the nursing profession by deeply integrating it with the "1 + X Certificate System" to effectively improve teaching efficacy. This paper primarily investigates the effectiveness of the talent development model for higher vocational nursing programs under the "1 + X Certificate System"; the findings are reported below.

2. Materials and methods

2.1. Research subjects

Using convenience sampling, a total of 280 higher vocational nursing students who were interning at a tertiary Grade-A hospital in Sichuan Province between May 2024 and March 2025 were recruited. These students were randomly assigned to either an experimental group or a control group, with 140 students in each group. There were no statistically significant differences between the two groups in baseline characteristics such as gender, age, or academic performance ($p > 0.05$), indicating comparability between the groups; all participants consented to participate in this study.

2.2. Teaching methods

2.2.1. Control group

The control group received the traditional teaching methodology:

(1) Pre-class preparation

Using the "LXT" APP, the hospital-based clinical instructors should assign students pre-class preparatory tasks, enabling them to gain an early understanding of the key teaching points of the course,

identify the critical and challenging concepts to be covered in class, and prepare for subsequent classroom learning.

(2) Classroom instruction

The clinical instructors should systematically explain professional theoretical knowledge in the classroom based on nursing textbooks. For the Basic Nursing course, the principles, procedures, and precautions associated with nursing procedures should be elaborated in detail; for example, the principle of intravenous infusion involves the relationship between liquid static pressure and human venous pressure—this should be explained by the instructor using blackboard writing, PowerPoint presentations, or other appropriate methods to help interns understand the underlying theory. For courses such as Medical Nursing and Surgical Nursing, the instructor should introduce the etiology, clinical manifestations, diagnostic methods, and nursing interventions for various conditions in a systematic manner, categorized by disease type. When teaching cardiac nursing, the instruction should cover different types of cardiac disorders—such as coronary artery disease and cardiomyopathy—and incorporate relevant clinical cases to provide students with a more intuitive understanding of the material.

(3) Practical observation

Students are arranged to accompany their clinical instructors into hospital clinical departments for practical observation sessions. In the ward, the instructor should demonstrate various nursing procedures—such as catheterization and oxygen therapy—on the spot, while students observe; the instructor should emphasize key procedural points and standard practices as they perform the procedures. During these clinical department observations, students should follow their clinical nurse to observe actual nursing workflows, including routine patient care and patient condition monitoring. For example, in a surgical ward, students should observe the actual implementation of nursing procedures such as postoperative wound care and drainage tube management. Students should also engage in independent practice under the guidance of their teachers to master the course content.

(4) After-class homework for consolidation

Teachers should assign appropriate written assignments that cover a variety of question types, which helps students reinforce the theoretical knowledge acquired in class. For example, a case study involving a diabetic patient can be presented, requiring students to analyze the nursing challenges and develop a nursing care plan—thereby enhancing their ability to apply the knowledge in practice. Students may also engage in self-directed learning using the Xuexitong APP. Additionally, regular theoretical examinations should be conducted to assess students' intermediate learning outcomes and encourage continuous learning. Furthermore, a certain number of practical assignments should be assigned, allowing students to apply the nursing skills learned in class during clinical practice in hospitals, with teachers providing on-site guidance and evaluation.

2.2.2. Experimental group

The experimental group was assigned the vocational nursing talent cultivation model under the 1+X Certificate System.

(1) Development of a curriculum system that integrates academic courses with professional certifications.

① Talent Development Program Development. The 1+X Certificate System should serve as a guiding framework and benchmark for adjusting the current talent development programs for higher vocational

nursing programs. These programs should be tailored to meet the current demands for nursing professionals as identified by institutions such as our hospital, clearly defining the specific skills that nursing practitioners need to master. The adjustment of nursing talent development programs should be based on the standards outlined in certification requirements for fields such as maternal and infant nursing and elderly care; this process requires the collaborative participation of both the hospital and the educational institution. For example, for the Elderly Care Certification program, the criteria for obtaining the certificate should be integrated into the nursing professional internship curriculum system to ensure effective alignment between teaching standards and certification requirements. The structure of course hours should be adjusted to incorporate additional specialized theoretical and practical teaching components in the relevant modules, and the assessment mechanisms for academic courses should be aligned with those for relevant skill-level certifications, thereby facilitating the integration of academic credentials and professional certifications. This approach enables nursing students to obtain both an academic degree and multiple tiered professional certifications, fostering the development of versatile, technically skilled nursing professionals who possess both academic qualifications and practical expertise. ② Curriculum System Development. Since many certificates do not correspond to a single course—often resulting in overlapping between course content and certificate-based training content—it is essential to develop supporting learning resources and teaching materials in strict accordance with the certificate standards. This involves incorporating certificate-related content not covered in conventional academic education and optimizing both the instructional content and the course structure. For example, in a geriatric nursing course, content such as the use of rehabilitation assistive devices for elderly patients and care techniques for seniors with dementia should be added in line with the Professional Competence Level Certificate for Geriatric Care Standards, ensuring that the course content precisely aligns with the actual demands of the industry. Additionally, specialized certificate training course modules should be developed; for popular "X" -certificates—such as those in maternal and infant care or emergency nursing—experienced physicians from the relevant fields should be invited to deliver intensive lectures, providing detailed explanations of key examination points, standardized skill operation procedures, and case study methodologies. This approach ensures the seamless integration of vocational skills training content with general course material, enabling students to complete their certificate-based training even through traditional classroom instruction.

(2) Faculty development

To effectively implement the nursing education program under the "1 + X Certificate System," it is essential to have nursing instructors with enhanced professional capabilities, which entails higher qualifications and competencies for these educators. Such instructors should possess a thorough understanding of current professional practice requirements, demonstrate strong ability to integrate certification processes into their teaching, and be well-versed in the examination standards and procedures for relevant professional qualification certificates. However, in practice, such instructors are scarce; therefore, it is necessary to strengthen the existing nursing faculty within hospitals. First, existing hospital nursing instructors should be trained to deepen their knowledge of the latest advancements in their respective fields and to familiarize themselves with the job competency standards associated with these certification programs. Hospitals should also revise their assessment criteria for nursing instructors by incorporating instructors' skill levels into their evaluation frameworks, thereby motivating them to adapt their teaching

practices and place equal emphasis on both instructional delivery and certification processes. During the training of nursing instructional instructors, professionals from the elderly care sector and experts responsible for certifying these qualifications should be invited to provide specialized technical and skill-based training as well as practical guidance to enhance their teaching capabilities. Key nursing staff should be selected for targeted training focused on the vocational skill level standards, enabling them to master the core content and educational objectives of these certifications, clarify the specific assessment requirements, and integrate the relevant certification standards and content into their professional teaching practices. Additionally, through school-enterprise partnerships, nursing instructors can be dispatched to elderly care facilities or other relevant organizations for learning, communication, and rotational practical experience, thereby enhancing their professional practice skills and vocational competencies.

(3) Teaching Practice

① Theoretical instruction: In the theoretical teaching component of the nursing program, information technology resources and tools should be fully leveraged to implement a blended learning approach through the integration of curriculum and certification training. The "Xuexitong" APP can be utilized to optimize core nursing courses by uploading relevant certification-related teaching materials and content to this platform, enabling students to engage in self-directed online learning via the platform. For example, when optimizing the existing core nursing courses, content related to geriatric care should be incorporated; this allows students to study geriatric care practice videos and related knowledge anytime and anywhere during their free time. A question bank for obtaining the Basic Geriatric Care Certificate should be compiled and analyzed, and the textbook content within this bank should be restructured and systematized to establish a foundational question bank for the institution's geriatric care curriculum. To expand the scope of this question bank, questions relevant to the National Nurse Professional Qualification Examination should be curated, with those that are pertinent to geriatric care extracted and the resulting question bank uploaded to the platform, enabling students to conduct self-assessment on theoretical knowledge through the online platform. For in-person classroom instruction, hospitals should collaborate with educational institutions to develop offline teaching materials and other resources; through classroom teaching by faculty members, students can systematically master the skills and knowledge related to geriatric care, thereby acquiring the practical operational competencies required in this field. ② Practical Teaching: In line with the teaching content and educational requirements, a practical training base shall be established through collaboration between hospitals and educational institutions; this base will be utilized for the time-based development and assessment of relevant clinical skills. As a result, nursing students will not only be able to participate in routine clinical rotations within hospitals but also engage in the actual implementation of home care, community nursing, and other related programs conducted at other healthcare facilities. During their clinical practice, students shall receive on-site guidance from both specialized nursing professionals at these institutions and hospital-based clinical instructors. The practical training base shall be developed in accordance with the requirements and certification standards for geriatric care, featuring a standardized patient training center, a modern nursing practical training center, and simulated home wards; for the Maternal and Infant Nursing Certification program, a dedicated Maternal and Infant Nursing Room shall be established, enabling students to undertake rotational clinical practice under the supervision of various specialized clinical instructors within the department. Within this authentic hospital clinical environment, students can practice basic nursing procedures firsthand; however, for high-complexity nursing tasks—

such as emergency procedures in the Intensive Care Unit (ICU)—students shall undergo repeated practice in simulated training rooms, thereby enhancing their proficiency in performing nursing interventions and improving their ability to respond to emergent situations. At this training base, both curricular skill training and certification-based skill assessments shall be conducted simultaneously.

2.3. Evaluation methodology

During the entire teaching period, nursing students shall maintain thorough observation records and be assessed and compared against the following metrics: their theoretical assessment scores (on a 100-point scale), their clinical practice competency scores (including dimensions such as nursing assessment, diagnosis, and implementation), their clinical thinking skills before and after the teaching intervention, and the Nursing Curriculum Evaluation Questionnaire.

2.4. Statistical methods

Statistical analysis was performed using SPSS 26.0 software; *t*-tests and χ^2-tests were employed. Measurement data were expressed as mean ± standard deviation ($\bar{x} \pm s$), while categorical data were presented as [n (%)]. A *P*-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of theoretical assessment results between the experimental group and the control group among nursing students

The theoretical scores in the experimental group were significantly higher than those in the control group ($p < 0.001$); detailed results are presented in **Table 1**.

Table 1. Comparison of theoretical assessment results between the two groups of nursing students ($\bar{x} \pm s$)

Group	n	Theoretical assessment score (points)	Classroom assessment full mark rate (%)
Test team	140	88.94 ± 2.80	92.19 ± 3.81
Control group	140	76.94 ± 3.31	79.81 ± 4.78
t	-	17.714	13.642
p	-	< 0.001	< 0.001

3.2. Comparison of clinical practice competence between the experimental group and the control group among nursing students

The experimental group demonstrated higher scores in nursing diagnoses, nursing assessments, health education, nursing interventions, and total scores compared to the control group ($p < 0.05$); detailed results are presented in **Table 2**.

Table 2. Comparison of clinical practice competency assessment scores between the two groups of nursing students ($\bar{x} \pm s$, points)

Group	n	Nursing diagnosis and plan	Nursing assessment	Health guidance	Nursing implementation	Total points
Test team	140	22.80 ± 2.01	22.94 ± 1.13	23.48 ± 1.32	23.64 ± 1.36	89.59 ± 5.45

Control group	140	19.12 ± 1.25	20.67 ± 1.15	20.20 ± 1.49	19.07 ± 1.48	78.96 ± 5.79
t	-	5.132	4.864	8.652	7.849	12.594
p	-	< 0.05	< 0.05	< 0.001	< 0.001	< 0.001

3.3. Comparison of clinical thinking skills between the experimental and control groups of nursing students before and after teaching intervention

There was no statistically significant difference in clinical thinking ability scores between the first two groups before intervention ($P > 0.05$); after intervention, the scores across all dimensions and the total score in the experimental group were significantly higher than those in the control group ($p < 0.05$); detailed results are presented in **Table 3**.

Table 3. Comparison of clinical thinking skills between the two groups of nursing students before and after teaching ($\bar{x} \pm s$, points)

Group	n	Seeking the truth		Open-mindedness		Analyzing ability		Systematic capability	
		Before Teaching	After Teaching	Before Teaching	After Teaching	Before Teaching	After Teaching	Before Teaching	After Teaching
Test team	140	34.05 ± 5.26	46.40 ± 5.67	38.24 ± 5.46	45.19 ± 5.94	35.46 ± 5.90	42.74 ± 5.82	36.14 ± 5.31	42.92 ± 7.82
Control group	140	33.67 ± 5.14	35.42 ± 6.16	37.85 ± 5.03	39.54 ± 6.88	34.22 ± 5.85	36.27 ± 6.29	35.88 ± 4.99	37.61 ± 7.64
t	-	0.411	9.873	0.399	4.605	1.121	5.497	0.569	3.618
p	-	> 0.05	< 0.001	> 0.05	< 0.001	> 0.05	< 0.001	> 0.05	< 0.001

Continued

Group	n	Critical thinking confidence		Thirst for knowledge		Cognitive maturity		Total points	
		Before Teaching	After Teaching	Before Teaching	After Teaching	Before Teaching	After Teaching	Before Teaching	After Teaching
Test team	140	33.84 ± 5.65	42.96 ± 5.44	42.10 ± 6.24	46.62 ± 6.60	38.81 ± 6.70	43.69 ± 5.91	259.32 ± 20.15	310.15 ± 21.22
Control group	140	32.64 ± 5.23	34.55 ± 6.26	40.58 ± 5.92	42.82 ± 6.95	38.09 ± 6.05	39.97 ± 6.87	253.19 ± 19.78	266.04 ± 20.91
t	-	1.652	8.862	1.305	2.894	0.592	3.013	1.605	10.942
p	-	> 0.05	< 0.001	> 0.05	< 0.05	> 0.05	< 0.001	> 0.05	< 0.001

3.4. Comparison of curriculum evaluation between the experimental group and the control group among nursing students

The total course evaluation score in the experimental group was significantly higher than that in the control group ($p < 0.001$); detailed results are presented in **Table 4**.

Table 4. Comparison of nursing curriculum evaluation scores between the two groups ($\bar{x}$ ± s, points)

Group	n	Content learning	Course value	Behavioral learning	Personal understanding	Total points
Test team	140	31.47 ± 3.21	27.99 ± 1.82	31.32 ± 3.04	27.36 ± 3.14	118.09 ± 6.28

Control group	140	26.84 ± 2.76	22.17 ± 1.62	26.61 ± 2.81	23.62 ± 2.31	102.35 ± 5.80
t	-	7.986	8.013	8.317	7.136	10.361
p	-	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

4. Discussion

In the cultivation of nursing professionals at higher vocational institutions, the talent development model under the "1 + X Certificate System" offers the following advantages.

4.1. Enhances the effectiveness of theoretical knowledge acquisition

When implementing this system, hospitals need to restructure their nursing professional internship curriculum frameworks by integrating the theoretical knowledge covered by the certification into conventional nursing curricula, enabling students to acquire a broader and more comprehensive range of nursing theoretical knowledge [7,8]. Furthermore, the process of restructuring the curriculum framework significantly improves its hierarchical structure and makes it more modular; within such a framework, students can progressively master nursing professional knowledge. Additionally, to simultaneously facilitate both certification-based learning and professional training in the teaching process, diverse instructional resources are incorporated into the curriculum content. Students can not only acquire relevant knowledge through online learning platforms but also gain richer theoretical understanding by utilizing case study repositories, instructional videos, and other materials [9,10]. Offline, through collaboration between the hospital and other professional organizations, students can access the latest theoretical advancements, thereby building a more extensive theoretical knowledge base. In this study, the experimental group achieved superior scores in theoretical assessments compared to the control group ($p < 0.05$), which directly demonstrates this advantage.

4.2. Enhancing clinical practice competence

Under this teaching model, hospitals can establish deep collaborations with other specialized healthcare institutions, enabling students to gain opportunities to participate in real-world clinical projects at these institutions, as well as to acquire and develop relevant clinical skills at dedicated training bases. For example, in the field of geriatric care, students can directly engage with communities to provide nursing care to elderly individuals, thereby honing their practical skills. Alternatively, they can perform and practice nursing procedures in simulated environments using various virtual scenarios and equipment, which helps enhance their clinical practice competence [11–12]. In this study, the experimental group demonstrated higher scores in the clinical practice competence assessment ($p < 0.05$), which aligns with this advantage.

4.3. Cultivating clinical thinking skills

In the certificate-based training programs offered by the hospital, instructors consistently incorporate a large number of real-world hospital cases into their teaching. This enables students to develop nursing care plans based on actual case studies, assess changes in patients' conditions, and implement specific nursing interventions within the clinical training facility—thereby applying theoretical knowledge in practice, examining clinical problems from multiple perspectives, and ultimately effectively honing their clinical thinking skills [13,14]. The experimental group demonstrated significantly stronger clinical thinking skills after

the intervention ($p < 0.05$), effectively demonstrating the advantage of this teaching approach.

4.4. Higher nursing course evaluations

This teaching model primarily requires instructors to continuously enhance their professional competencies, thereby improving the quality of instruction. As a result, this teaching approach is more targeted and practical, making it easier for students to understand the material and leading to higher student evaluations. In this study, the experimental group received higher course evaluations ($p < 0.05$), which aligns with this advantage.

5. Conclusions

In conclusion, implementing the nursing talent cultivation model under the "1 + X Certificate System" for training vocational nursing professionals can enhance their clinical practice skills and theoretical knowledge mastery, effectively foster their clinical thinking abilities, and ultimately yield superior evaluation outcomes for nursing curriculum assessments.

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Exploration of the Application of Artificial Intelligence Technology in Radiological Medical Image Processing

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Abstract: Artificial Intelligence Technology has been applied to Radiological Medical Image Processing in recent years. Based on the collection of 5,000 cases of imaging data from August 2024 to August 2026, this paper systematically studies the applications of artificial intelligence in radiological medical image pre-processing, diagnosis and treatment. First, the general kinds of radiological medical images and the foundations of artificial intelligence technology were introduced; then, intelligent methods in the preprocessing stage, such as image denoising, segmentation and registration, were explored for diagnostic purposes, focusing on lesion detection, classification and auxiliary decision-making, and finally extended to treatment areas, including target volume delineation, dose prediction and efficacy evaluation. Based on the above analysis, this paper will address some actual problems in the field of data quality, model interpretability and clinical trust, and look ahead to the future direction of multimodal fusion and explainable AI to provide a reference for the intelligent transformation of radiological medical image processing.

Keywords: Artificial intelligence; Radiological medicine; Image processing; Deep learning; Auxiliary diagnosis

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1. Introduction

Radiological medical images serve as the foundation for many diagnoses and treatments today, so both the speed and precision of these images' processing directly impact patient health. As imaging equipment has been continuously improved and the number of examinations has steadily increased, the old way of doing things manually is no longer feasible. Artificial intelligence has good feature extraction and pattern recognition abilities, so now it can be used to solve problems such as image denoising, segmentation, detection and prediction. Based on 5000 cases of imaging data collected from August 2024 to August 2026, this paper systematically studies the application paths of artificial intelligence in radiological medical image processing, analyzes its practical challenges and development prospects, and aims to provide theoretical support for clinical practice and subsequent research [1].

2. Foundations of artificial intelligence and radiological medical image processing

2.1. Basic types and features of radiological medical images

Radiological medical images generally refer to X-rays, CT scans, MRI, PET scans, ultrasounds, etc. Different modalities have different imaging principles, resolutions and information dimensions. X-rays and CT scans are based on density differences, so they are good at showing bones and lungs; MRI has high contrast for soft tissue and is often used to examine the nervous system and joints; PET shows metabolic activity and is very useful for tumor diagnosis. Generally speaking, these images have the features of a large amount of data, complex grayscale distribution, and the presence of noise and artefacts. Due to differences in equipment and parameters, there will be noticeable image heterogeneity; thus, standardized processing cannot be achieved, and artificial intelligence needs to be introduced to address this problem.

2.2. Basic concepts and main approaches to artificial intelligence technology

Artificial Intelligence technology uses machine learning to learn features and patterns from data automatically. Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs) and Transformers are all deep learning models that have achieved good results in image recognition and sequence modelling. Convolutional Networks use local receptive fields and weight sharing to extract spatial features for lesion detection and segmentation; Generative Adversarial Networks can be employed for image enhancement and reconstruction; Attention Mechanisms focus on important areas in the representation. Transfer learning and self-supervised learning address the problem of limited annotated data, and federated learning offers a privacy-preserving way for multi-center cooperation. In short, the above ways provide the technical basis and algorithms for intelligent processing of radiological medical images [2].

2.3. Applications of artificial intelligence in radiological medical image processing

Artificial Intelligence has many applications in the field of medical imaging. It will have good processing speed, reduce the time needed for image reconstruction, segmentation and analysis, and lighten the load on radiologists. AI can find small lesions that are not visible to the naked eye and thus increase the proportion of early-stage diagnoses; at the same time, it will also reduce false negatives and false positives. Algorithm output does not vary due to changes in the operator's mood, so it is relatively stable. Artificial intelligence can also extract rich information from images to help predict the course of disease and personalized treatment plans, and promote the shift from experience-based care to data-driven care in radiology; this has considerable clinical value and social benefits.

3. Application of artificial intelligence in radiological medical image preprocessing

3.1. Image denoising and enhancement

Radiological medical images are prone to noise and artefacts at the time of acquisition and transmission, thus affecting subsequent analysis. Artificial Intelligence trains a network to learn the mapping from noise distribution to clean images and then performs adaptive denoising. Convolutional Neural Networks (CNNs) and Generative Adversarial Networks (GANs) have shown good results in low-dose CT denoising and MRI noise reduction, and can reduce noise without losing edges and other features. Deep learning can be used to enhance the contrast and sharpen the structure of an image, reduce uneven lightness, etc., to make lesions more prominent. Based on research of 5,000 cases, intelligent denoising and enhancement can significantly

improve the quality of the image and provide strong support for segmentation and diagnosis [3].

3.2. Image segmentation and organ recognition

The first purpose of image segmentation in medical imaging is to divide organs, tissues and lesions from the background. Fully convolutional networks, U-Net and its variations have been used by artificial intelligence to achieve end-to-end pixel-level classification, and they have shown good results in segmenting the liver, lungs, brain and tumors. Organ recognition, on the other hand, employs classification networks and localization algorithms to automatically annotate anatomical structures and provide support for subsequent quantitative analysis. Attention mechanisms and multi-scale feature fusion can also enhance the segmentation performance of small targets and regions with blurry borders. Train a model on a large amount of data, then apply it to various devices and protocols, reduce manual delineation errors, and improve segmentation consistency and repeatability [4].

3.3. Image registration and fusion

Image registration is to align images taken at different times, in various ways or at different places, and fusion integrates multiple sources of information to improve the representation. Artificial Intelligence directly predicts the deformation field via a regression network for fast non-rigid registration without the need for expensive iterative optimization. Multimodal fusion integrates CT, MRI and PET data to obtain combined anatomical and functional images for all-around assessment of the disease. A Deep Learning-based Fusion Method can dynamically weigh the features of different modalities and focus on the lesion area. Based on 5000 cases of data, intelligent registration and fusion have improved both the spatial consistency and information richness of images, thus providing strong support for accurate diagnosis and radiotherapy plan construction.

4. Applications of artificial intelligence in radiological medical image diagnosis

4.1. Lesion detection and localization

The first is to find the disease in this way. A network for object detection is employed by artificial intelligence to automatically find abnormal areas in images and indicate their positions. Convolutional Neural Networks and Feature Pyramid Structures are used together to address lesions at various scales and enhance the detection rate of small nodules simultaneously. Intelligent systems have achieved good sensitivity and specificity in the detection of pulmonary nodules, breast masses and liver lesions. The localization function adds annotations for the coordinates and extents of the lesions to help doctors view and compare them. Large-sample training helps the model learn well and perform consistently across all kinds of scans; thus, it can improve both the detection rate and diagnostic accuracy of radiologists [5].

4.2. Lesion classification and benign-malignant determination

Detection is used to identify lesions, and then AI classifies them as either benign or malignant. A classification network extracts morphological, textural and enhanced features, combines them with clinical data, and outputs a probability result. Deep Learning models have achieved good results in differentiating between benign and malignant pulmonary nodules, grading breast lesions, and classifying brain tumors. Transfer Learning and Ensemble Methods Improve Classification Stability Further. Based on the research

of 5,000 cases, intelligent classification can reduce subjectivity and offer doctors an objective reference. Although the final diagnosis needs to be confirmed by pathology, artificial intelligence has shown some benefits in early screening and risk assessment to help optimize the use of medical resources and diagnostic-treatment processes.

4.3. Diagnosis result prediction and support for decision-making

Artificial Intelligence can now be used to recognize images and diagnose diseases, predict how long people will live after being diagnosed with cancer, etc., all to help doctors make better decisions. Combine radiomic features with clinical information to build a model that can determine the risk of death and the likelihood of tumor recurrence. Recently, some research has begun applying deep learning to problems such as survival analysis and drug response prediction to provide personalized medical support. An auxiliary decision-support system combines the results of algorithms with rules and presents them visually to help doctors make decisions more efficiently and consistently. Based on the large-scale follow-up data, intelligent prediction models have been continuously optimized to promote the shift of radiological diagnosis from description to prediction and expand the clinical application of imaging [6].

5. Application of artificial intelligence in radiological medical image treatment

5.1. Automatic delineation of radiotherapy target volumes

The delineation of the target area for radiation therapy will affect both the precision of irradiation and the protection of healthy tissue. Manual division is relatively slow and has inter-observer differences. Artificial intelligence can automatically identify tumor size and organs-at-risk by means of segmentation networks for fast and uniform target selection. Models based on U-Net and attention mechanisms have shown relatively good results in delineating head-and-neck, thoracic and pelvic tumors, and have reduced the preparation time for treatment planning considerably. Training on 5,000 cases can help the model learn various anatomical features and image qualities, thus reducing under-delineation and over-delineation. As one of the links in the radiotherapy workflow, intelligent division can enhance the uniformity of treatment and work efficiency.

5.2. Optimization of the treatment plan and dose prediction

Set up a treatment plan that covers the target area and protects healthy organs. Artificial Intelligence helps physicists quickly generate candidate plans by predicting dose distribution. A deep-learning model can directly output a 3D dose distribution based on the patient's anatomy and prescribed dose without multiple optimizations. Reinforcement Learning and Multi-Objective Optimization methods will also be used to explore the space of personalized plans. Based on large-scale data, dose prediction models can learn clinical preferences and constraints to improve plan quality and consistency. Intelligent Optimization reduces the planning period and allows more patients to receive radiotherapy promptly; thus, both clinically and operationally, it is feasible.

5.3. Efficacy assessment and follow-up observation

The first two links in the treatment cycle are efficacy assessment and follow-up observation. Compare the pre-treatment and post-treatment images to automatically measure changes in lesion size, density, metabolism, etc., by means of artificial intelligence for objective evaluation of treatment response.

Longitudinal registration and change detection algorithms can observe changes in lesions over time and find early signs of expansion or recurrence. Radiomics features and prediction models can be used to evaluate the risk of death and other diseases. Based on the follow-up data of 5000 cases from August 2024 to August 2026, intelligent systems can continuously learn and optimize evaluation criteria, provide timely evidence for clinical adjustments to treatment plans, and promote the application of personalized medicine [7].

6. Challenges and prospects for artificial intelligence in radiological medical image processing

6.1. Data quality and annotation problems

The first two reasons for the lack of AI applications are poor data quality and annotation. Medical images obtained by X-rays may have noise, artefacts and variations due to different devices, etc., thus affecting model stability. High-quality annotations require experienced doctors, are expensive, and are subject to individual differences; therefore, they have significant problems such as small sample sizes and class imbalance. Multi-center data sharing has privacy and ethical issues, so model generalization is limited. Federated learning and self-supervised learning can reduce the need for manual annotation, but data normalization and quality control still need to be improved. Build a standardised process for collecting, cleaning and annotating data to support the clinical application of artificial intelligence.

6.2. Model interpretability and clinical trust

Many deep learning models are considered black boxes; thus, the reasons for their decisions cannot be easily understood by people, leading to reduced clinical confidence and unclear accountability. Doctors should be informed about the areas that the algorithm has focused on and what attributes have been selected for judgment. Explainable AI shows how a model makes decisions by displaying heat maps, attention visualizations and concept attributions to increase transparency. However, there is still a gap between the explanation results and clinical logic, so validation in conjunction with medical knowledge is required. Set up a mechanism for reviewing algorithms, monitoring performance and sharing responsibilities to boost the acceptance of clinicians and promote the development of artificial intelligence from an auxiliary tool into a trusted companion.

6.3. Technology integration and future development directions

In the future, artificial intelligence in radiological medical image processing will move towards multi-technology integration. Multimodal large models can combine images, text and genomics to gain a deeper understanding of the disease. Edge computing and cloud computing work together to provide real-time processing and remote cooperation. Generative artificial intelligence can be applied to image reconstruction, data augmentation and simulation training to address the problem of data scarcity. Federated Learning and Privacy-Preserving Computation Promote Multi-Center Cooperation and Improve Model Generalization Ability. With the strengthening of regulatory systems and the deepening of clinical trials, artificial intelligence is expected to cover all links in the process of screening, diagnosis, treatment and follow-up, thereby advancing radiology towards intelligence, precision and personalization.

7. Conclusion

Artificial Intelligence technology has many applications in radiological medical image processing at present. Based on 5000 cases of data collected from August 2024 to August 2026, this paper systematically studies the methods and values of artificial intelligence in preprocessing, diagnosis and treatment, and analyzes problems such as data quality, interpretability and technological integration. Artificial intelligence can enhance the speed and accuracy of image processing and optimize radiotherapy workflow and efficacy assessment; however, there are still problems of standardization, trust and regulation in its clinical application. In the future, with the progress of multimodal fusion and explainable AI, artificial intelligence will be applied more broadly in radiology to assist doctors in making precise diagnoses and treatments for patients.

Disclosure statement

The author declares no conflict of interest.

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Analysis of Influencing Factors for Pulmonary Consolidation in Children with *Mycoplasma Pneumoniae* Pneumonia and Construction-Validation of a Nomogram Model

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Abstract: *Objective*: To explore the independent influencing factors for pulmonary consolidation complicated by *mycoplasma pneumoniae* pneumonia (MPP) in children, and construct a nomogram prediction model capable of individualised quantitative risk assessment, so as to provide evidence for early clinical identification of high-risk children and formulation of precise intervention strategies. *Methods*: A retrospective cohort design was adopted in this study. A total of 316 children diagnosed with MPP at Wuming Hospital Affiliated to Guangxi Medical University from June 2023 to June 2024 were enrolled as research subjects. According to imaging findings, the children were divided into pulmonary-consolidation group (n = 177) and non-pulmonary-consolidation group (n = 139). Baseline clinical data and laboratory indicators of the two groups were compared via univariate analysis. Variables with statistical differences in univariate analysis were included in multivariate binary Logistic regression analysis to screen independent risk factors for pulmonary consolidation among children with MPP. A nomogram prediction model was constructed based on screened results, and internal validation was performed using the Bootstrap method (1 000 repeated samplings). The discrimination, calibration and predictive performance of the model were comprehensively evaluated by calculating the concordance index (C-index), plotting calibration curves and receiver operating characteristic (ROC) curves. *Results*: Univariate analysis showed that peripheral white blood cell count (WBC), high-sensitivity C-reactive protein (hs-CRP), erythrocyte sedimentation rate (ESR) and fibrinogen (FIB) levels in the pulmonary-consolidation group were significantly higher than those in the non-pulmonary-consolidation group (all $p < 0.05$). Multivariate Logistic regression analysis further confirmed that elevated WBC (OR = 1.054, 95%CI: 1.001–1.111), elevated hs-CRP (OR = 1.044, 95% CI: 1.018–1.070) and elevated FIB (OR = 1.492, 95% CI: 1.007–2.212) were independent risk factors for pulmonary consolidation in children with MPP (all $p < 0.05$). For the nomogram prediction model constructed based on the above three indicators, the C-index from internal validation was 0.718 (95% CI: 0.659–0.802), suggesting acceptable discrimination capacity of the model. The calibration curve indicated high consistency between predicted probabilities

and actually-observed probabilities. ROC-curve analysis yielded an area under curve (AUC) of 0.731 for the model to predict pulmonary consolidation, with a sensitivity of 61.4 % and specificity of 75.2 %. Clinical decision-curve analysis further verified positive net clinical benefit of the model across a wide range of threshold probabilities. In summary, this nomogram model achieves a sensitivity of 61.4 % and specificity of 75.2 %, with acceptable discrimination and calibration, and possesses certain clinical practical value. *Conclusion*: WBC, hs-CRP and FIB are independent risk factors for pulmonary consolidation complicated by paediatric MPP. This study successfully constructed and validated a nomogram prediction model based on these three indicators. With favourable predictive performance and clinical practicality, the model can serve as clinical reference. It facilitates early individualised risk assessment of pulmonary consolidation for children with MPP and provides an intuitive, quantitative decision-supporting tool for prospective clinical interventions.

Keywords: *Mycoplasma pneumoniae*; Pulmonary consolidation; Influencing factors; Nomogram model

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1. Introduction

Mycoplasma pneumoniae pneumonia (MPP) is a common respiratory disease in children. Cases of severe and refractory MPP have increased in recent years. Pulmonary consolidation represents one of the most frequent severe manifestations. Pulmonary consolidation is significantly correlated with longer fever duration, more persistent cough symptoms and more complicated clinical courses. It also acts as an important risk marker indicating possible progression to necrotising pneumonia, atelectasis, and even sequelae such as bronchiolitis obliterans [1]. It may prolong hospital stay, raise treatment difficulty and affect long-term pulmonary function, thus leading to unfavourable prognosis [2]. Existing researches mostly focus on severe or refractory MPP, while specialised prediction models targeting the specific complication of pulmonary consolidation remain insufficient [3,4]. Analysing influencing factors for pulmonary consolidation in MPP bears great significance for assessing children's conditions and improving prognosis. As a visual prediction model, a nomogram can integrate multiple risk factors to realise individualised risk evaluation. Therefore, this study aims to screen independent risk factors for pulmonary consolidation in children with MPP via retrospective analysis, construct and validate a nomogram prediction model, and offer reference evidence for early clinical identification and intervention strategies.

2. Materials and methods

2.1. Sample-size estimation

This study followed methodological specifications for prediction-model research and adopted the pmsampsize package of R software for sample-size calculation. To follow a conservative principle, parameters were set as below: preset model discrimination (C-index) = 0.8, expected number of predictive variables = 3, and estimated prevalence of the outcome (pulmonary consolidation) = 22 % according to literature [5]. Calculation yielded a theoretical minimum total sample size of 301 cases with 67 pulmonary-consolidation events. Finally, 316 children were enrolled in this study; the total sample size met requirements, among which 177 pulmonary-consolidation events were observed, 2.6 times the theoretical value. The events-per-predictor parameter (EPP) reached 59.0, far exceeding the standard of EPP ≥ 10. This guaranteed extremely stable

parameter estimation and reliable internal validation of the model. Adopting a relatively low estimated prevalence for calculation was a strategy adopted in this study to enhance argumentative rigour.

2.2. Research subjects

A total of 316 children infected with MPP treated in our hospital from June 2023 to June 2024 were selected as research subjects. They were divided into pulmonary-consolidation group (n = 177) and non-pulmonary-consolidation group (n = 139) according to pulmonary-consolidation status. This study obtained approval from the Hospital Medical Ethics Committee.

2.2.1. Inclusion criteria

Conforming to diagnostic criteria specified in *Diagnosis and Treatment Guidelines for Children with Mycoplasma Pneumoniae Pneumonia (2023 Edition)* [6]; children aged below 14 years; complete clinical data; first-time hospital admission.

2.2.2. Exclusion criteria

Suffering from other respiratory diseases; long-term glucocorticoid therapy; other infectious diseases; complicated cardiac, hepatic or renal dysfunction.

2.3. Collection of clinical data

Clinical medical records of the 316 subjects were collected, including age, gender, disease course, cough, wheezing, fever, WBC, hs-CRP, ESR, activated partial thromboplastin time (APTT), FIB, complement C3, complement C4, lactate dehydrogenase (LDH), alanine aminotransferase (ALT), aspartate aminotransferase (AST).

2.4. Statistical analysis

SPSS 26.0 software was used for statistical analysis. Count data were expressed as case number and percentage, and the Chi-square test was adopted for inter-group comparison. Measurement data with non-normal distribution were presented as median and interquartile range , and the Mann-Whitney U test was used for inter-group comparison. Variables with $p < 0.05$ in univariate analysis were imported into multivariate Logistic regression analysis to identify independent risk factors. Based on regression outputs, R language was utilised to construct the nomogram prediction model, and the Bootstrap method (1 000 repeated samplings) was applied for internal validation. Receiver operating characteristic (ROC) curve, calibration curve, Hosmer-Lemeshow test and decision curve were employed to assess model discrimination, calibration and clinical practicality. $p < 0.05$ was defined as statistically significant difference.

3. Results

3.1. Baseline characteristics and univariate analysis of children with MPP

Among the 316 enrolled children with MPP, 159 were male and 157 were female. Levels of WBC, ESR, hs-CRP and FIB in the pulmonary-consolidation group were higher than those in the non-pulmonary-consolidation group, with statistically-significant differences ($p < 0.05$), see **Table 1**.

Table 1. Baseline characteristics of children infected with MPP

Factor		Non-pulmonary-consolidation group (n = 139)	Pulmonary-consolidation group (n = 177)		
Age (years)		5.00 (3.00, 7.00)	5.00 (3.00, 7.00)	-0.037	0.970
Gender	Male	74 (53.20 %)	85 (48.00 %)	0.874	0.357
	Female	65 (46.80 %)	92 (52.00 %)		
Disease course (d)		8.00 (6.00, 14.00)	7.00 (5.00, 10.00)	-2.347	0.019
Cough	Yes	136 (43.50 %)	177 (56.50 %)	4.964	0.026
	No	3 (100.00 %)	0 (0.00 %)		
Wheezing	Yes	11 (50.00 %)	11 (50.00 %)	0.347	0.556
	No	128 (43.50 %)	166 (56.50 %)		
Fever	Yes	79 (40.50 %)	116 (59.50 %)	2.495	0.114
	No	60 (49.60 %)	61 (50.40 %)		
WBC	9.26 (7.02, 12.26)	10.73 (8.46, 14.34)	3.244	0.001	WBC
hs-CRP (mg/L)	6.05 (2.74, 13.61)	11.19 (6.97, 24.22)	5.753	0.000	hs-CRP (mg/L)
ESR (mm/h)	23.00 (14.00, 37.00)	29.00 (20.00, 42.00)	2.792	0.005	ESR (mm/h)
APTT (s)	41.5 (39.20, 45.30)	41.3 (38.40, 45.00)	-1.302	0.193	APTT (s)
FIB (g/L)	4.00 (3.51, 4.61)	4.38 (3.88, 4.94)	4.014	0.000	FIB (g/L)
C3 (g/L)	1.25 (1.10, 1.38)	1.25 (1.13, 1.36)	0.719	0.472	C3 (g/L)
C4 (g/L)	0.30 (0.25, 0.36)	0.33 (0.25, 0.39)	1.964	0.050	C4 (g/L)
LDH (U/L)	260.00 (223.10, 297.00)	268.00 (234.00, 305.50)	1.703	0.089	LDH (U/L)
ALT (U/L)	13 (11.00, 16.00)	12.40 (10.00, 16.00)	-1.056	0.291	ALT (U/L)
AST (U/L)	31.00 (27.00, 37.00)	33.00 (28.00, 38.00)	1.342	0.180	AST (U/L)

Note: Since the positive rate of cough reached 100 % in the pulmonary-consolidation group with quasi-complete separation, this variable was not incorporated into the multivariate regression model.

3.2. Binary logistic regression analysis of influencing factors for pulmonary consolidation in MPP

The occurrence of pulmonary consolidation was taken as the dependent variable (assignment: 0 = non-consolidation, 1 = consolidation). Variables yielding $p < 0.05$ in univariate analysis were selected as candidate independent variables. The variable "cough" was excluded for quasi-complete separation risk due to extremely skewed distribution (100 % positive rate in consolidation group). After multicollinearity diagnosis and elimination of variables with severe multicollinearity (VIF > 5), WBC, hs-CRP, ESR and FIB were imported into the multivariate binary Logistic regression model via the Enter method (forced-entry approach) to screen independent risk factors, see **Table 2**.

Table 2. Binary logistic regression analysis of influencing factors for pulmonary consolidation in MPP

Factor		SE	Wald		OR	95 % CI
WBC	0.053	0.027	3.965	0.046	1.054	1.001–1.111
hs-CRP	0.043	0.013	11.305	0.001	1.044	1.012–1.065
ESR	-0.003	0.008	0.162	0.688	0.997	0.980–1.013
FIB	0.400	0.201	3.975	0.046	1.492	1.007–2.212

3.3. Construction and clinical application of the nomogram prediction model

R software was adopted to build the nomogram prediction model for pulmonary-consolidation risk among children with MPP according to influencing factors (**Figure 1**). In this model, every 5-unit increment in WBC corresponds to approximately 7 points; every 10 mg/L increment in CRP corresponds to approximately 12 points; every 1 g/L increment in FIB corresponds to approximately 12 points. Clinicians obtain three routine laboratory test results including peripheral-blood white-blood-cell count (WBC), high-sensitivity C-reactive protein (hs-CRP) and fibrinogen (FIB) from children with MPP at early hospital admission. Locate each measured value on corresponding indicator axes above the nomogram, project vertically upwards onto the "Points" axis and read individual scores for each indicator. Sum the three individual scores to obtain "Total Points". Locate this total score on the "Predicted Probability" axis at the bottom of the nomogram, and the percentage value corresponding to vertical downward projection represents the individualised predicted probability of pulmonary consolidation for this child.

3.4. Validation of the nomogram prediction model

Model validation showed satisfactory performance. For discrimination: training-set AUC = 0.731 (95 %CI: 0.659-0.802), sensitivity 61.4 %, specificity 75.2 %; validation-set AUC = 0.728 (95 %CI: 0.636–0.819); bias-corrected C-index values were 0.718 and 0.727 respectively (**Figure 2, 3**). Calibration was satisfactory (training-set = 1.270, = 0.530; validation-set = 1.005, = 0.605). Decision-curve analysis confirmed significant net clinical benefit within clinically-relevant threshold ranges, indicating high clinical applicability (**Figure 4**).

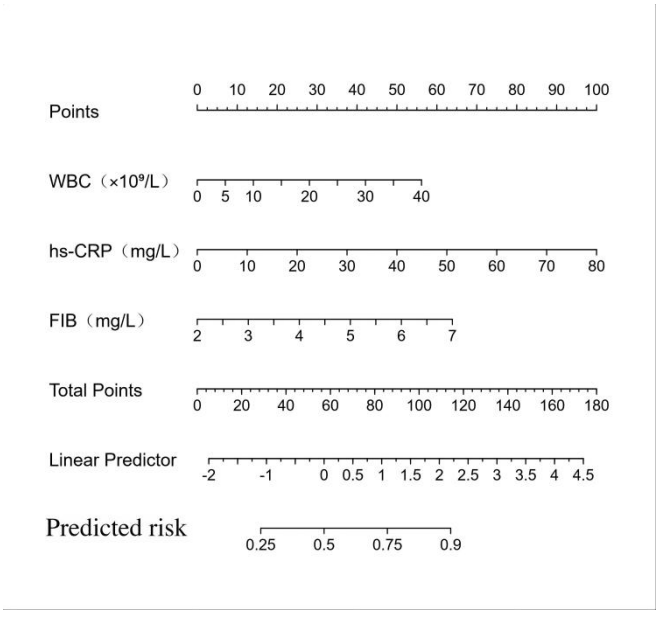


Figure 1. Nomogram prediction model for pulmonary-consolidation occurrence in MPP.

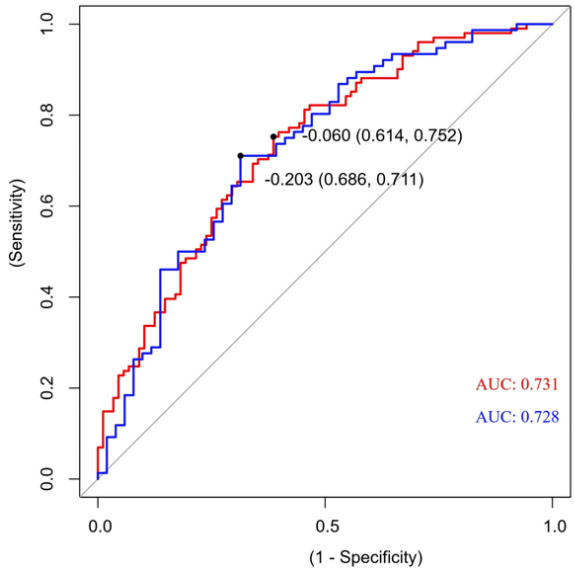


Figure 2. ROC curves of the prediction model for training set and validation set.

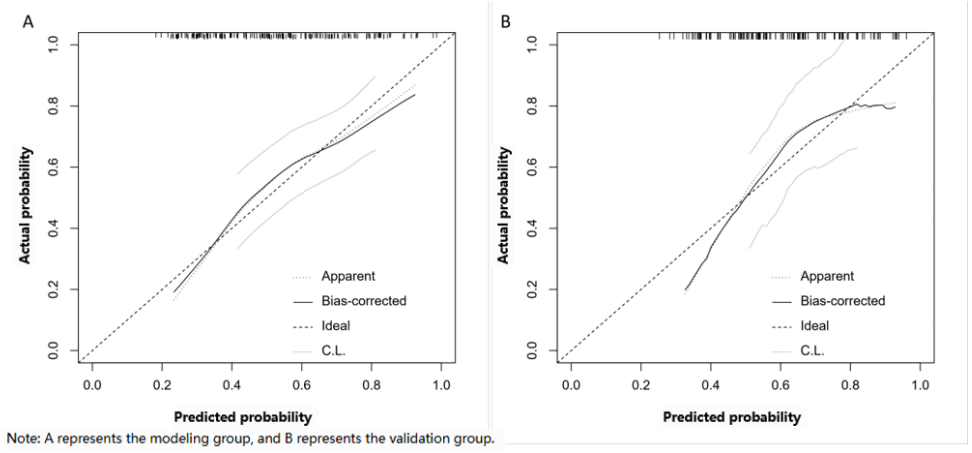


Figure 3. Calibration curves of the prediction model for training set and validation set.

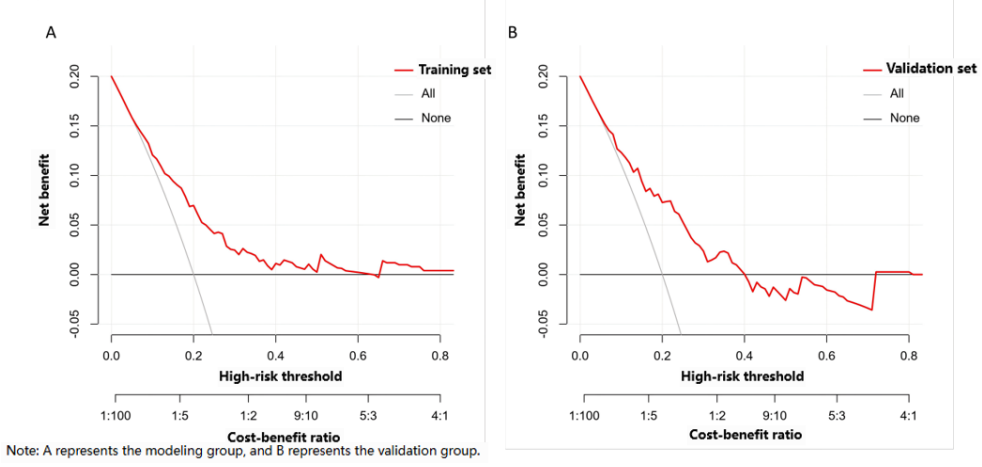


Figure 4. Decision-curve diagrams for training set and validation set.

4. Discussion

The primary objective of this study was to predict pulmonary-consolidation risk for children with MPP at an early stage and construct a quantitative tool. Pulmonary consolidation serves as an objective imaging turning point marking progression of MPP into substantive pneumonia and correlates with poor prognosis [6–8]. Therefore, adopting it as the grouping cut-off point possesses both objectivity and clinical guiding value. The total sample size of this study satisfied theoretical estimation based on conservative parameters, and event counts were sufficiently abundant. Nevertheless, measured against broader prediction-model sample-size criteria (e.g. lower expected C-index or more anticipated predictors), there remains room for total-sample-size improvement. It should be emphasised that the core strength of this study lies in its extremely high positive-event count (177 cases) and EPP value (59.0). These fundamentally guarantee stable model-parameter estimation and reliable internal validity. The internal-validation outputs from the Bootstrap method (C-index = 0.718, favourable calibration curves) enjoy good credibility and reliably demonstrate acceptable discrimination and calibration of the model under current data patterns and population characteristics.

This study identified that WBC, hs-CRP, ESR and FIB correlated with pulmonary consolidation in MPP, among which WBC, hs-CRP and FIB acted as independent risk factors, suggesting intense stress-immune reactions during MPP-related pulmonary consolidation. ESR suffers interference from age, anaemia and other factors, hence it showed no independent effect [9,10]. As inflammatory markers, WBC and hs-CRP verify that uncontrolled host inflammatory responses constitute core driving forces for disease deterioration. This explains why pathogen-targeted therapy cannot stop progression towards pulmonary consolidation in some children, and highlights the importance of early monitoring and intervention against excessive inflammation [11]. This study confirmed correlations between WBC, hs-CRP and pulmonary consolidation, re-affirming that inflammatory intensity acts as a key factor influencing MPP prognosis [12]. The moderate OR values of both indicators indicate limited association between elevated WBC/hs-CRP and increased pulmonary-consolidation risk. As a key protein for coagulation cascade and acute-phase reaction, FIB bears important independent predictive value. It marks coagulation activation during severe MPP progression, possibly associated with endothelial injury and immune-thrombus formation that promotes pulmonary consolidation [13]. Multivariate regression analysis in this study demonstrated independent correlation of FIB elevation with increased pulmonary-consolidation risk, and validated that FIB, as a critical molecule bridging inflammation and coagulation, continuously functions in the pathophysiological process of pulmonary-parenchymal injury [14,15]. Nevertheless, controversies exist regarding the independent predictive value of FIB. This study supports the viewpoint that MPP is accompanied by hypercoagulable status. Discrepancies versus some published studies may stem from differences in population disease severity and test timing [16]. Consequently, clinicians shall pay attention to elevated levels of WBC, hs-CRP and FIB. This combined indicator panel achieves a sensitivity of 61.4 % and specificity of 75.2 % for predicting MPP-related pulmonary consolidation and delivers certain clinical reference value.

Previous prediction models incorporating complicated and costly indicators such as LDH, D-dimer, procalcitonin and specific cytokines mostly apply to severe or refractory cases [17,18]. In real-world clinical practice, especially in primary-level hospitals, most children with pulmonary infection receive hospital admission before developing severe manifestations. This study focuses on three routine items: WBC, hs-CRP and FIB, which feature rapid, low-cost detection available in hospitals of all tiers, greatly improving model universality. This model directly predicts the concrete and vital clinical-decision node “pulmonary consolidation”, instead of the broad concept “severe pneumonia”. Its outputs can more directly guide decisions such as whether to perform chest CT, bronchoscopic therapy or adjust pharmaceutical regimens. Primary-care physicians only need to obtain risk probabilities from the nomogram according to the three

test results of each child to conduct individualised risk stratification, optimise primary-level referral, realise resource allocation and standardised diagnosis-treatment. It complies with requirements of the national medical-health "Strengthening Grass-roots Initiative" and fits primary-level medical-and-health institutions with limited laboratory resources yet urgent demand for valid risk-stratification tools. Against the backdrop of DRG payment reform and medical-resource optimisation, balancing precise diagnosis-treatment and cost-effectiveness has become an important clinical topic. Conventional prediction for MPP-related pulmonary consolidation largely depends on repeated imaging review and monitoring of multiple non-specific inflammatory markers, which incur high costs with limited efficiency. The nomogram constructed in this study only incorporates three low-cost, rapidly-available routine laboratory indicators including WBC, hs-CRP and FIB, with favourable clinical accessibility and practicality. Relying on initial routine test results obtained at admission, the model enables individualised risk stratification, which further guides differentiated clinical decisions: strengthen monitoring and intervention for high-risk children to prevent disease deterioration; reduce unnecessary examinations and therapies for low-risk children so as to optimise resource allocation. This strategy improves diagnosis-treatment quality while controlling costs. It provides solid empirical evidence and easy-to-implement decision-making tools for stratified standardised management of MPP under DRG payment reform.

Limitations of this study should be noted. This is a retrospective study. The proportion of pulmonary-consolidation cases (56 %) among enrolled subjects is higher than previously-reported 22 %, which may result from single-centre admission bias. The generalisability of the model still requires verification via multi-centre prospective studies. Single-centre research carries inherent bias and external validation is needed. Future multi-centre prospective researches are required to verify model generalisability and incorporate more-dimensional biomarkers for continuous model optimisation.

5. Conclusion

In conclusion, WBC, hs-CRP and FIB constitute important independent factors for pulmonary consolidation in MPP. The constructed nomogram prediction model achieves sensitivity of 61.4 % and specificity of 75.2 %. It can serve as clinical reference, facilitates individualised clinical assessment, and delivers certain reference value for early identification of high-risk children and formulation of intervention strategies.

Disclosure statement

The authors declare no conflict of interest.

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The Impact of Palliative Care on Agitation Behavior and Rehabilitation Treatment Compliance in Elderly Dementia Patients

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Abstract: *Objective:* To explore the effect of palliative care on agitation behavior and rehabilitation treatment compliance in elderly dementia. *Method:* 80 elderly dementia patients admitted to our hospital from October 2021 to October 2023 were randomly divided into a control group of 40 cases, receiving routine care; Forty cases in the observation group were given palliative care on the basis of routine care. Score the patient's arousal behavior using the arousal behavior assessment form and observe their compliance with rehabilitation treatment. *Result:* The agitation behavior score of the observation group was significantly lower than that of the control group ($p < 0.05$), and the complete compliance rate was also significantly higher than that of the control group ($p < 0.05$). *Conclusion:* Implementing palliative care for elderly dementia patients can reduce their agitation behavior and improve their compliance with rehabilitation treatment.

Keywords: Senile dementia; Palliative care; Exciting behavior; Rehabilitation therapy

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1. Introduction

Patients with dementia not only exhibit symptoms of cognitive dysfunction but also experience varying degrees of mental and behavioral abnormalities [1]. Agitation is one of the most common mental and behavioral abnormalities in dementia patients, characterized by symptoms such as cursing, aggression, irritability, wandering, restlessness, and inappropriate handling of objects [2, 3]. Wei Zhihua et al. found that agitation is prevalent among dementia patients, with diverse manifestations related to mental intelligence, dementia type, and disease severity [4]. The occurrence of agitation increases the risk of safety incidents such as fractures, falls, self-harm, or harm to others, which, once they occur, exacerbate the suffering of patients and their families. Agitation negatively impacts patients' daily functioning abilities, increasing the physical and psychological burden on caregivers [5]. For society, the occurrence of agitation in dementia patients often

necessitates hospitalization, increasing the societal burden. When patients no longer respond to curative medical treatments, implementing hospice care, which provides comprehensive care from physiological, psychological, and social perspectives, can uphold the dignity of patients as human beings, offer them peace, and improve the quality of their end-of-life experience [6]. This study primarily explores the impact of hospice care on agitation and rehabilitation treatment adherence in dementia patients, as reported below.

2. Materials and methods

2.1. General information

Eighty dementia patients admitted to our hospital from October 2021 to October 2023 were included in the study. Patients/family members provided informed consent for participation and were randomly assigned using a random number table to either an observation group or a control group, with 40 patients in each group. The observation group consisted of 19 males and 21 females, aged 60–82 years with an average age of (68.83 ± 5.33) years, including 14 cases of vascular dementia, 15 cases of Alzheimer's disease, and 11 cases of mixed dementia. The control group consisted of 22 males and 18 females, aged 60–85 years with an average age of (68.98 ± 5.42) years, including 16 cases of vascular dementia, 14 cases of Alzheimer's disease, and 10 cases of mixed dementia. There was no significant difference in general information between the two groups ($p > 0.05$).

2.1.1. Inclusion criteria

(1) Age ≥ 60 years, gender not limited;
(2) Diagnosed with dementia according to ICD-10;
(3) Patients/family members provided informed consent.

2.1.2. Exclusion criteria

(1) Coma;
(2) Diagnosed with psychiatric disorders such as schizophrenia;
(3) Incomplete medical records;
(4) Severe cardiac, renal, or hepatic diseases;
(5) Malignant tumors.

2.2. Methods

The control group received routine care, where nursing staff provided basic care, assisted with daily activities and movements, intervened in uncomfortable symptoms, and followed medical advice when agitation occurred, while ensuring the safety of both the patient and others. The observation group received hospice care in addition to routine care, as follows:

2.2.1. Prevention of complications

Regular rounds were conducted to comprehensively assess the patient's condition and evaluate the risk of complications and potential risk factors. Nutritional support was provided, with professional dietitians assessing the patient's nutritional status, identifying nutritional risks, and developing individualized nutritional support plans to reduce nutritional risks and enhance resistance to complications.

2.2.2. Improvement of sleep quality

The hospital environment was optimized, with appropriate temperatures maintained in activity and sleeping areas, and patients' favorite items placed to enhance comfort. Before bedtime, indoor lighting was controlled to reduce blue light exposure, and a quiet environment was maintained to minimize disturbances.

2.2.3. Pain intervention

The patient's pain intensity was assessed, and a combination of interventions was used to alleviate pain. Non-pharmacological pain management strategies included frequent conversations to divert the patient's attention to topics of interest, music therapy with light and soothing music played when pain did not necessitate medication or before bedtime, and encouraging participation in aerobic exercises such as walking or Baduanjin [7]. When pharmacological interventions were necessary, analgesics were administered according to the patient's treatment status and complication profile, with guidance provided to patients and caregivers to alleviate concerns and emphasize the importance of pain relief in maintaining patient dignity.

2.2.4. Emotional therapy

A combination of videotapes, music, and photographs was used to guide patients in recalling past events, with nursing staff engaging in conversations to help patients recognize the emotions behind their behaviors and language. The causes of aggressive behavior were analyzed, and precursors to such behavior were identified to reduce stressors [8]. When symptoms such as loneliness, withdrawal, and indifference were severe, empathy dolls were provided for patients to name and treat gently as their own infants, with daily contact lasting no less than 1 hour; nursing staff avoided confiscating dolls due to inappropriate patient behavior or language [9]. Patients were encouraged to engage in activities they enjoyed with family members whenever possible.

2.2.5. Behavioral and psychological symptom therapy

The activity space was optimized to provide sufficient room for patients while ensuring safety. Patients were encouraged to participate in outdoor activities. Cognitive, memory, and thinking skills were trained through activities such as number sequencing, picture recognition, chess, and card games. Language communication skills were trained by fully utilizing gestures, smiles, and nods during conversations with patients [10]. In daily life, assistance was provided without forcing patients to adhere to specific schedules or routes, minimizing psychological pressure. Patients' social adaptability was enhanced by organizing activities such as origami and flower watering, encouraging participation and helping patients identify their social roles.

2.3. Observation indicators and evaluation criteria

After one month of nursing intervention, agitation scores were observed before and after intervention. The community version of the Chinese Cohen-Mansfield Agitation Inventory was used for assessment, with a reliability coefficient of 0.86. The inventory consists of 23 items categorized into verbal and behavioral types, further subdivided into aggressive and non-aggressive verbal/behavioral types [11]. Scores were assigned based on the frequency of behaviors over the past 14 days, ranging from 1 (never occurred) to 7 (occurred several times per hour). Total scores ranged from 23 to 161, with higher scores indicating more severe agitation. Rehabilitation treatment adherence was assessed using a self-designed questionnaire, evaluating whether patients could follow rehabilitation instructions, the frequency of rehabilitation, and daily rehabilitation duration. Patients were classified as fully adherent if they actively engaged in rehabilitation

under guidance, partially adherent if daily rehabilitation duration or weekly frequency was insufficient or methods were inappropriate, and non-adherent if unwilling to participate in functional exercises. The fully adherent rate was calculated.

2.4. Statistical analysis

Data were processed using SPSS 23.0, with *t*-tests for continuous data ($\overline{x} \pm s$) and chi-square tests for categorical data. The significance level was set at $\alpha = 0.05$.

3. Results

3.1. Comparison of agitation scores

As shown in **Table 1**, after intervention, all agitation scores and the total score significantly decreased in the observation group ($p < 0.001$). In the control group, physical aggressive behavior, verbal non-aggressive behavior, and the total score significantly decreased after intervention ($p < 0.001$), while physical non-aggressive behavior and verbal aggressive behavior showed no significant difference compared to before intervention ($p > 0.05$). Additionally, there was no significant difference in agitation scores between the two groups before intervention ($p > 0.05$), but after intervention, all agitation scores in the observation group were significantly lower than those in the control group ($p < 0.001$).

Table 1. Comparison of agitation scores ($\overline{x} \pm s$, points)

Group	Time	Physical aggressive behavior	Physical non-aggressive behavior	Verbal aggressive behavior	Verbal non-aggressive behavior	Total score
Observation group	Before intervention	12.501.22	13.034.72	4.651.34	6.582.54	38.829.53
	After intervention	8.891.34	10.181.44	3.081.20	4.021.10	24.476.22
	t	12.599	3.653	5.520	5.849	7.975
	p	< 0.001	0.001	< 0.001	< 0.001	< 0.001
Control group	Before intervention	12.842.31	13.404.38	4.481.26	6.802.43	39.029.43
	After intervention	10.321.47	12.311.53	3.890.84	5.060.82	30.147.38
	t	5.821	1.486	2.464	4.291	4.690
	p	< 0.001	0.144	0.016	< 0.001	< 0.001
Between-group comparison before intervention	*t*	0.823	0.363	0.585	0.396	0.094
	p	0.414	0.717	0.561	0.693	0.925
Between-group comparison after intervention	*t*	4.547	6.412	3.497	4.794	3.716
	p	< 0.001	< 0.001	0.001	< 0.001	< 0.001

3.2. Comparison of rehabilitation treatment adherence

After the intervention, the full adherence rate in the observation group was significantly higher than that in the control group ($P < 0.05$), as shown in **Table 2** and **Table 3**.

Table 2. Comparison of rehabilitation treatment adherence (n, %)

Group	n	Complete compliance	Partial compliance	Non-compliance	Compliance rate
Observation group	40	22(55.00)	16(40.00)	2(5.00)	22(55.00)
Control group	40	11(27.50)	23(57.50)	6(15.00)	11(27.50)
χ^2	/	/	/	/	6.241
p	/	/	/	/	0.012

Table 3. Comparison of compliance rates in rehabilitation treatment (n, %)

Group	n	Complete compliance rate	Partial compliance rate	Non-compliance rate
Observation group	40	22 (55.00)	16 (40.00)	2 (5.00)
Control group	40	11 (27.50)	23 (57.50)	6 (15.00)
χ^2	/	5.158	1.801	1.25
p	/	0.023	0.180	0.264

4. Discussion

The philosophy of hospice care is to "preserve life, view death as a normal physiological process, neither hasten nor delay death, and manage pain and psychological issues". Hospice care does not mean abandoning active treatment for patients but rather using professional methods to help them achieve the best possible quality of life. In this study, for physical pain in dementia patients, hospice care employed a combination of communication, music therapy, and exercise therapy. Strengthening communication with patients helped divert their attention and enhance their psychological resilience; music therapy reduced sympathetic nervous system activity, lowering pain thresholds and reducing physiological stress; exercise therapy alleviated physical pain, and all these measures diverted patients' attention, reducing excessive focus on pain. When administering analgesic medications, emphasis was placed on improving compliance among patients and caregivers, alleviating their psychological burden. These measures effectively reduced physical pain in patients, decreased stressors, and subsequently reduced the occurrence of agitation.

The study results showed that after hospice care intervention, agitation scores in dementia patients were significantly lower than those in the control group, with statistical significance. Furthermore, compared to the control group, compliance with rehabilitation treatment was significantly higher in the hospice care group. These findings confirm that hospice care can reduce agitation and improve compliance with rehabilitation treatment in dementia patients.

To improve sleep quality in dementia patients, nursing staff created a favorable living and sleeping environment, reducing environmental stressors and alleviating patients' feelings of insecurity, thereby ensuring better sleep quality. Nursing staff played soothing music for patients, activating central nervous system function and promoting the release of endorphins and melatonin, which had a calming, sedative, and sleep-inducing effect.

To reduce the occurrence of complications, nursing staff assessed patients' conditions and identified potential risk factors for high-risk complications, facilitating early detection. Strengthening nutritional support improved patients' physical condition and enhanced their resistance to diseases.

5. Conclusion

For agitation in dementia patients, hospice care emphasized patients' emotional experiences during nursing, using various media to help patients recall past memories and understand their emotions. Nursing staff

employed empathy dolls to accompany patients, stimulating their protective instincts and facilitating emotional connections, making patients more receptive to these interventions. For agitation and other psychiatric symptoms, nursing staff created safe activity spaces for patients and encouraged participation in outdoor activities. Emphasis was placed on training patients' cognitive, memory, and thinking abilities to help them adapt to society, reducing stress and subsequently agitation. During interventions for psychiatric symptoms, hospice care did not force improvements in cognitive, memory, and thinking abilities but rather used demonstration and guidance to stimulate patients' interests, reducing resistance and improving compliance with rehabilitation treatment. In summary, implementing hospice care for dementia patients can reduce agitation and improve compliance with rehabilitation treatment.

Disclosure statement

The author declares no conflict of interest.

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Analysis of Airborne Pollen Concentration and Pollen Sensitization Characteristics in Harbin City

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Abstract: *Objective*: To investigate the species, counts, and dispersal patterns of airborne pollen in the urban area of Harbin over two consecutive years, and to clarify the correlation between airborne pollen and allergic rhinitis in combination with clinical patient data. *Methods*: The gravity sedimentation method was employed to continuously collect daily pollen particles in Daowai District, Harbin, from March 1 to October 15 in both 2020 and 2021. Pollen species were counted and identified under a light microscope. Specific IgE (sIgE) test results from outpatients attending the hospital between June 2021 and June 2022 were analyzed. *Results*: A total of 63,080 pollen grains were monitored in 2020, and 29,229 grains in 2021 (pollen count per 1,000 mm² per day). The identified pollen taxa included *Salicaceae* (Populus and Salix), *Ulmaceae*, *Betulaceae*, *Juglandaceae*, *Oleaceae* (Fraxinus), *Cupressaceae*, *Pinaceae*, *Rosaceae*, *Fabaceae*, *Moraceae*, *Cyperaceae*, *Fagaceae*, *Polygonaceae*, *Asteraceae* (Artemisia), *Poaceae*, *Chenopodiaceae*, *Typhaceae*, *Anacardiaceae*, and *Tiliaceae*. Two annual peaks occurred in April and August. In April, Populus pollen was the most abundant, accounting for 51.47% and 37.21% in the two years, respectively, followed by Ulmus (18.74% and 26.75%). In August, Artemisia pollen dominated, accounting for 7% and 7.83%, followed by *Moraceae* (6.12% and 2.06%). Among 170 patients with allergic rhinitis who underwent allergen testing, 101 (59.4%) were positive for serum sIgE, with most showing sensitization to multiple allergens. Among these, 78 patients (77.2%) were sensitized to pollen. Specifically, Artemisia allergen positivity accounted for 63.3% (64/101), tree combination 2 positivity for 38.6% (39/101), followed by Ambrosia (23.7%, 24/101) and Humulus (4.95%, 5/101). The onset of symptoms was mainly concentrated in April and August, consistent with the peak periods of major allergenic pollen dispersal. *Conclusion*: The temporal distribution and concentration of airborne pollen in Harbin are positively correlated with the impact on allergic rhinitis. Tree pollen dominates in spring, while Artemisia pollen causes the most severe allergic symptoms in autumn.

Keywords: Pollen; Allergic rhinitis; Seasonal; Pollen monitoring; Artemisia

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1. Introduction

Airborne pollen is a major trigger of allergic rhinitis (AR), with distinct regional and seasonal patterns.

AR is a common disease that significantly impairs patients' quality of life and work productivity, and both individual treatment and social prevention present considerable challenges [1]. Worldwide, the prevalence of AR ranges from 10% to 40% [2]. In China, the selfreported prevalence in 11 cities is 17.6%, and nearly 30% of AR cases are attributed to pollen exposure [3,4]. With social progress and changes in modern lifestyles, the prevalence of AR has been increasing.

Therefore, analyzing the species of allergenic airborne pollen and their seasonal dispersal patterns in a given region can effectively guide the prevention and treatment of allergic diseases and inform choices for urban greening. The present study investigates and analyzes allergenic pollen in Harbin from multiple perspectives, aiming to improve the management of allergic rhinitis and to provide reference for urban greening planning.

2. Materials and methods

2.1. General information

2.1.1. Sample collection

Pollen counts were collected from daily 24hour continuous exposure slides from March 1 to October 15 in 2020 and 2021. Pollen sampling was performed using the gravity sedimentation method. The sampler (provided by Beijing Tongren Hospital) was placed on the fifthfloor platform of the EmergencyENT Building of our hospital, at a height of 16 m above ground level. A 24hour cycle was used as one sampling unit: slides were set up at 8:00 a.m. each day and retrieved at 8:00 a.m. the following day. After retrieval, the slides were stained using the agar staining method, with reagents provided by Beijing Tongren Hospital. Subsequently, 24 mm × 50 mm coverslips were applied, and pollen counting was performed under a light microscope.

2.1.2. Pollen counting and classification

The stained pollen slides were examined under a light microscope. Pollen counts were obtained at low magnification (×10), and pollen types were identified at high magnification (×40). Species identification was conducted with reference to the Atlas of Airborne Pollen in China [5] and Pollen Morphology of Chinese Plants [6]. Pollen content was expressed as grains per 1000 mm^2. The slides were sent to a designated professional institution designated by Beijing Tongren Hospital for classification and verification, ensuring the accuracy and reliability of the test data.

2.1.3. Analysis of allergen test results

Serum specific IgE (sIgE) testing for inhalant allergens was performed on outpatients from the Allergy Department of our hospital using the EU Inhalant Allergen Specific IgE Antibody Detection Kit (immunoblotting method). The tested inhalant allergens included dust mite mix 1 (*Dermatophagoides pteronyssinus*/*Dermatophagoides farinae*), house dust, cockroach, cat dander, dog epithelium, mold mix 1 (Penicillium chrysogenum/*Cladosporium*/*Aspergillus fumigatus*/*Alternaria alternata*), tree mix 2 (willow/poplar/elm), hops, common ragweed, and mugwort, totaling 10 types.

2.1.4. Statistical analysis

Statistical analysis was performed using SPSS 16.0 software. A *p*value of < 0.05 was considered statistically significant.

3. Results

3.1. Content and species of airborne pollen in Daowai District, Harbin

In the airborne pollen analysis from March to October in 2020 and 2021, a total of 63,080 pollen grains were collected in 2020 and 29,229 in 2021. The identified pollen taxa included *Salicaceae* (Populus and Salix), *Ulmaceae*, *Betulaceae*, *Juglandaceae*, *Oleaceae* (Fraxinus), *Cupressaceae*, *Pinaceae*, *Rosaceae*, *Fabaceae*, *Moraceae*, *Cyperaceae*, *Fagaceae*, *Polygonaceae*, *Asteraceae* (Artemisia), *Poaceae*, *Chenopodiaceae*, *Typhaceae*, *Anacardiaceae*, and *Tiliaceae* (see **Table 1** and **Table 2**). In both spring seasons, poplar pollen was the most abundant, accounting for 51.47% and 37.21% respectively, followed by elm at 18.74% and 26.75%. In both autumn seasons, mugwort pollen was the most prevalent at 7% and 7.83% respectively, followed by *Moraceae* at 6.12% and 2.06% (see **Figure 1**).

3.2. Serum test results of AR patients

From June 2021 to June 2022, a total of 170 patients with allergic rhinitis (AR) were tested, aged 672 years. Serum sIgE was positive in 101 cases, with a positive rate of 59.4%. Most positive patients exhibited sensitization to multiple allergens. Among them, 78 cases were sensitized to pollen, accounting for 77.2% of positive patients. Specifically, mugwort allergen positivity accounted for 63.3% (64/101), tree mix 2 positivity for 38.6% (39/101), followed by ragweed at 23.7% (24/101) and hops at 4.95% (5/101). The peak time of disease onset occurred in April and August, which was consistent with the periods of high pollen concentration (see **Figure 2**).

Table 1. Species and quantities of airborne pollen from March to October 2020

Pollen taxa	Pollen count (grains/1000 mm²)									
	March	April	May	June	July	August	September	October	Total	Percentage (%)
Cupressaceae	6	2	152	14	0	0	0	0	174	0.27
Betulaceae	9	210	2577	36	0	0	0	0	2832	4.48
Salicaceae (Salix)	11	1464	320	0	0	0	0	0	1795	2.85
Salicaceae (Populus)	37	32157	444	0	0	0	0	0	32638	51.74
Ulmaceae	86	11644	95	0	0	0	0	0	11825	18.74
Juglandaceae	0	187	346	55	0	0	0	0	588	0.94
Oleaceae (Fraxinus)	0	210	0	15	0	0	0	0	225	0.35
Rosaceae	0	42	1576	70	0	0	0	0	1688	2.67
Pinaceae	0	3	2202	235	7	0	0	0	2447	3.89
Fabaceae	0	0	81	7	32	5	0	0	125	0.2
Poaceae	0	0	11	208	79	544	97	9	948	1.5
Fagaceae	0	0	145	5	0	0	0	0	150	0.24
Polygonaceae	0	0	1	40	1	0	0	0	42	0.07
Moraceae	0	0	71	24	15	1086	105	1	1302	2.06
Cyperaceae	0	0	13	6	0	0	0	0	19	0.03
Chenopodiaceae	0	0	0	43	126	632	67	1	869	1.38
Anacardiaceae	0	0	0	9	0	0	0	0	9	0.02
Typhaceae	0	0	0	3	0	0	0	0	3	0.004
Tiliaceae	0	0	0	4	0	0	0	0	4	0.006
Asteraceae	0	0	0	0	0	296	109	49	454	0.73
Asteraceae (Artemisia)	0	0	0	13	0	4437	490	3	4943	7.83
Total	149	45919	8034	787	260	7000	868	63	63080	100

Table 2. Airborne pollen species and counts from March to October 2021

Pollen taxa	Pollen count (grains/1000 mm²)									
	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Total	Percentage (%)
Cupressaceae	16	22	26	0	0	0	0	0	64	0.21
Betulaceae	184	302	1100	4	0	0	0	0	1590	5.45
Salicaceae (Salix)	16	1134	28	0	0	0	0	0	1178	4.03
Salicaceae (Populus)	44	10806	28	0	0	0	0	0	10878	37.21
Ulmaceae	278	7506	36	0	0	0	0	0	7820	26.75
Juglandaceae	0	34	134	1	0	0	0	0	169	0.58
Oleaceae (Fraxinus)	10	10	88	0	0	0	0	0	108	0.37
Rosaceae	0	370	288	0	4	0	0	0	662	2.27
Pinaceae	4	56	1060	38	10	0	0	0	1168	3.99
Fabaceae	0	0	182	20	0	0	0	0	202	0.69
Poaceae	1	0	14	54	144	574	102	4	893	3.06
Fagaceae	0	0	0	0	0	0	0	0	0	0
Polygonaceae	0	0	6	0	0	0	0	0	6	0.02
Moraceae	0	2	264	40	74	1324	84	2	1790	6.12
Cyperaceae	0	14	88	4	4	0	0	0	110	0.39
Chenopodiaceae	1	0	0	0	28	370	16	0	415	1.42
Anacardiaceae	0	0	0	0	0	0	0	0	0	0
Typhaceae	0	0	0	0	16	0	0	0	16	0.05
Tiliaceae	0	0	0	0	0	0	0	0	0	0
Asteraceae	0	0	0	0	2	112	2	0	116	0.39
Asteraceae (Artemisia)	0	0	0	0	10	1972	60	2	2044	7.00
Total	554	20256	3342	161	292	4352	264	8	29229	100

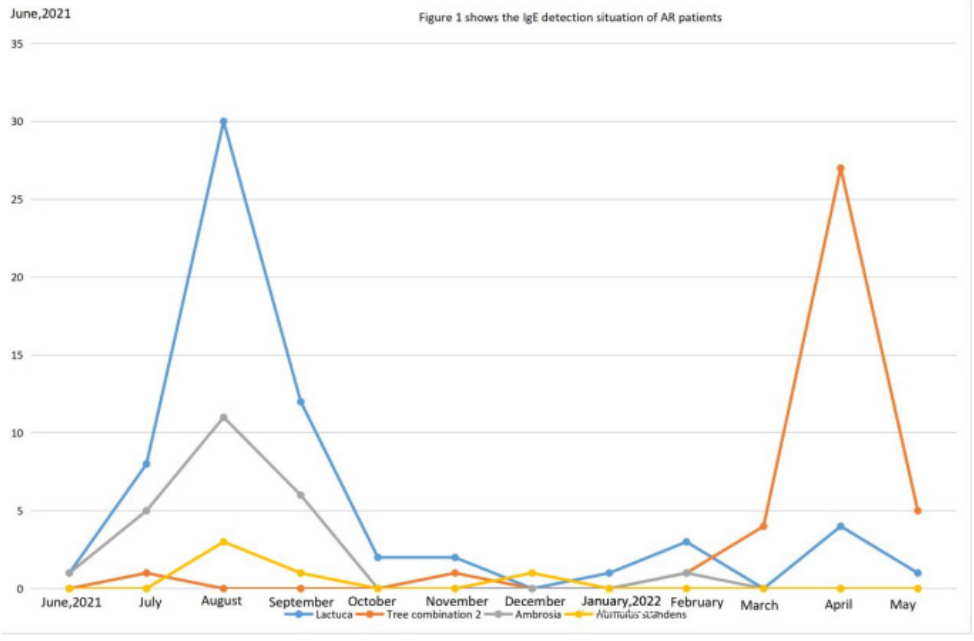


Figure 1. The IgE detection situation of AR patients.

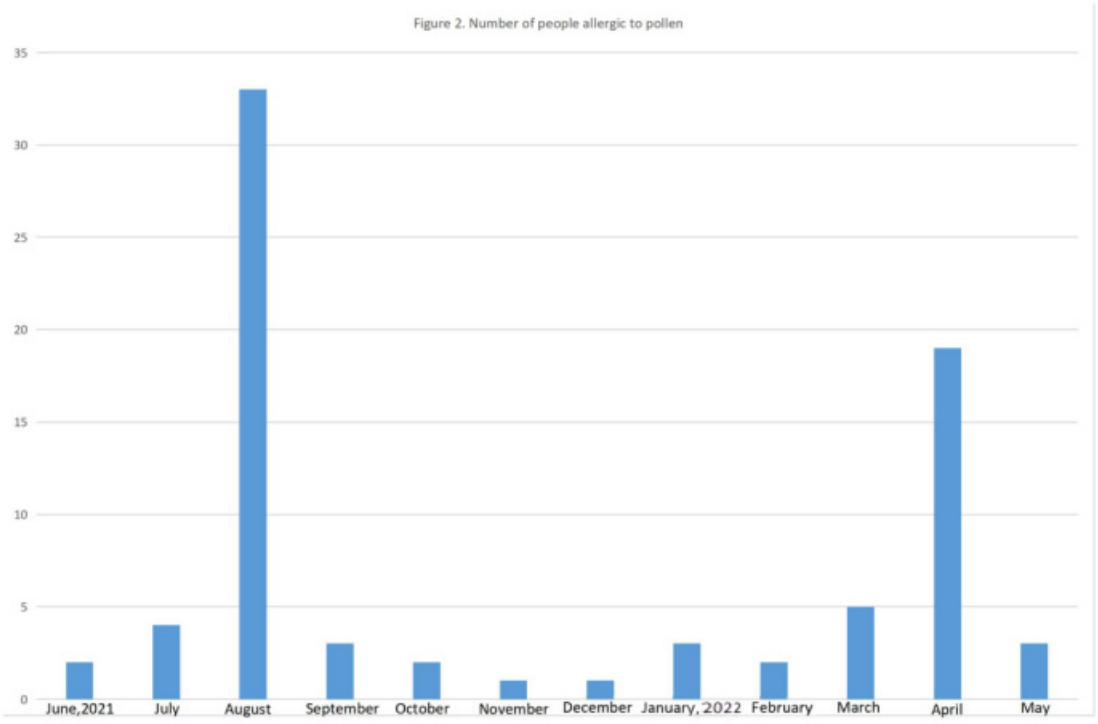


Figure 2. Number of people allergic to pollen.

4. Discussion

With the continuous changes in the social environment, the incidence of allergic rhinitis has been rising, and airborne pollen is one of the major inhalant allergens [5]. International reports indicate that the prevalence of seasonal allergic rhinitis ranges from 5% to 22% [6]. A Korean study from 2003 to 2011 demonstrated a positive correlation between the airborne pollen index and outpatient visits for allergic diseases [7]. In China, pollen allergy ranks second only to dust mite allergy, and the concentration of sensitizing pollen is closely associated with patient symptoms [8]. Many provinces and cities in China have been conducting pollen monitoring to provide early warning for the protection of patients with allergic rhinitis.

Harbin is located along the Songhua River. The unique vegetation and climatic conditions endow the airborne pollen in Harbin with distinct regional characteristics. Meanwhile, due to the development of urban greening and the introduction of new species, more than 20 genera and families of pollen have been detected in the air over the past two consecutive years. Nevertheless, the predominant types remain poplar and elm pollen in spring, and Artemisia (Compositae) pollen in autumn, which are the main sensitizing allergens for allergic rhinitis. In spring, poplar and elm pollen account for approximately 70% of the total pollen count, while in autumn, Compositae (Artemisia) pollen accounts for about 7%. Based on the twoyear monitoring results and analysis of weather conditions, the airborne pollen concentration is significantly affected by weather factors such as temperature, wind, and rainfall, which markedly influence pollen counts. Therefore, there were considerable variations in pollen counts during the same season across the two years, but the dispersal pattern and the timing of peak occurrence remained unchanged. Artemisia pollen shows higher sensitization potency than tree pollen, and increased pollen concentration is closely related to the onset of disease in patients. However, due to the impact of the COVID19 pandemic in recent years, the number of outpatient visits declined notably, and the quantity of allergen

testing for allergic rhinitis patients was relatively small, which could not fully reflect the epidemiological characteristics of pollinosis patients in Harbin.

5. Conclusion

In summary, through two years of pollen monitoring, we have preliminarily obtained the dispersal pattern of airborne pollen in Harbin. Moreover, our study demonstrates that the airborne pollen concentration in Harbin is significantly influenced by weather conditions, and the dispersal time and concentration are directly correlated with the incidence of allergic rhinitis—the higher the concentration, the higher the incidence. Poplar pollen is the most frequent sensitizer in April, while Artemisia pollen causes the most severe sensitization in August. Therefore, a systematic investigation and analysis of the quantity, species, and seasonal distribution patterns of airborne sensitizing pollen, combined with the incidence of allergic rhinitis, can provide a basis for prevention in pollenallergic individuals. At the same time, it offers references for urban greening and environmental management, such as reducing the planting of poplar trees and timely removal of Artemisia weeds, to decrease the dispersal of sensitizing pollen in the air and better serve public health.

Disclosure statement

The authors declare no conflict of interest.

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Study on the Synergistic Mechanism of Modified Shenling Baizhu Powder in Treating Obesity Based on Network Pharmacology and Molecular Dynamics

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Abstract: *Objective*: To investigate the molecular mechanisms of Shenling Baizhu Powder with modifications in treating obesity using network pharmacology and molecular dynamics approaches. *Methods*: Active components of Shenling Baizhu Powder were identified from the TCMSP and BATMAN-TCM databases, and their target molecules were predicted using Swiss Target Prediction and SEA; obesity-related targets were retrieved from GeneCards, CTD, NCBI, and the GEO dataset GSE151839, with potential therapeutic targets identified through intersection analysis; drug-component-target networks and protein-protein interaction (PPI) networks were constructed, followed by GO and KEGG enrichment analyses; molecular docking was performed using Schrödinger, and molecular dynamics simulations were conducted with GROMACS. *Results*: A total of 196 active components were screened, among which 73 were identified as potential targets for obesity. Key components included ent-Epicatechin, licorice glycoside E, and dehydroglyasperins C, with PIK3R1, PIK3CA, and SRC as critical targets. Enrichment analyses revealed involvement in pathways such as insulin resistance, lipid metabolism, and atherosclerosis. Molecular docking demonstrated that PIK3CA exhibited the lowest binding affinity with licorice glycoside E, and molecular dynamics simulations confirmed optimal stability of this complex. *Conclusion*: The modified Shenling Baizhu Powder exerts multi-target, multi-pathway effects in combating obesity, with core components including ent-Epicatechin, licorice glycoside E, and dehydroglyasperins C, thereby providing a theoretical foundation for clinical applications.

Keywords: Obesity; Modified Shenling Baizhu Powder; Network pharmacology; Molecular dynamics

Online publication: October 23, 2026

1. Introduction

Obesity is a chronic metabolic disorder characterized by excessive accumulation and abnormal distribution of fat in the body, influenced by multiple factors including genetics and environment [1]. It is a significant predisposing factor for cardiovascular diseases, diabetes mellitus, polycystic ovary syndrome, and other conditions [2]. Western medicine commonly employs central weight-loss agents and lipase inhibitors, though these may cause cardiovascular and gastrointestinal adverse reactions. Recent clinical studies have demonstrated that traditional Chinese medicine exhibits significant efficacy in obesity treatment, particularly compound formulations such as modified Shenling Baizhu Powder, which primarily focuses on strengthening the spleen and eliminating dampness, offering unique advantages [1,2]. Traditional Chinese Medicine holds that obesity primarily results from excessive consumption of greasy and sweet foods, prolonged sedentary behavior with insufficient physical activity, and emotional disturbances leading to spleen deficiency with impaired transportation and transformation functions, as well as the accumulation of dampness, turbidity, phlegm, and stasis internally. Shenling Baizhu Powder, as a classical herbal formula, plays a significant role in the treatment of obesity [3,4]. However, the precise mechanisms underlying these modified formulations remain unclear. This study integrates network pharmacology, molecular docking, and molecular dynamics to systematically elucidate the target pathways and molecular mechanisms of modified Shenling Baizhu Powder in treating obesity.

2. Materials and methods

2.1. Collection and screening of active chemical components from compound traditional Chinese medicines and their corresponding predictive targets

From TCMSP the database (OB ≥ 30%, DL ≥ 0.18) was utilized to screen active components from Hyacinth bean, *Atractylodes macrocephala*, *Poria cocos*, *Glycyrrhiza uralensis*, Cinnamon Twig, *Platycodon grandiflorus*, Lotus Seed, Ginseng, *Amomum villosum*, *Dioscorea opposita*, Coix seed, *Alisma orientale*, and *Polyporus umbellatus*; the composition of Lotus Seed was obtained from BATMAN-TCM [5]. Swiss Target Prediction was employed for analysis [6]. (Species "Homo sapiens", probability > 0) and the SEA database predict target [7].

2.2. Identification of obesity-related therapeutic targets

Search CTD, GeneCards, and NCBI using the term "obesity" [8]. The databases yielded 5,000,2,194, and 5,000 genes respectively; the GEO2R software was employed to analyze the GSE151839 dataset [9]. A total of 3,564 differentially expressed genes were identified. The intersection of these four datasets was obtained and standardized using UniProt to identify obesity-related targets.

2.3. Construction of venn diagrams and the "active compound-disease target" regulatory network

Using the MicroBioinformatics Platform Construct a Venn diagram comparing drug targets and disease targets, with the intersection representing potential therapeutic targets [10]. Use Cytoscape 3.7.2 for analysis [11]. Establish a "drug-active ingredient-target" network.

2.4. Construction of protein interaction networks and screening of key targets

Import the intersection targets into STRING (with a maximum confidence score of 0.9), construct a protein-protein interaction (PPI) network, and use the Degree algorithm via the CytoNCA plugin in Cytoscape to identify key targets.

2.5. Analysis of GO functions and KEGG pathway enrichment

Using Metascape, we performed GO (binding proteins, cellular components, molecular functions) and KEGG pathway enrichment analyses on potential targets, ranked the results by LogP values, selected the top 20 entries, and visualized them using MicroBioinformatics.

2.6. Molecular docking validation

Select the top three targets by degree in the PPI network and perform docking with all 196 active compounds. Obtain ligand structures (in MOL2 format) from TCMSP and target protein structures (in PDB format) from PDB. Perform molecular docking using Schrodinger and Maestro, generate a heat map based on the top five results with the lowest binding energy, and visualize the optimal binding mode with Pymol.

2.7. Molecular dynamics simulations were conducted for validation.

Molecular dynamics simulations were performed using GROMACS on the three complexes with the lowest binding energies [12]. Using a total simulation duration of 100 ns with the Amber14SB force field, GAFF2 density functional force field, and TIP3P water model, energy minimization was performed via the steepest descent method (Fmax <1000 $kJ \cdot mol^{-1} \cdot nm^{-1}$). The system was equilibrated under both NVT and NPT ensembles at 298 K, 1.0 bar, for 100 ps, followed by simulations with a time step of 2 fs, with trajectories saved every 10 ps. Analysis parameters included RMSD, RMSF, RG, and Buried SASA.

3. Results

3.1. Active components and their corresponding target sites

A total of 196 active ingredients were identified, among which 9 were common components. Target prediction identified 1,096 corresponding targets. Through intersection analysis across four databases, 244 disease-related targets and 73 shared targets with drug targets were obtained (**Figure 1**).

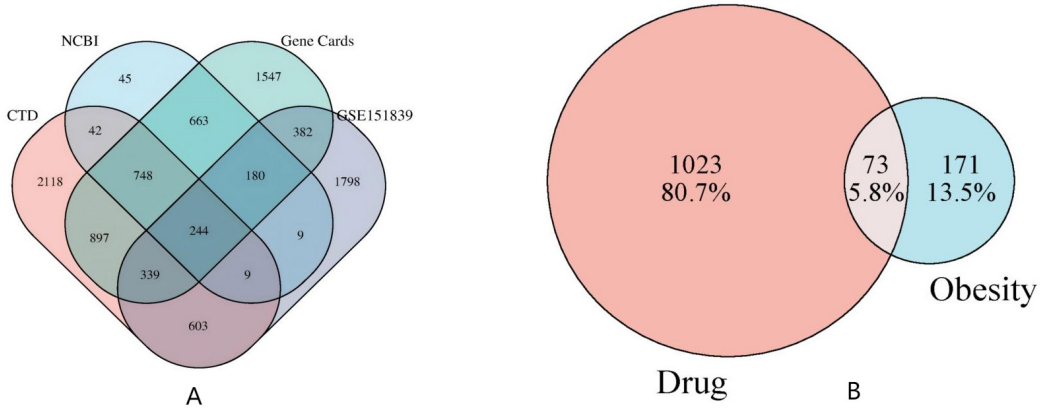


Figure 1. Venn diagram of disease targets (A) and venn diagram of drug active ingredient targets and disease targets (B).

3.2. Construction of a "Drug–Active Ingredient–Target" network

The "Drug-Active Ingredient-Target" network comprises 474 nodes and 475 edges (**Figure 2**). The PPI network (154 nodes, 1,387 edges) (**Figure 3**) was filtered using the Degree criterion, retaining 13 nodes, 66 edges, and 13 key targets ranked by Degree value (**Figure 4**).

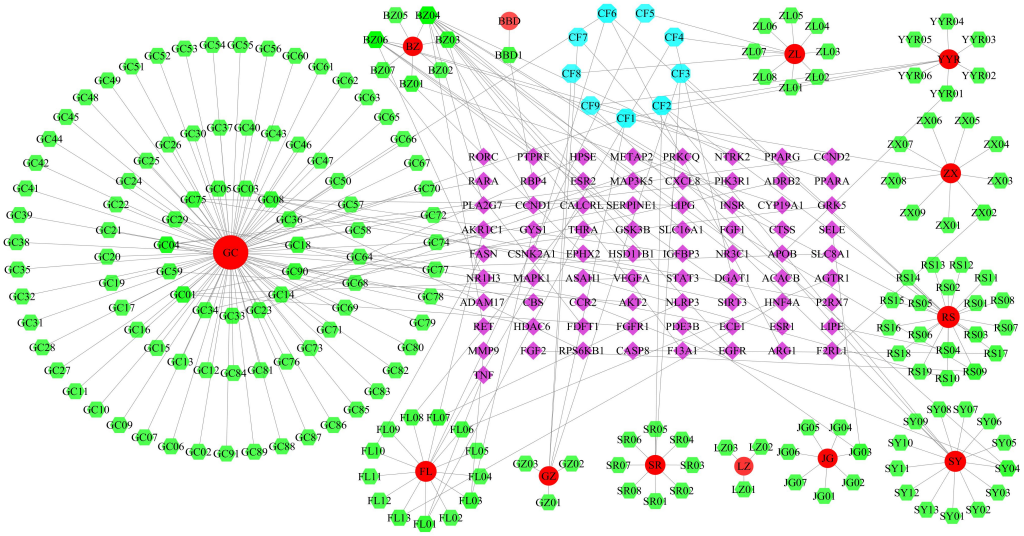


Figure 2. Network diagram of the modified Shenling Baizhu Powder as a traditional Chinese medicine formulation for obesity intervention (the purple circle in the center represents targets corresponding to active ingredients; the outer green circles denote individual active ingredients; the red circles indicate drug components; and the blue circles represent shared active ingredients among the drugs).

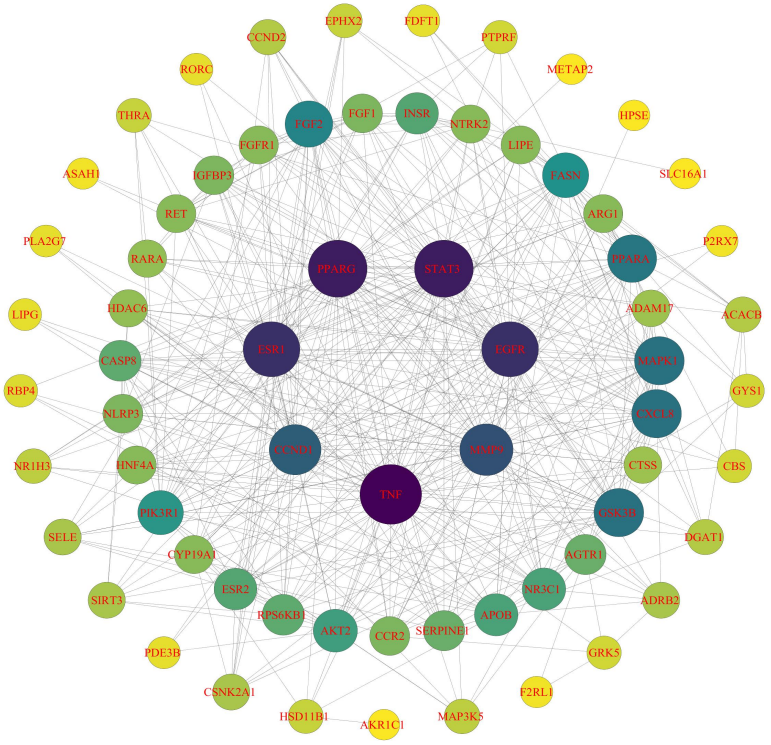


Figure 3. Modified Shenling Baizhu Powder for intervening in obesity: PPI network diagram.

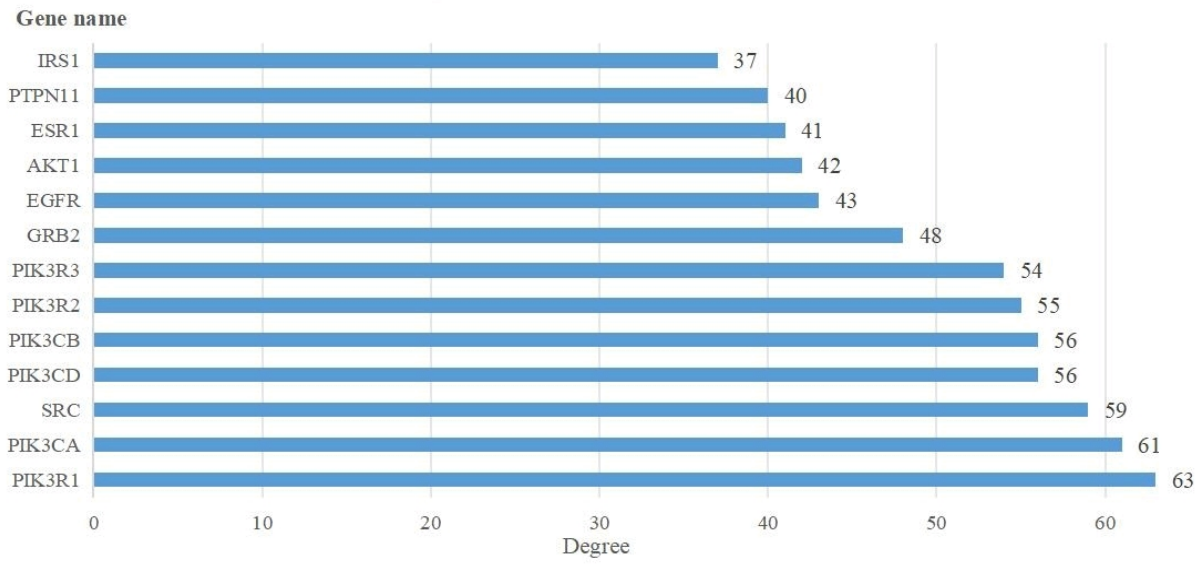


Figure 4. Bar chart of 13 key target genes.

3.3. Enrichment analysis

The GO analysis identified 3,703 pathways (primarily involving lipid metabolism regulation, cellular responses to hormonal stimuli, and growth regulation), 299 CC pathways (including membrane rafts, early endosomes, and vacuolar cavities), and 627 MF pathways (covering nuclear receptor activity, ligand-mediated regulation of transcription factor activity, and transcription factor binding). KEGG enrichment revealed 237 biological pathways, with the top 17 primarily related to insulin resistance, lipid metabolism and atherosclerosis, and the insulin signaling pathway (**Figure 5** and **Figure 6**).

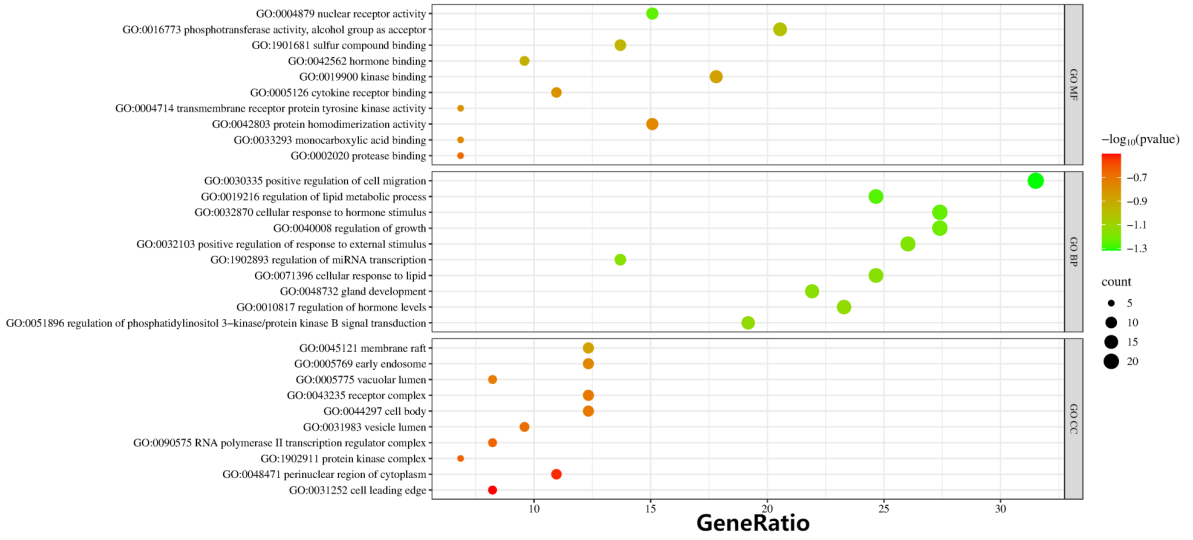


Figure 5. GO MF, GO BP, GO CC bubble charts.

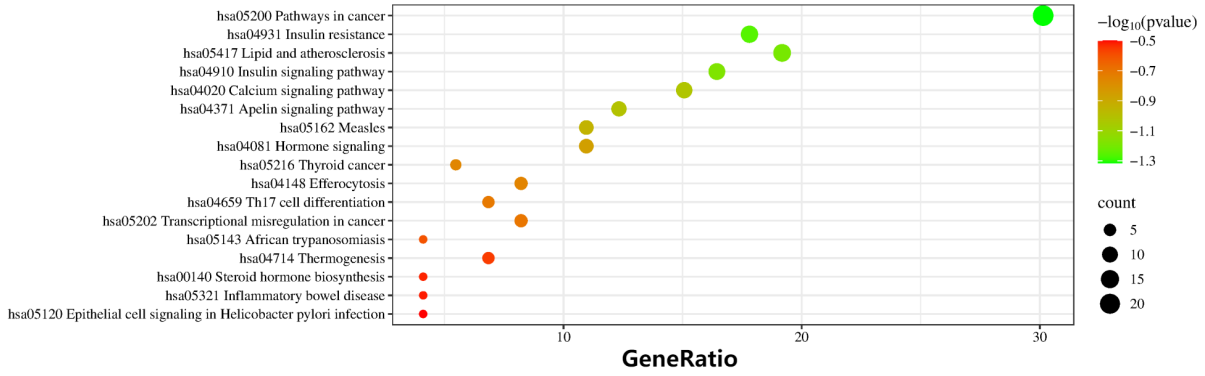


Figure 6. KEGG bubble charts.

3.4. Molecular docking validation results

Three targets (PIK3R1, PIK3CA, and SRC) were docked with 196 compounds, all exhibiting binding energies ≤ -4.514 kcal/mol. The complexes with the lowest binding energies were: PIK3R1 with ent-Epicatechin (-5.708 kcal/mol, forming 4 hydrogen bonds); PIK3CA with licorice glycoside E (-7.124 kcal/mol, forming 7 hydrogen bonds); and SRC with dehydroglyasperins C (-6.166 kcal/mol, forming 3 hydrogen bonds and 1 Pi–Pi bond). The top 15 compounds by binding energy are listed in **Figure 7**–**9**.

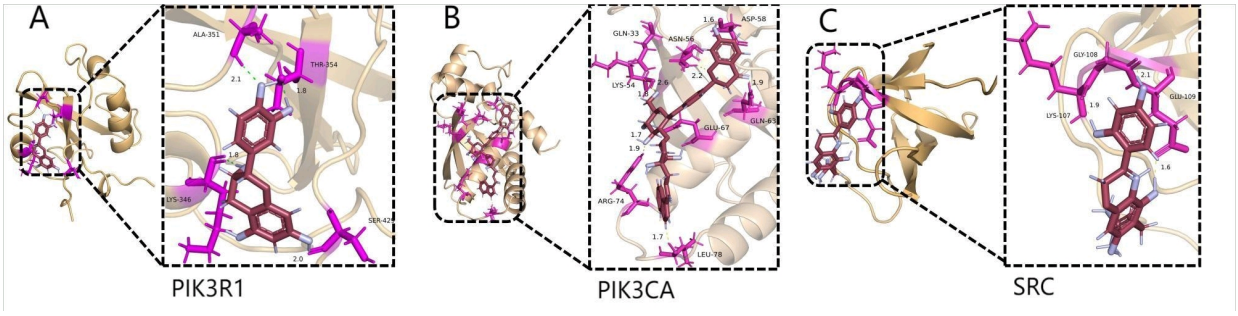


Figure 7. The molecular docking results are displayed in 3D
(A:PIK3R1 with ent-Epicatechin, B:PIK3CA with licorice glycoside E, C:SRC with dehydroglyasperins C).

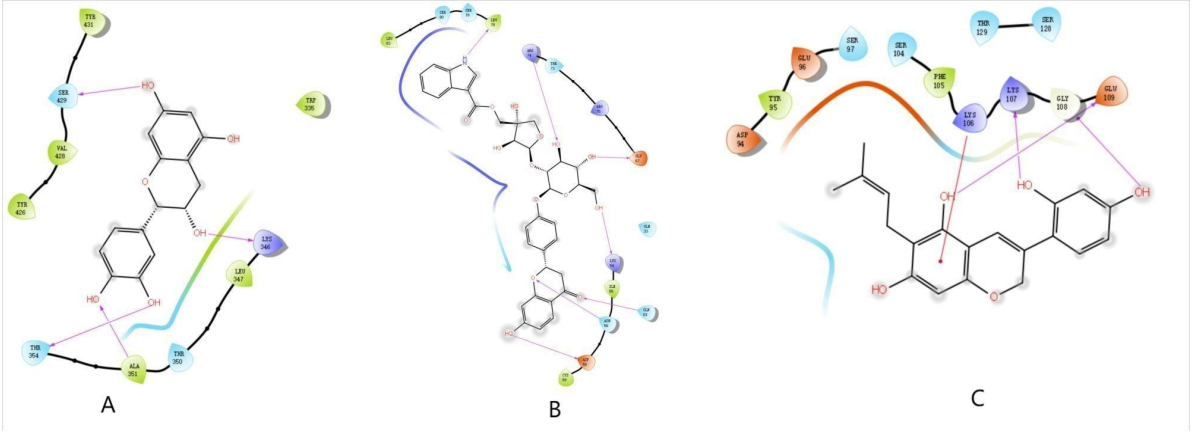


Figure 8. The three results with the lowest molecular docking binding energy
Vimentin: Purple arrows indicate hydrogen bonds; red line segments represent Pi-Cat bonds; and green curves represent Pi-Pi bonds.



Figure 9. Thermal map of molecular docking and binding energy.

3.5. Molecular dynamics simulations

During the 100 ns simulation, the RMSD of the PIK3CA complex stabilized after 15 ns at an average value of 0.4076 nm; that of the PIK3R1 complex was 0.2400 nm on average, and that of the SRC complex was 0.2359 nm. RMSF analysis revealed relatively stable residue fluctuations in the PIK3CA complex, with residues such as LYS-54, ASN-56, and GLN-63 exhibiting relatively active states. Both RG and Buried SASA analyses indicated a more compact structure and tighter binding in the PIK3CA complex (**Figure 10–13**).

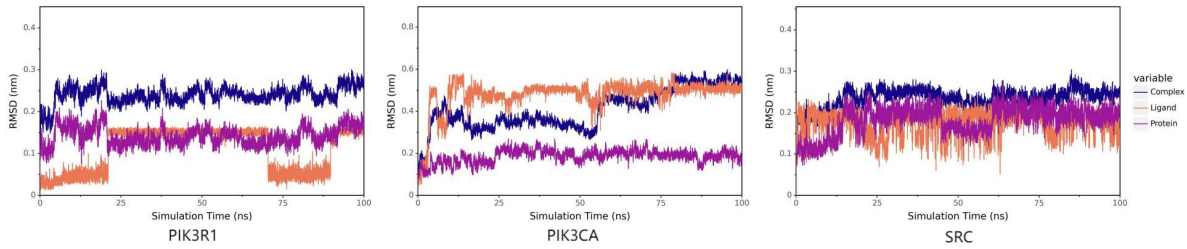


Figure 10. RMSD analysis of complex systems.

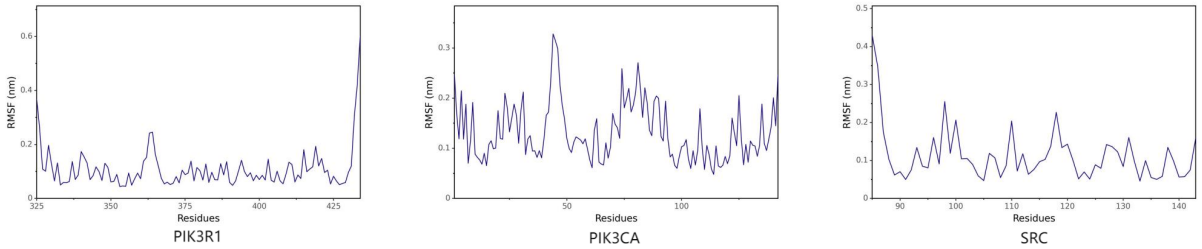


Figure 11. RMSF analysis of complex systems.

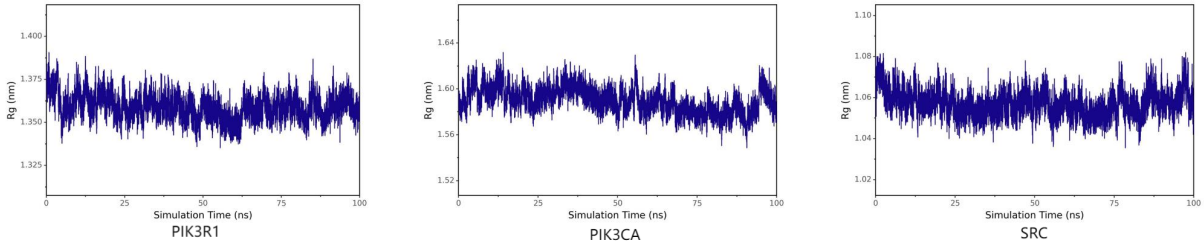


Figure 12. RG analysis of complex systems.

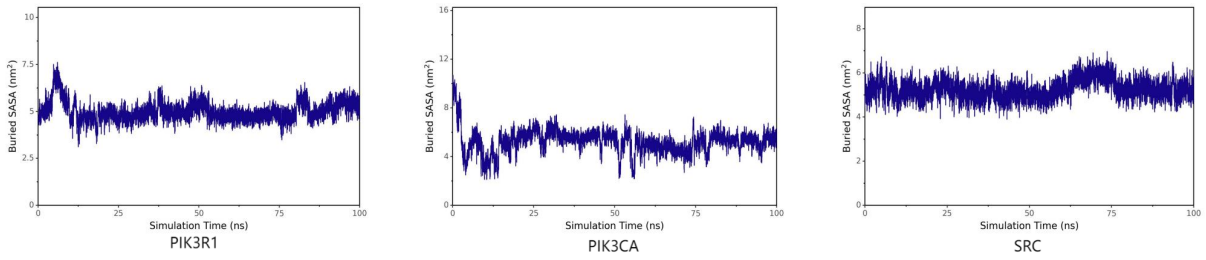


Figure 13. SASA analysis of complex systems.

4. Discussion

Obesity is closely associated with type 2 diabetes mellitus, hypertension, coronary heart disease, and other conditions. Data from the World Health Organization (WHO) indicate that the global prevalence rate continues to rise [13]. Traditional Chinese Medicine holds that the pathogenesis of obesity involves spleen deficiency leading to impaired transportation, internal obstruction by phlegm-dampness, and stagnation in the middle energizer [14]. Shenling Baizhu Powder is derived from the "Taiping Huimin Heji Jufang" and consists of ginseng, *poria cocos*, white *atractylodes rhizome*, hyacinth bean, Chinese yam, licorice root, lotus seed, *amomum villosum*, coix seed, and platycodon root [15]. It strengthens the spleen and replenishes Qi, while eliminating dampness to relieve diarrhea. The formula is supplemented with *Alisma plantago-aquatica* and *Polyporus umbellatus* to promote diuresis and resolve dampness, and Cinnamon Twig (*Cinnamomum cassia*) to warm yang and transform Qi, collectively achieving the therapeutic effect of "strengthening earth to generate metal [14,15]".

Pharmacological analysis revealed that the active components of the modified Shenling Baizhu Powder for treating obesity include Dehydroglyasperin C, glycyroside, Licoisoflavone B, among others. These core active constituents primarily derive from *Atractylodes macrocephala*, *Cinnamomum cassia*, and *Glycyrrhiza uralensis*, highlighting their significance. Existing studies have demonstrated that Glycyrrhiza extract exhibits potent inhibitory effects on subcutaneous fat in sheep and significantly downregulates enzyme activity in lipid synthesis pathways [16]. Clinically, the development of obesity is attributed to multiple factors; therefore, it is recommended to tailor treatment regimens based on fundamental theories of Traditional Chinese Medicine and combine them with other herbal medicines to enhance efficacy and reduce side effects, thereby maximizing the therapeutic potential of *Atractylodes macrocephala*, Cinnamon Twig Branch, and Licorice Root rather than using them alone. Dehydroglyasperin C, as an isoflavone, exhibits antioxidant, neuroprotective, cancer chemopreventive, and anti-inflammatory properties, and serves as an effective inducer of both NAD(P)H: oxidoreductase (NQO1) and phase 2 enzymes. Within adipocytes, Dehydroglyasperin C enhances NQO1 activity, mitigating oxidative stress responses and inflammatory damage in adipocytes [17,18]. Furthermore, studies have reported that isoflavones can improve insulin sensitivity, lipid levels, and fat metabolism, primarily by regulating four signaling pathways: miRNAs, AMPK, MCE, and neuroregulation [19]. As a flavonoid component of licorice, glycyroside exhibits antibacterial, anti-inflammatory, antioxidant, and anti-atherosclerotic effects. Existing studies have demonstrated that glycyroside significantly reduces body weight in obese rats, suppresses insulin resistance, and attenuates oxidative stress responses induced by obesity [20]. Among the key targets, PIK3 serves as a core component of the PI3K-Akt signaling pathway. It is primarily composed of two subunits: p110 and p85, with PIK3CA encoding the catalytic subunit p110α

and PIK3R1 encoding the regulatory subunit p85α. As a critical downstream effector of the insulin receptor, PIK3 facilitates the translocation of the glucose transporter GLUT4 to the cell membrane; proper functioning of this pathway is essential for maintaining systemic insulin sensitivity. Studies have shown that while mutations in the PIK3R1 gene still enable stable p110 subunit formation, they impair its ability to inhibit p110 enzyme activity, thereby enhancing PI3K activity and promoting cellular malignant transformation [21]. As the catalytic subunit of PIK3, dysfunction of PIK3CA leads to inhibition of the PIK3/AKT signaling pathway, resulting in disturbances in lipid and glucose metabolism [22]. As a coactivator of the P160 family and a key regulatory factor in maintaining systemic energy homeostasis, SRC regulates the expression of numerous critical metabolic enzymes. There are three main types of SRC: SRC-1 collaboratively activates CEBPα, promoting transcription of key enzymes in the gluconeogenesis pathway; SRC-2 not only enhances insulin sensitivity, stimulates fat breakdown, and reduces fat uptake, but also activates NR1H4 to promote ABCB11 expression, thereby maintaining systemic energy homeostasis; SRC-3 is involved not only in white adipocyte regulation but also in modulating SLC25A20 expression [23]. This indicates that PIK3R1, PIK3CA, and SRC are all closely associated with the onset and progression of obesity.

It is worth noting that numerous research reports have consistently demonstrated the importance of drug compatibility, as exemplified by Hu Fang et al.' studies have shown that "licorice" can be combined with "angelica" and "white peony root" to promote Qi circulation, activate blood flow, and resolve stasis; "white atractylodes" possesses the effects of strengthening the spleen, replenishing Qi, drying dampness, and promoting diuresis; it can also be paired with "poria" and "alisma" to enhance spleen function, eliminate dampness, and facilitate urination [24]. This is consistent with the pathogenesis of obesity characterized by "deficiency at the root and excess at the surface [24,25] ". This approach can effectively target obesity. Additionally, both *Poria cocos* and *Polyporus umbellatus* contain the common active component cerevisterol. Studies have demonstrated that *Poria cocos* and *Polyporus umbellatus* can significantly improve obesity in rats [26]. The ginsenoside Rc present in ginseng can upregulate SIRT6 expression, inhibit H3K9ac and H3K56ac acetylation, and enhance the activity of AMPK, PGC-1α, and PPARα, thereby ameliorating dyslipidemia [27].

The study identified that the target genes affected by the active components of modified Shenling Baizhu Powder align with those previously reported as associated with obesity development, demonstrating its multi-target and multi-pathway therapeutic mechanism. Analysis of the protein-protein interaction (PPI) network revealed that all 13 selected key target genes participate in these metabolic pathways. Molecular docking results confirmed strong binding affinities between all active components of the formula and the top three core target genes. To validate network pharmacological findings, molecular docking and molecular dynamics simulations were conducted to assess binding stability between core components and targets. The top three complexes based on binding affinity exhibited optimal stability and structural integrity, particularly the complex formed between PIK3CA and licorice glycoside E, which showed the highest binding affinity and compact structure as evidenced by RMSD, RMSF, RG, and SASA analyses. Comprehensive validation using multiple methodologies demonstrated consistent findings across both static and dynamic molecular levels, confirming that the active components of modified Shenling Baizhu Powder play a pivotal role in obesity intervention. The potential mechanisms of Shenling Baizhu Powder with modified formula in treating obesity.

5. Conclusion

Network pharmacology and molecular dynamics analyses revealed that Modified Shenling Baizhu Powder treats obesity through multi-component, multi-target, and multi-pathway mechanisms. Ent-Epicatechin, licorice glycoside E, and dehydroglyasperin C were identified as core active components, acting primarily on PIK3R1, PIK3CA, and SRC. These targets are mainly enriched in insulin resistance, lipid metabolism, and the PI3K-Akt signaling pathway. Molecular docking and dynamics simulations confirmed stable binding, particularly between PIK3CA and licorice glycoside E. These findings provide a theoretical foundation for the clinical application of Modified Shenling Baizhu Powder in obesity treatment.

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Disclosure statement

The authors declare no conflict of interest.

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Research on Refined Cost Control and Operational Optimization Pathways in Intensive Care Units under DIP Payment Reform

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Abstract: With the comprehensive implementation of regional global budget combined with disease-based score settlement (DIP) medical insurance payment reform across medical institutions nationwide, intensive care units (ICUs) are facing all-dimensional structural adjustments in revenue composition, expenditure control, and daily operational models. Based on a review of industry literature, field research in frontline departments, and comprehensive analysis of real operational cases from ICUs in multiple hospitals, this paper systematically deconstructs the operational pressures and management challenges that the DIP payment mechanism imposes on intensive care departments. Incorporating the inherent characteristics of critical care departments—including high resource consumption for critically ill patients, pronounced individual variation in disease conditions, and complex comorbidities—this study constructs a set of actionable refined cost control schemes and long-term operational optimization implementation pathways. The research findings demonstrate that standardizing clinical medication practices throughout the full treatment cycle, establishing a full-process management system for consumables covering procurement, storage, and utilization, and enhancing the utilization efficiency of large-scale monitoring and life-support medical equipment can directly reduce ineffective medical expenditures in the department. Simultaneously, implementing dynamic staffing allocation mechanisms for medical and nursing personnel, shortening average length of stay, and establishing a normalized multidisciplinary collaborative diagnosis and treatment platform can achieve the dual objectives of improving medical service quality and enhancing departmental operating efficiency. The practical management schemes compiled in this paper can provide referable practical evidence for intensive care departments at all levels of hospitals to adapt to DIP medical insurance settlement rules, balance cost control with medical safety, and achieve sustainable high-quality operations.

Keywords: DIP payment reform; Intensive care unit; Refined cost control; Departmental operations; Medical quality and safety

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1. Introduction

1.1. Background of DIP payment reform implementation

DIP, which stands for regional point-based global budget combined with disease-based score payment,

is a core reform initiative for refined management and control of medical insurance funds and optimization of regional medical resource allocation in China. This payment model standardizes and categorizes patients' principal diagnoses and clinical procedures into groups, employs fuzzy mathematical models to calculate scores corresponding to different disease combinations, and completes unified settlement based on the annual global budget of medical insurance pooling, thereby institutionally constraining unreasonable medical behaviors such as excessive examinations, excessive medication, and misuse of consumables by medical institutions [1]. In 2020, the National Healthcare Security Administration issued pilot implementation documents, and 71 cities nationwide took the lead in launching pilot programs. After years of tiered promotion, DIP payment has now covered the vast majority of public general hospitals and specialized hospitals in China, compelling medical institutions to abandon the previous extensive operational model of "fee-for-service" and shift toward full-process cost accounting and lean management at the disease-specific level.

1.2. Unique operational challenges of intensive care units

Intensive care units undertake the centralized treatment of all types of acute and critical patients throughout the hospital, with overall operating costs significantly higher than those of general internal medicine and surgical clinical departments, and they face long-term heavy operational pressure. First, the diagnosis and treatment of critically ill patients throughout the entire process require large quantities of special anti-infective drugs, disposable high-value interventional consumables, ventilators, CRRT and other life-support equipment, with substantial baseline expenditures on various consumables, equipment depreciation, and pharmaceuticals, making daily management and control significantly more difficult. Second, critically ill patients experience rapid changes in condition, with high incidence of multiple comorbidities and complications, creating substantial resistance to the implementation of standardized clinical pathways and making it extremely easy for single-case medical costs to exceed medical insurance score compensation standards. Industry practice data from the previous DRG payment phase show that most hospital ICUs have long been in a state of medical insurance settlement losses due to excessively high per-case resource consumption, which not only compresses development funds for departmental talent cultivation and equipment renewal but also aggravates the overall financial operational burden of hospitals [2].

1.3. Research objectives and practical value

This paper takes the new DIP payment regulations as its research foundation, conducts systematic analysis targeting the operational pain points of intensive care departments, and systematically examines the profound transformations that medical insurance payment reform brings to departmental revenue-expenditure structures and daily management models, along with supporting tiered implementation cost control measures and long-term operational optimization strategies. The research aims to address the practical problems commonly existing in current ICUs, including cost overruns, resource waste, imbalanced manpower allocation, and poor interdepartmental collaboration. Under the premise of safeguarding the bottom line of medical safety, it seeks to balance cost control with treatment quality, providing a complete and actionable management scheme for hospital intensive care departments to adapt to the DIP settlement system and achieve quality improvement and efficiency enhancement.

2. Literature review

2.1. Theoretical foundations of DIP payment

Disease-based score payment (DIP), as a novel medical insurance settlement tool, has as its core logic the achievement of balanced allocation of medical resources and curbing unreasonable loss of medical insurance funds through standardized disease grouping. The theoretical foundation of this system originates from the practical needs of domestic medical insurance payment reform, while simultaneously accommodating two core objectives: stability of medical service quality and efficiency of fund utilization. The DIP mechanism, through unified standardized assessment of diagnosis and treatment behaviors for different diseases, assigns corresponding score weights, directly linking medical insurance fund disbursement with disease complexity and diagnostic resource consumption, thereby compelling hospitals to establish internal disease-specific cost accounting systems and promoting standardized transformation of in-hospital diagnostic and treatment processes. At the same time, DIP reform closely aligns with the overall direction of China's healthcare system reform, possessing irreplaceable institutional value in enhancing the efficiency of medical insurance fund utilization and reducing the economic burden of medical treatment for ordinary patients [3].

2.2. Existing research on ICU costs and operations

Existing academic achievements both domestically and internationally discuss ICU cost composition and departmental operational models from multiple dimensions. Established research generally confirms that high operating expenditures in intensive care departments primarily originate from three major categories: high-priced anti-infective drugs, disposable interventional consumables, and depreciation and maintenance of large-scale monitoring equipment, with the management level of these items directly determining the annual operating profit or loss of the department. Some scholars, drawing on previous DRG payment implementation experience, analyze the contradictions existing in ICUs regarding the balance between cost control and medical quality, and propose improvement approaches such as retrospective review of loss-making cases and optimization of diagnostic and treatment plans [4]. However, existing research still has notable shortcomings: most literature focuses on cost management approaches under traditional fee-for-service and DRG payment models, while systematic research targeting ICU revenue-expenditure changes and management adaptation schemes under the DIP score settlement system is relatively scarce, lacking practical research on refined departmental operations that aligns with DIP rules.

2.3. Insights from existing research

A review of existing literature yields two core research insights: First, the implementation of DIP payment brings entirely new opportunities for cost control and operational model upgrading in intensive care departments, while also imposing strict cost constraint requirements, with disease-specific cost accounting and diagnostic efficiency improvement being the core improvement directions for departmental transformation. Second, existing research achievements related to ICU cost control possess foundational reference value, but there exists a research gap in specialized management schemes adapted to DIP settlement rules, necessitating empirical analysis based on real operational data from frontline departments to fill this practical research gap. Based on this, this paper takes the DIP payment system as its core thread, combines the unique diagnostic and treatment attributes of intensive care departments, and explores new models of cost control and refined operations adapted to ICUs, contributing to the enhancement of overall hospital operational efficiency.

3. Multidimensional impact analysis of DIP payment on intensive care units

3.1. Changes to departmental revenue structure

After the implementation of DIP payment, the revenue sources and composition of intensive care departments have undergone fundamental adjustments, with the overall departmental revenue level directly tied to disease grouping scores and the matching degree of admitted cases. Under the traditional fee-for-service model, ICU revenue primarily relied on high-value consumable usage fees, high-priced drugs, and complex invasive procedure service charges. However, DIP adopts an annual global budget plus disease-based score settlement mechanism, whereby medical insurance fund disbursement no longer separately accounts for individual medical service charges, substantially reducing the contribution proportion of consumables and drugs to total departmental revenue. Clinical operational data show that disease score levels directly determine departmental operating returns, primarily manifested in two aspects: First, critically ill cases with extremely high resource consumption have diagnostic and treatment input costs exceeding the medical insurance compensation amount corresponding to the disease score, directly resulting in per-case losses. Second, cases of low-risk mild conditions transferred into the ICU have score compensation higher than actual diagnostic and treatment consumption, possessing certain operating profit margins. This requires intensive care departments, under the premise of ensuring treatment safety, to precisely analyze the profitability and loss situations of various diseases, proactively adjust diagnostic and treatment plans to optimize revenue structure, and adapt to DIP settlement rules to achieve long-term stable operations.

3.2. Deep impact on departmental cost structure

The DIP payment mechanism comprehensively constrains departmental expenditures, exerting significant management and control pressure on the three core cost sectors of drugs, consumables, and manpower. First, pharmaceutical expenditure, as the largest cost item in ICUs, is strictly limited under score settlement rules. Departments must prioritize cost-effectiveness in drug selection, strictly control the frequency and duration of use of high-grade antibiotics without indications and high-priced adjuvant drugs, and reduce ineffective pharmaceutical expenditures. Second, high-value disposable consumables represent another major expenditure in ICUs. The use of catheters, interventional consumables, and monitoring accessory consumables is no longer unrestricted. With disease scores imposing cost ceiling constraints, departments must restructure consumable procurement and usage processes to eliminate waste and excessive use. Third, pressure for manpower cost control increases simultaneously. Medical and nursing staff scheduling and position allocation must match disease admission volumes to avoid idle manpower inflating per-case labor costs. Overall, DIP payment compels departments to conduct all-dimensional refined cost accounting, transforming the previous extensive resource deployment model [5].

3.3. Reshaping of traditional operational management models

DIP payment fundamentally disrupts the original extensive operational management system of ICUs from two dimensions: resource allocation and performance assessment [6]. At the resource allocation level, the traditional management model took patient treatment needs as the sole orientation, prioritizing the supply of materials and equipment to critically ill patients. However, under DIP global budget constraints, when allocating medical equipment, drugs, and manpower, departments must simultaneously consider diagnostic efficiency and cost-effectiveness, dynamically allocating resources according to differences in resource consumption across diseases, driving departments to shift from “demand-oriented” to “efficiency-balanced”

refined management. At the performance assessment level, traditional departmental assessment indicators focused on workload metrics such as admission volume, nursing procedure volume, and diagnostic completion rate. After DIP reform, departmental performance assessment adds efficiency-type indicators including disease cost control, proportion of profitable versus loss-making cases, and average length of stay, with cost control effectiveness directly linked to medical and nursing performance. In summary, DIP payment drives comprehensive upgrading of intensive care departmental operational management through bidirectional promotion from resource allocation and assessment systems.

4. Actionable cost control measures for intensive care units under DIP payment

4.1. Standardizing rational drug use throughout the full clinical process

Intensive care departments utilize a complex variety of drugs with large single-day dosages and high proportions of total pharmaceutical costs, making medication rationality directly determinative of departmental medical insurance settlement profitability. Currently, common clinical problems include misuse of adjuvant drugs, escalated use of antibiotics, and excessively prolonged medication courses, which not only elevate patients' medical economic burden but also cause medical insurance score overrun losses. To address these issues, departments need to establish tiered medication protocols based on standardized clinical pathways combined with DIP disease-specific cost ceilings. For anti-infective treatment, priority should be given to first-line antibiotics with high cost-effectiveness within the medical insurance catalog, strictly limiting the indications and duration of use for special high-grade antibiotics. A dynamic departmental pharmaceutical monitoring ledger should be established, with monthly statistics on usage amounts and frequencies of various drugs, and special medication reviews conducted for drugs with abnormal usage or high unit prices to promptly correct irrational prescribing behaviors. Simultaneously, normalized specialized training on rational drug use should be conducted for medical and nursing staff to strengthen cost control awareness among all personnel and compress ineffective pharmaceutical expenditures from the clinical source.

4.2. Establishing a full lifecycle refined management system for consumables

Consumable management is the core lever for cost reduction in ICUs and must cover all stages of procurement, warehousing, and clinical use. Procurement stage: precise procurement plans should be formulated based on monthly departmental consumable usage to avoid large-scale stockpiling that ties up working capital; centralized collective price negotiation with consumable suppliers should be conducted to reduce unit procurement prices through bulk purchasing. Warehousing stage: a consumables information management system should be deployed to monitor inventory quantities and expiration dates in real time, regularly clearing near-expiry consumables to eliminate capital losses from expired disposal. Clinical use stage: a dual-person verification and full-process registration system for high-value consumables should be established, with each interventional and monitoring consumable necessarily matched to corresponding patient diagnostic and treatment records, standardizing operational procedures to reduce human-induced losses; regular practical training on standardized consumable use should be organized for nurses and resident physicians to reduce consumable losses caused by improper operation [7].

4.3. Enhancing comprehensive utilization efficiency of advanced medical equipment

Intensive care departments are equipped with large quantities of high-priced specialized equipment such

as ventilators, blood purification machines, and extracorporeal life support devices, with high costs for procurement, annual maintenance, and depreciation allocation, where equipment idleness substantially inflates per-case fixed costs. Improving equipment utilization can be implemented from two aspects: First, establish an intra-hospital cross-departmental equipment sharing and scheduling mechanism, whereby idle high-end monitoring and therapeutic equipment in the ICU can be reserved for use by operating rooms, emergency departments, and general surgery to share depreciation costs. Second, formulate regular equipment maintenance plans, conducting monthly equipment inspection and upkeep to reduce downtime and ensure equipment is always ready for clinical use. Simultaneously, departments should predict critical patient flow across different seasons based on historical admission data, rationally plan new equipment procurement to eliminate long-term idleness of blindly purchased equipment, and reduce fixed cost waste.

5. Long-term operational optimization strategies for intensive care units under DIP payment

5.1. Dynamically optimizing medical and nursing human resource allocation

DIP payment requires departmental manpower allocation to balance treatment quality and labor cost control. ICU critically ill patients experience significant fluctuations in condition, with obvious peak-valley differences in manpower demand, and fixed scheduling patterns easily result in insufficient manpower during peaks and idle personnel during valleys. Departments can establish a dynamic manpower allocation system: calculate medical-nursing ratio standards based on monthly DIP disease admission volumes and critical patient proportions; activate mobile nursing staff and in-hospital specialist nurse support during critical peak periods; and rationally arrange rotation rest and training when patient flow declines to reduce idle labor costs. Simultaneously, optimize the medical and nursing position structure, increase the proportion of critical care specialist nurses, rationally delineate physician and nurse responsibilities, and balance workload across positions. A performance distribution scheme aligned with DIP management objectives should be implemented, incorporating cost control effectiveness and disease profitability into medical and nursing performance calculations to mobilize proactive cost control enthusiasm among all staff [8].

5.2. Optimizing diagnostic and treatment processes to shorten average length of stay

Patient average length of stay directly affects bed turnover efficiency and overall departmental costs, with prolonged hospitalization simultaneously elevating pharmaceutical, consumable, and equipment depreciation expenditures, making DIP disease cost overruns highly likely. Core measures for shortening average length of stay are divided into two points: First, implement standardized DIP-adapted clinical pathways, unifying examination, medication, and treatment processes for critically ill patients, and eliminating valueless repetitive tests and unnecessary adjuvant therapeutic items [9]. Second, routinely conduct multidisciplinary joint diagnosis and treatment, with early organization of consultations from surgery, nephrology, respiratory, laboratory and other departments for critically ill patients with multiple comorbidities to rapidly clarify diagnostic and treatment plans and shorten diagnostic waiting periods. A supporting diagnostic information platform should be deployed to track each patient's hospitalization duration and cost consumption progress in real time, with early intervention for cases approaching threshold values, and early initiation of rehabilitation and transfer assessment under safety assurance to improve bed turnover efficiency.

5.3. Building a normalized multidisciplinary collaborative diagnosis and treatment mechanism

Critically ill patients mostly present with multiple organ damage and multiple underlying diseases, making it difficult for a single ICU department to independently complete comprehensive diagnosis and treatment, and insufficient multidisciplinary collaboration prolongs treatment cycles and increases ineffective medical expenditures. Strengthening disciplinary collaboration possesses dual value: On one hand, establishing rapid green channels with laboratory and imaging departments ensures priority issuance of critical examination reports, shortening diagnostic waiting time and reducing hospitalization consumption. On the other hand, linking with surgery, cardiovascular, neurology and other clinical departments for early intervention treatment, formulating integrated diagnosis and treatment plans to avoid duplicate examinations and duplicate medication from segmented treatment. Departments can conduct fixed weekly multidisciplinary critical care consultations, utilizing electronic medical record systems to open up hospital-wide patient data sharing channels, with all departments synchronizing patient diagnostic and treatment progress in real time, reducing communication costs, and lowering overall diagnostic and treatment expenses while improving treatment efficiency.

6. Practical challenges in implementation and countermeasures

6.1. Insufficient in-hospital information system adaptation

Currently, most hospitals' existing HIS and LIS systems only meet basic billing and medical record requirements, making it difficult to adapt to DIP payment's refined management requirements for real-time disease score calculation, automatic disease cost accounting, and cost control data early warning, with data lag and inconsistent statistical calibers constraining cost control implementation. Countermeasures: Hospitals should uniformly upgrade and transform in-hospital information architecture, establish a DIP-specific data management module to achieve real-time disease score calculation and dynamic per-case cost early warning; introduce big data analysis tools to automatically aggregate departmental drug, consumable, and hospitalization duration data, and automatically screen cost-overrun cases for departmental review; adopt modular system design so that subsequent medical insurance policy adjustments require only partial updates without overall reconstruction, reducing long-term transformation costs; assign dedicated information department personnel to interface with the ICU, regularly maintaining the system and optimizing data statistical functions to ensure real-time accuracy of cost control data [10].

6.2. Policy adaptation difficulties among medical and nursing staff

DIP payment involves entirely new management requirements including disease score calculation, disease cost control, and clinical pathway constraints. Most medical and nursing staff have long been accustomed to traditional diagnostic and treatment models, with insufficient understanding of cost control rules and medical insurance settlement logic, and problems of resistance and non-standard operations existing at the clinical implementation level. Countermeasures: Conduct tiered, normalized specialized training. For department directors and head nurses, conduct in-depth DIP policy interpretation training explaining disease profitability accounting and core departmental cost control indicators; for frontline physicians and nurses, conduct case-based practical training, using departmental loss-making case reviews to explain settlement losses caused by irrational diagnostic and treatment behaviors; regularly organize internal departmental cost control case discussions, sharing practical methods for compliant cost control while ensuring treatment efficacy, gradually

transforming the ingrained mindset of prioritizing treatment over cost among medical and nursing staff.

6.3. Multidisciplinary collaboration communication barriers

DIP implementation involves coordination among multiple departments including medical affairs, nursing, finance, information, equipment, pharmacy, and procurement. Differences in work objectives and assessment indicators across departments easily lead to communication disconnection and lagging implementation of control measures. Countermeasures: Establish a hospital-level DIP special working group led by the medical affairs department, with designated personnel from finance, information, ICU, pharmacy, and equipment departments participating, clarifying departmental responsibilities and collaboration processes; hold monthly cross-departmental joint meetings to collectively address bottlenecks in ICU cost control, data statistics, and equipment and consumable procurement, and uniformly formulate solutions; establish an online collaborative communication ledger to synchronize problem rectification progress in real time, break through departmental communication barriers, and ensure synchronized implementation of all cost control and operational measures [11].

7. Conclusion

7.1. Summary of core research findings

Through systematic analysis of the multidimensional impact of DIP payment on intensive care department revenue-expenditure and operational models, this paper provides a complete set of cost control and operational optimization schemes. The research confirms that through three core measures—standardizing clinical medication, full-cycle consumable management, and revitalizing large-scale medical equipment utilization efficiency—departmental unnecessary medical expenditures can be effectively reduced, achieving refined cost savings. Simultaneously implementing dynamic manpower allocation, optimizing diagnostic and treatment processes to shorten length of stay, and establishing a multidisciplinary collaborative diagnosis and treatment system can simultaneously improve medical service efficiency and departmental operating returns. The entire set of management measures aligns with ICU clinical reality, possesses strong operability, and can provide complete theoretical support and practical reference for refined operations of intensive care departments under the DIP payment environment [12].

7.2. Practical significance for hospital and departmental development

Intensive care units are the core carriers of a hospital's comprehensive acute and critical care treatment capacity. ICU cost control and operational level optimization can directly enhance the utilization efficiency of hospital-wide medical resources, improve overall medical insurance settlement performance, and strengthen long-term stable operating capacity. Simultaneously, standardized cost-controlled diagnostic and treatment models can reduce excessive medical treatment, lower patients' medical economic burden, balance hospital operating efficiency with public medical access satisfaction, and achieve a three-way equilibrium among medical quality, departmental efficiency, and patient satisfaction.

7.3. Research limitations and future research directions

This study primarily relies on existing medical insurance policies, industry literature, and departmental cases for analysis, lacking large-scale multicenter clinical operational data as empirical support, and the long-term quantitative effects of some management measures remain to be verified. Additionally, given the relatively

short time since DIP payment implementation nationwide, long-term policy impacts and ICU adaptation differences across hospitals of different levels have not yet fully manifested. Future related research can be deepened from three directions: First, collect long-term operational data from intensive care departments across multiple hospitals to empirically test the actual cost-reduction and efficiency-enhancement effects of the management measures in this paper. Second, conduct in-depth analysis of the dynamic equilibrium mechanism between ICU medical quality and cost control under long-term DIP payment operation. Third, explore innovative applications of digital and intelligent tools in ICU cost control to adapt to the management needs of continuous medical insurance policy updates and iterations.

Disclosure statement

The author declares no conflict of interest.

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Application Effect of Comprehensive Pelvic Floor Rehabilitation Therapy in Patients with Myofascial Pelvic Pain Syndrome

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Abstract: *Objective*: To explore the application effect of comprehensive pelvic floor rehabilitation therapy in patients with myofascial pelvic pain syndrome (MPPS). *Methods*: A total of 84 MPPS patients admitted to the pelvic floor rehabilitation clinic of Shaanxi Provincial People's Hospital from December 2023 to June 2025 were divided into an observation group and a control group, with 42 cases in each group. The control group received pelvic floor electrical stimulation, while the observation group received a 5-week, 15-session comprehensive pelvic floor rehabilitation program including myofascial manual release, diaphragmatic breathing training, electrical stimulation, biofeedback, magnetic stimulation and home Kegel training. The numerical rating scale (NRS) of pelvic floor pain and the dyspareunia scores were compared before treatment, at the end of treatment and one month after treatment; the Glazer surface electromyography (sEMG) parameters and the Nottingham Health Profile (NHP) scores were compared at the end of treatment; clinical efficacy was also evaluated. *Results*: At the end of treatment and at the one-month follow-up, the observation group showed significantly lower NAS scores, pre-/post-resting potentials and the coefficient of variation of pre-resting potential, and higher amplitudes of rapid, sustained and endurance contractions, together with lower NHP scores and dyspareunia scores, than the control group (all $p < 0.05$); the total effective rate was 92.3 % in the observation group versus 73.7% in the control group ($p < 0.05$). *Conclusion*: Comprehensive pelvic floor rehabilitation therapy can effectively relieve pelvic floor pain, reduce pelvic floor muscle hypertonicity and improve pelvic floor electrophysiological function and quality of life in MPPS patients, and is superior to electrical stimulation alone.

Keywords: Myofascial pelvic pain syndrome; Comprehensive rehabilitation; Physical therapy; Pelvic floor dysfunction; Nursing

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1. Introduction

Myofascial pelvic pain syndrome (MPPS) is a chronic pelvic pain caused by involuntary spasms, tension bands, and myofascial trigger points (MTrPs) of the pelvic floor muscles, including the piriformis, levator ani, iliopsoas, and obturator internus muscles. It manifests as pelvic floor muscle hypertonicity, myalgia,

overexertion, and fatigue, which worsens with prolonged sitting and may be accompanied by dyspareunia, urinary and defecation abnormalities [1,2]. Epidemiological data from abroad show that the prevalence of chronic pelvic pain in women is 5.7% to 26.6%, of which about 15% are related to myofascial pain [3]; the reported incidence of MPPS in postpartum and reproductive-age women in my country is 14% to 23% [4]. The etiology of this disease is complex, the clinical manifestations lack specificity, and the diagnosis and treatment involve multiple disciplines such as gynecology, urology, and rehabilitation. The disease awareness rate is low, and it is easy to misdiagnose or miss the diagnosis. It has become a common disease that endangers women's physical and mental health and quality of life [1,5].

Currently, the treatment of MPPS mainly includes medication, psychological intervention, physical therapy, and acupuncture. Among them, physical therapy is the most widely used due to its simple operation, non-invasiveness, and safety [6]. Commonly used physical therapy methods include myofascial manipulation, transcutaneous electrical nerve stimulation, pelvic floor muscle training, biofeedback, radiofrequency and magnetic stimulation, etc., but the effect of a single treatment method is limited [6–8]. The European Association of Urology (EAU) guidelines for chronic pelvic pain and related expert consensus recommend that myofascial pelvic pain should be treated with an individualized comprehensive plan that combines multiple methods with pelvic floor physical therapy as the core [3,9]. Based on clinical needs, the pelvic floor rehabilitation clinic of our hospital has integrated myofascial release, abdominal breathing training, electrical stimulation, biofeedback, magnetic stimulation, and home training to construct a set of comprehensive pelvic floor rehabilitation techniques. This study uses a randomized controlled trial design to evaluate the application effect of this comprehensive plan in MPPS patients, aiming to provide a basis for standardized nursing intervention for MPPS. The results are reported below.

2. Materials and methods

2.1. General information

The convenience sampling method was used to select MPPS patients who visited the pelvic floor rehabilitation clinic of the Department of Gynecology of Shaanxi Provincial People's Hospital from December 2023 to June 2025 as the research subjects. The diagnostic criteria were formulated with reference to "Myofascial Manipulation for Musculoskeletal Pain", and the main criteria were: regional pain; abnormal sensation in the expected distribution area of trigger point referred pain; palpable tension bands in the affected myofascia; severe punctate tenderness at a certain point of the tension band; and a certain degree of motor limitation [10].

2.1.1. Inclusion criteria

(1) Meeting the above diagnostic criteria;
(2) Chronic pelvic pain ≥ 6 months;
(3) Having a history of sexual activity and not receiving related treatment within 1 month before enrollment;
(4) Not participating in other clinical trials and being able to adhere to treatment and follow-up;
(5) Informed consent and signing of informed consent form.

2.1.2. Exclusion criteria

(1) Contraindications to electro- or magnetic-stimulation therapy (epilepsy, pacemaker implantation,

malignant tumors, presence of local metal implants, etc.);

(2) Pain caused by acute inflammation or tumors of the urinary, reproductive, or digestive systems;

(3) Mental illness or cognitive impairment;

(4) Comorbid severe heart, brain, liver, kidney, or vascular diseases.

This study was approved by the Ethics Committee of our hospital. Patients meeting the criteria were randomly assigned to an observation group and a control group using a random number table, with 42 patients in each group. During the study, 3 patients dropped out of the observation group (2 due to job transfer, 1 due to menstrual interruption) and 4 patients dropped out of the control group (2 due to travel difficulties, 2 lost to follow-up). Ultimately, 39 patients in the observation group and 38 patients in the control group completed the study. There were no statistically significant differences in age, disease duration, body mass index (BMI), education level, and type of medical insurance between the two groups ($p > 0.05$), indicating comparability (see **Table 1**).

Table 1. Comparison of general information between the two groups of patients

Project	**Observation group (n = 39)**	**Control group (n = 38)**	**Statistic**	***p*-value**
Age (years, $\bar{x} \pm s$)	38.6 ± 7.2	39.1 ± 7.5	$t = 0.297$	0.767
Disease course (months, $\bar{x} \pm s$)	14.8 ± 6.3	15.2 ± 6.7	$t = 0.268$	0.789
BMI (kg/m², $\bar{x} \pm s$)	22.9 ± 2.8	23.1 ± 2.6	$t = 0.322$	0.748
Educational level (e.g., college degree or above / high school or below)	26/13	24/14	$\chi^2 = 0.116$	0.733
Medical insurance type (e.g.) Employees/Residents and others	28/11	25/13	$\chi^2 = 0.302$	0.583

2.2. Methods

2.2.1. Control group

Pelvic floor electrical stimulation therapy was administered. The patient emptied her bladder and assumed a semi-recumbent position with the backrest at approximately 120°; the legs were naturally extended with the feet externally rotated by about 30°, and the entire body was relaxed. A lubricated vaginal electrode was inserted into the vagina, ensuring the metal electrode plates were positioned against the lateral vaginal walls, and connected to a neuromuscular stimulation device (PHENIX USB 4, France). Electrical stimulation was delivered at a frequency of 5–20 Hz and a current intensity of 0–100 mA; the intensity was adjusted from low to high, reaching the maximum level the patient could tolerate without discomfort. Each session lasted 20 minutes, with treatments administered three times a week; a full course consisted of 15 sessions over five weeks, with treatment paused during menstruation.

2.2.2. Observation group

Patients in the observation group received comprehensive pelvic floor rehabilitation therapy in addition to the control group's regimen. The treatment course spanned 5 weeks, comprising 15 sessions (3 sessions per week), with each session lasting approximately 40–50 minutes and conducted in specific stages:

(1) Week 1 (Sessions 1–3)

5 minutes of abdominal breathing for relaxation, with guidance to ensure patient cooperation; 2–3 minutes of myofascial manual therapy (applying lubricant and performing ischemic compression on pelvic

floor muscle trigger points via the vagina, moving from deep to superficial layers; each point was compressed for approximately 10 seconds with pressure adjusted to elicit slight pain); and magnetic stimulation therapy (sacral nerve S2–S4 modulation, with frequency increasing from 5 to 20 Hz based on patient tolerance).

(2) Week 2 (Sessions 4–6)

Pelvic floor electrical stimulation was added to the above regimen, using the same method as the control group.

(3) Weeks 3–4 (Sessions 7–12)

Biofeedback therapy was introduced, converting pelvic floor electromyographic signals into visual and auditory feedback; patients were guided in abdominal breathing, relaxation of the anal and perineal regions, and Kegel exercises using a template (20 minutes per session: 5 minutes of breathing relaxation followed by 15 minutes of template-guided training), alternating between 5–10 seconds of contraction and 10 seconds of relaxation in a progressive manner.

(4) Week 5 (Sessions 13–15)

Consolidation training and instruction on home-based Kegel exercises for post-discharge, requiring at least 120 repetitions daily, totaling over 30 minutes. The entire treatment process was administered by a single rehabilitation nurse who had undergone standardized training and certification, while a physician was responsible for medical management and clinical guidance.

2.3. Observation indicators and evaluation tools

(1) Numerical rating scale (NAS) for pelvic floor muscle pain

Pain intensity is assessed on a scale of 0 to 10, with 0 indicating no pain, 1–3 indicating mild pain, 4–6 indicating moderate pain, and 7–10 indicating severe pain. The higher the score, the more severe the pain. The assessment is conducted by the same nurse before treatment, at the end of treatment, and one month after the end of treatment.

(2) Glazer surface electromyography (sEMG) assessment of pelvic floor muscle

Detected using a biofeedback therapy device, the mean amplitude and coefficient of variation (CV) of the following measurements are recorded sequentially: 60 seconds before rest (relaxation function), 5 rapid contractions (fast-twitch muscle function), 5 consecutive 10-second sustained contractions (10 seconds of contraction followed by 10 seconds of relaxation) (slow-twitch muscle strength and coordination), 60-second endurance contraction (slow-twitch muscle endurance), and 60 seconds after rest (fatigue recovery ability).

(3) Nottingham Health Profile (NHP)

Used to evaluate health-related quality of life. Part 1 contains 38 items in 6 dimensions: physical activity, energy, pain, sleep, social connection, and emotional response. Each dimension has a score of 0 to 100. The higher the score, the more severe the health impairment. The scale has a Cronbach's α coefficient of 0.89 and a content validity index of 0.88 [11].

(4)Painful intercourse score

The painful intercourse diagnostic scale included in the Behavioral Medicine Scale Handbook was used for evaluation. The higher the score, the more severe the painful intercourse.

(5) Clinical efficacy

The NAS reduction rate was used for evaluation. The reduction rate = (pre-treatment score - post-treatment score) / pre-treatment score × 100%. A reduction rate of ≥ 75% is considered cured, 50% to <

75% is considered significantly effective, 25% to < 50% is considered effective, and < 25% is considered ineffective. The total effective rate = (number of cured + significantly effective + effective cases) / total number of cases × 100%.

2.4. Statistical methods

Data was entered using EpiData 3.4 with dual-user input and logical error checking. Statistical analysis was performed using SPSS 26.0 software. Normally distributed continuous data were expressed as mean ± standard deviation ($\overline{x} \pm s$), and independent samples *t*-tests were used for comparisons between two groups. Repeated measures data were analyzed using repeated measures ANOVA. Count data were expressed as number of cases or percentages, and the χ^2 test was used for comparisons. Rank-sum tests were used for comparisons of ordinal data. A *p*-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of NAS scores before and after treatment in the two groups

There was no statistically significant difference in NAS scores between the two groups before treatment ($p > 0.05$); at the end of treatment and one month after treatment, the NAS scores of both groups decreased compared with those before treatment, and the observation group was lower than that of the control group, with statistically significant differences ($p < 0.05$). See **Table 2**.

Table 2. Comparison of NAS scores before and after treatment in the two groups (scores, $\overline{x} \pm s$)

Group	Cases(n)	Before treatment	At the end of treatment	One month after treatment
Observation group	39	6.8 ± 1.3	2.1 ± 0.9	1.8 ± 0.8
Control group	38	6.7 ± 1.4	3.4 ± 1.1	3.1 ± 1.0
t-value	—	0.324	5.647	6.321
p-value	—	0.747	< 0.001	< 0.001

3.2. Comparison of Glazer pelvic floor surface electromyography parameters before and after treatment in the two groups

Before treatment, there were no statistically significant differences in Glazer parameters between the two groups ($p > 0.05$). At the end of treatment, the mean amplitudes of the pre- and post-resting potentials and the coefficient of variation of the pre-resting potential were lower in the observation group than in the control group, while the maximum amplitude of rapid contraction, the amplitude of sustained contraction at 10 s, and the amplitude of endurance contraction at 60 s were higher in the observation group than in the control group, and all differences were statistically significant ($p < 0.05$). See **Table 3**.

Table 3. Comparison of Glazer pelvic floor surface electromyography parameters between the two groups at the end of treatment ($\overline{x} \pm s$)

Index	Observation group (n = 39)	Control group (n = 38)	*t*-value	*p*-value
Pre-resting potential amplitude (μV)	2.6 ± 0.9	3.8 ± 1.2	4.913	< 0.001
Post-resting potential amplitude (μV)	2.9 ± 1.0	4.2 ± 1.3	4.876	< 0.001
Coefficient of variation of pre-resting potential	0.21 ± 0.07	0.30 ± 0.09	4.872	< 0.001

Rapid contraction of maximum amplitude (μV)	48.6 ± 10.2	39.4 ± 9.1	4.147	< 0.001
10 s sustained contraction amplitude (μV)	36.8 ± 8.4	29.5 ± 7.6	3.979	< 0.001
60 s endurance contraction amplitude (μV)	29.4 ± 7.1	23.1 ± 6.5	4.035	< 0.001

3.3. Comparison of NHP scores before and after treatment in the two groups

Before treatment, there were no statistically significant differences in the NHP scores of the two groups ($p > 0.05$). At the end of treatment, the scores of the observation group in all six dimensions—physical activity, energy, pain, sleep, social connection, and emotional response—were lower than those in the control group, indicating a more significant improvement in health-related quality of life ($p < 0.05$). See **Table 4**.

Table 4. Comparison of NHP scores between the two groups at the end of treatment (scores, $\overline{x} \pm s$)

Dimension	Observation group (n = 39)	Control group (n = 38)	*t*-value	*p*-value
Physical activity	12.4 ± 6.8	18.7 ± 7.5	3.842	< 0.001
energy	18.6 ± 9.4	28.3 ± 10.6	4.223	< 0.001
pain	15.2 ± 8.1	27.6 ± 9.8	6.021	< 0.001
sleep	16.8 ± 9.2	26.4 ± 10.3	4.286	< 0.001
Social connection	10.5 ± 6.3	16.9 ± 7.4	4.062	< 0.001
Emotional response	17.3 ± 8.6	26.8 ± 9.7	4.513	< 0.001

3.4. Comparison of dyspareunia scores before and after treatment in the two groups

Before treatment, there was no statistically significant difference in the dyspareunia scores between the two groups ($p > 0.05$); at the end of treatment and one month after treatment, the dyspareunia scores in the observation group were lower than those in the control group, and the difference was statistically significant ($p < 0.05$). See **Table 5**.

Table 5. Comparison of sexual dyspareunia scores before and after treatment in the two groups (scores, $\overline{x} \pm s$)

Group	Cases(n)	Before treatment	At the end of treatment	One month after treatment
Observation group	39	7.2 ± 1.5	2.6 ± 1.1	2.2 ± 1.0
Control group	38	7.1 ± 1.6	4.1 ± 1.3	3.8 ± 1.2
t-value	—	0.281	5.429	6.338
p-value	—	0.779	< 0.001	< 0.001

3.5. Comparison of clinical efficacy between the two groups

At the end of treatment, in the observation group, 12 cases were cured, 16 cases showed significant improvement, 8 cases showed improvement, and 3 cases showed no improvement, with a total effective rate of 92.3% (36/39); in the control group, 6 cases were cured, 12 cases showed significant improvement, 10 cases showed improvement, and 10 cases showed no improvement, with a total effective rate of 73.7% (28/38); the difference in efficacy between the two groups was statistically significant ($Z = 2.764$, $p = 0.006$).

4. Discussion

4.1. Comprehensive pelvic floor rehabilitation therapy can effectively relieve pelvic floor pain in MPPS patients.

The results of this study showed that the NAS score and dyspareunia score of the observation group were significantly lower than those of the control group at the end of treatment and 1 month after treatment, and the total effective rate was higher than that of the control group ($p < 0.05$), which is consistent with the results of relevant studies at home and abroad [12–14]. Analysis of the reasons: The core pathological change of MPPS is that the long-term overactivity of the pelvic floor muscles leads to continuous contraction of muscle fibers, local ischemia and hypoxia and the formation of MTrPs [2]. Myofascial release can directly destroy the tension band, relieve muscle spasm, promote local blood circulation and clear pain substances by accurately locating the trigger point through the vagina and applying ischemic pressure; electrical stimulation activates Aβ nerve fibers through the gate control mechanism, inhibits the transmission of pain signals and promotes the release of endogenous opioid peptides [7]; magnetic stimulation uses pulsed magnetic field to non-invasively regulate the sacral nerve and reduce the excitability of the sympathetic nerve. The three combined with breathing relaxation and biofeedback form a synergistic analgesic effect of "peripheral release–neural regulation–central re-education", so the analgesic effect is better than that of simple electrical stimulation.

4.2. Comprehensive pelvic floor rehabilitation therapy can improve the electrophysiological function of pelvic floor muscles.

Glazer surface electromyography assessment is an objective indicator for quantifying pelvic floor muscle function. The pre- and post-resting potentials and coefficient of variation reflect the hypertonic state and relaxation ability of the pelvic floor muscles, while the contraction amplitude reflects the strength and endurance of fast and slow muscles. In this study, the resting potentials and coefficient of variation of the observation group were significantly reduced and the contraction amplitudes of each muscle were significantly increased after treatment ($p < 0.05$), suggesting that comprehensive treatment not only reduced the abnormal hypertonicity of the pelvic floor muscles but also enhanced the contraction strength, endurance and coordination of the pelvic floor muscles. This is consistent with the report by Yang Zhijuan et al. on how electrical-stimulation biofeedback combined with manual massage can improve the electromyographic indicators of pelvic floor muscles in MPPS patients [15]. Biofeedback helps patients establish a conditioned reflex between the brain and pelvic floor muscles through sound and image signals, correcting the pattern of "not being able to relax and contracting incorrectly"; abdominal breathing reduces the excitability of the sympathetic nerves and relieves the excessive activity of the bladder detrusor muscle, thereby improving the fatigue and spasm state of the pelvic floor muscles [8].

4.3. Comprehensive pelvic floor rehabilitation therapy can improve patients' health-related quality of life.

Patients with MPPS suffer from chronic pain, dyspareunia, and abnormal urination and defecation, often leading to secondary anxiety, depression, and sleep disorders, significantly impacting their social and family life [3,4]. In this study, the observation group showed greater improvement in NHP pain, energy, sleep, and emotional response scores compared to the control group after treatment ($p < 0.05$), indicating that with pain relief and improved pelvic floor function, patients' overall physical and mental well-being and daily activities are enhanced. The comprehensive approach combines nursing assessment, health education, treatment

implementation, and home training guidance, emphasizing patient participation and long-term adherence management, reflecting a patient-centered holistic nursing philosophy.

4.4. Nursing key points and compliance management

MPPS treatment has a relatively long cycle (15 sessions over 5 weeks), and most patients are working women. Because it involves transvaginal procedures, patients are prone to feelings of embarrassment and discomfort. Nursing care should include:

(1) Thoroughly explaining pelvic floor anatomy and treatment principles before treatment to protect patient privacy and alleviate anxiety;
(2) Gradually increasing the intensity of manual techniques and electrical stimulation to a level tolerable to the patient;
(3) Establishing a WeChat follow-up group to remind patients of treatment times and supervise home Kegel exercises to minimize interruptions due to menstruation or work conflicts;
(4) Having a designated nurse perform treatment and assessments to ensure consistency and data reliability.

5. Conclusion

Comprehensive pelvic floor rehabilitation therapy integrates myofascial manipulation, breathing exercises, electrical stimulation, biofeedback, magnetic stimulation, and home training. It can effectively relieve pelvic floor pain in MPPS patients, reduce pelvic floor muscle hypertonia, improve pelvic floor muscle electrophysiological function, and enhance health-related quality of life. Its short-term efficacy is superior to simple electrical stimulation therapy, and it has good safety profiles, making it worthy of widespread application in gynecological pelvic floor rehabilitation nursing. However, this study was a single-center study with a limited sample size, short follow-up period, and the inability to implement assessor blinding, thus limiting the extrapolation of its conclusions. Future research should include multi-center, large-sample, randomized controlled trials with long-term follow-up and sham stimulation controls to further validate its long-term efficacy and explore standardized operating procedures.

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A Qualitative Study on Midwives' Decision-Making in Perineal Protection

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Abstract: *Objective*: To study real-world decision-making experiences, decision-making bases and influencing factors of clinical midwives in perineal protection during vaginal delivery, analyze decision-making dilemmas regarding perineal protection, episiotomy and prevention-and-control of perineal injury, and provide empirical evidence for standardizing midwifery perineal management, reducing the incidence of maternal perineal injury and improving clinical midwifery decision-making. *Methods*: Adopting a qualitative phenomenological research method, maximum-variation sampling was used to recruit 12 clinical midwives from a municipal maternal-child specialized hospital and a maternal-child health-care hospital as research subjects. Semi-structured in-depth interviews were conducted from February to August 2025. The Colaizzi seven-step analysis method was applied to sort, code and extract interview themes. *Results*: Major considerations for perineal-protection decision-making, restrictive factors in perineal-protection implementation, critical decision-making indicators for episiotomy, as well as occupational stress and cognitive bias in the decision-making process were identified. Midwives' decisions mainly relied on four core indicators: perineal elasticity, fetal weight, labor progress and maternal cooperation level. Their decisions were also affected by clinical experience, working environment, doctor-patient perceptions, institutional norms and other factors. Junior midwives tended to make conservative decisions and perform excessive episiotomy, whereas senior midwives were prone to empirically-biased decision-making. *Conclusion*: Midwives' decision-making for perineal protection represents a process combining objective medical indications and subjective empirical judgment. At present, clinical practice is characterized by inconsistent decision-making criteria, heavy reliance on experience and prevalent risk-avoidance-oriented decisions. Hospitals shall establish standardized decision-making workflows, strengthen tiered training, improve midwifery practice environments, enhance the scientific nature and standardization of perineal-protection decision-making, and lower the rates of perineal injury and unnecessary episiotomy.

Keywords: Midwives; Perineal protection; Clinical decision-making; Vaginal delivery; Qualitative research

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1. Introduction

Perineal injury is one of the most common complications of vaginal delivery. First- to fourth-degree perineal

lacerations and pelvic-floor muscle injuries may cause short-term complications including postpartum pain, hemorrhage and infection, as well as long-term sequelae such as pelvic-floor dysfunction and impaired sexual intercourse. In severe cases, they adversely affect women's postpartum physical-mental health and quality of life. Perineal protection constitutes a core clinical operational skill for midwives, and also a key intervention to prevent perineal injury during childbirth and reduce unnecessary episiotomy. Perineal-protection decision-making is not a single operational act, but a dynamic judgment process in which midwives make comprehensive assessments based on maternal perineal conditions, fetal status, labor progress, personal experience and clinical risks [1]. Therefore, this paper adopts phenomenological qualitative research to deeply explore the whole process, influencing factors and practical pain points of midwives' perineal-protection decision-making, so as to offer references for establishing a standardized and normalized perineal-protection decision-making system and improving the quality of clinical midwifery services.

2. Subjects and methods

2.1. Research subjects

Maximum-variation sampling was used to select practicing midwives from two public medical institutions in a city, including one tertiary maternity and child healthcare specialty hospital and one tertiary maternity and child health care hospital, taking differences in hospital rank and midwifery working environments into account. Inclusion criteria: holding valid midwifery practice certificates; having at least 2 years of midwifery working experience; proficient in operations including perineal protection, episiotomy and labor management; capable of fluent communication; voluntary participation in interviews.

Finally, 12 subjects were enrolled, numbered N1-N12. All subjects were female, aged 24-45 years with a mean age of (33.56 ± 5.28) years. Their midwifery working experience ranged from 2 years to 22 years: 4 junior midwives (2–5 years), 4 mid-senior midwives (6–10 years), and 4 senior midwives (≥ 11 years). Educational background: 2 with college-diploma education, 10 with bachelor-degree education. Professional titles: 2 nurses, 6 nurse practitioners, 4 chief nurse practitioners. The annual number of independent deliveries attended ranged from 80 to 250 cases, with an average of (186.35 ± 42.62) cases. See **Table 1**.

Table 1. General information of the 12 interviewed midwives

No.	Age (Years)	Midwifery experience (Years)	Education	Professional title	Annual independent deliveries	Seniority stratification
N1	27	3	College	Nurse	112	Junior (2–5 years)
N2	29	4	College	Nurse	135	Junior (2–5 years)
N3	31	5	Bachelor	Nurse Practitioner	164	Junior (2–5 years)
N4	28	2	Bachelor	Nurse Practitioner	96	Junior (2–5 years)
N5	33	7	Bachelor	Nurse Practitioner	182	Mid-senior (6–10 years)
N6	35	9	Bachelor	Nurse Practitioner	195	Mid-senior (6–10 years)
N7	32	6	Bachelor	Nurse Practitioner	171	Mid-senior (6–10 years)
N8	34	8	Bachelor	Nurse Practitioner	188	Mid-senior (6-10 years)

N9	38	12	Bachelor	Chief Nurse Practitioner	226	Senior (≥ 11 years)
N10	41	16	Bachelor	Chief Nurse Practitioner	241	Senior (≥ 11 years)
N11	36	11	Bachelor	Chief Nurse Practitioner	204	Senior (≥ 11 years)
N12	45	22	Bachelor	Chief Nurse Practitioner	235	Senior (≥ 11 years)

2.2. Research methods

2.2.1. Data collection

Semi-structured in-depth interviews were used for data collection. An interview outline was formulated combining literature review and clinical practice. Two midwives were pre-interviewed to optimize the outline. Key questions in the final interview outline:

(1) What criteria do you use clinically to decide whether to implement perineal protection and adjust protection intensity?

(2) Under what circumstances will you abandon perineal protection and choose episiotomy?

(3) What difficulties and interfering factors are encountered in clinical perineal-protection decision-making? How do work experience, doctor-patient communication and work stress affect your choices?

(4) Existing problems and improvement directions for perineal-protection decision-making and episiotomy criteria [2].

2.2.2. Data sorting and analysis

Verbatim transcription of recordings was completed within 24 hours after each interview. Invalid utterances were eliminated to generate complete interview texts. The Colaizzi seven-step analysis method was adopted for data analysis:

(1) Read all interview texts to grasp overall content;

(2) Extract core statements and meaning units related to perineal-protection decision-making;

(3) Code, summarize and refine core statements;

(4) Assemble similar codes to form initial themes;

(5) Integrate initial themes and distill core themes and sub-themes;

(6) Elaborate theme connotations combined with clinical practice;

(7) Revisit partial respondents to verify the accuracy of theme induction and ensure research validity. NVivo 12.0 software was used for coding and theme analysis [3].

2.2.3. Ethical considerations

All respondents participated in interviews on a voluntary, anonymous and confidential basis. All interview materials were used solely for academic research. Real names were replaced by serial numbers, and personal privacy of subjects was strictly protected.

3. Research results

3.1. Theme 1: Multidimensional objective considerations in perineal-protection decision-making

3.1.1. Maternal perineal conditions

Perineal elasticity, perineal length, perineal edema and scar status constitute primary judgment indicators. All 12 respondents stated that mothers with good perineal elasticity, absence of edema and scars, and adequate perineal-body length would receive full-course perineal protection to preserve perineal integrity as far as possible. For mothers with rigid perineum, severe edema or old laceration scars, the success rate of protection is very low, and preparations for episiotomy will be made in advance. N3: "Some women have very tight and stiff perineum. There is barely room for expansion when the fetal head descends. Laceration will occur no matter how we perform protection. Therefore I make early assessments and will not insist blindly on perineal protection."

3.1.2. Fetal-related indicators

Fetal weight, fetal-head size and fetal position are key decision-making factors. Respondents generally believed that for mothers with an estimated fetal weight ≥ 3 500 g, large biparietal diameter of fetal head, or persistent occiput posterior position, the risk of perineal compression rises markedly and perineal-protection difficulty increases greatly [4].

3.1.3. Labor-progress status

Rapid second-stage labor and sudden expulsion of the fetal head are high-risk factors for perineal laceration. N8: "Precipitate labor carries the highest risk of severe laceration. The perineum has no time for gradual expansion. Even full-course protection can hardly completely prevent injury, so episiotomy indications may be appropriately loosened." Better perineal-protection outcomes are achieved for mothers with steady labor progress and slow fetal-head descent [5].

3.1.4. Maternal cooperation level

Maternal cooperation in breathing and exertion directly influences protection outcomes. All 12 respondents mentioned that some mothers feel nervous, exert force improperly and ignore midwives' instructions. Sudden expulsion of the fetal head easily invalidates perineal protection and causes irregular lacerations.

3.2. Theme 2: Multiple practical restrictive factors for perineal-protection implementation

3.2.1. Divergent doctor-patient perceptions

Mothers and family members with limited childbirth knowledge fear episiotomy, refuse any invasive procedures, and expect complete preservation of the perineum. Some family members are impatient and urge accelerated delivery, interfering with midwives' normal decision-making and operations. Family members misunderstand risks and attribute episiotomy to operational errors by medical staff. Midwives may perform protection out of fear of disputes, which in turn raises laceration risks [6].

3.2.2. Operational-condition constraints

Variations in delivery-room equipment, maternal positioning options and emergency-supply allocation

affect protection-related decisions. Grassroots delivery rooms suffer from limited delivery positions, lack specialized perineal-hot-compress equipment and unpopularized perineal-massage techniques. Pre-treatment for improving perineal elasticity cannot be implemented, thus increasing protection difficulty [7].

3.3. Theme 3: Critical decision-making indicators for episiotomy and experience-related discrepancies

3.3.1. Unified high-risk episiotomy indications

All respondents shared identical understanding of absolute indications: episiotomy shall be performed immediately in cases such as fetal distress requiring forceps delivery, extremely tense perineum without expansion potential, poor perineal conditions, previous anal-sphincter-injury history, and abnormal labor requiring rapid termination of delivery.

3.3.2. Seniority-related decision-making differences

Junior midwives tend to make conservative decisions and show strong risk-avoidance awareness. For borderline cases, they prefer episiotomy to avoid severe lacerations, resulting in higher episiotomy rates. Senior midwives rely on rich clinical experience and dare to implement meticulous perineal protection with lower episiotomy rates, yet they face risks of empirically-based misjudgment. In this survey, the episiotomy rate among junior midwives was 20.3 %, mid-senior midwives 15.1 %, and senior midwives 10.8 %. Episiotomy rate was negatively correlated with working seniority [8]. See **Table 2**.

Table 2. Comparison of episiotomy rates among midwives of different seniority

Midwife stratification	Number of subjects	Episiotomy rate (%)	Decision-making characteristics
Junior (2–5 years)	4	20.3	Conservative; prioritize episiotomy for borderline cases to avoid severe laceration risks
Mid-senior (6–10 years)	4	15.1	Gradually develop personal experience; achieve balanced decision-making
Senior (≥ 11 years)	4	10.8	Meticulous perineal protection; more cautious toward episiotomy; prone to empirical bias

3.4. Theme 4: Occupational stress and cognitive bias in decision-making

3.4.1. Occupational-risk-driven conservative decisions

Fear of medical-dispute risks and adverse events of deep laceration constitute subjective influencing factors for decision-making. Midwives generally worry that irregular or severe perineal lacerations may trigger maternal complaints and disputes. Compared with spontaneous lacerations, regular episiotomy allows more predictable prognosis. Therefore, most midwives opt for conservative episiotomy for borderline scenarios.

3.4.2. Lack of standardized cognition leading to arbitrary decision-making

At present, no unified, detailed quantitative criteria exist for perineal-protection and episiotomy decision-making in clinical practice. Decisions mostly depend on textbook knowledge and personal operational accumulation, leading to substantial discrepancies in decisions across departments and individual midwives with low consistency. N10: “There are no rigid quantitative criteria. Whether perineum can be preserved depends entirely on tactile sensation and experience. Novices can hardly grasp the scale.”

4. Discussion

4.1. Midwives' perineal-protection decision-making: Dynamic integration of objective indicators and subjective experience

Results of this study show that midwives' perineal-protection decision-making is not determined by a single technique. It represents a dynamic process formed by combining objective medical indicators including maternal perineal status, fetal conditions and labor progress with subjective judgments derived from clinical experience, risk perception and doctor-patient communication. Objective indicators lay the foundation for decision-making and determine feasibility and risk levels of perineal protection. Subjective experience and occupational cognition determine final operational choices. Relying on abundant practical experience, senior midwives can accurately grasp perineal-expansion speed and flexibly adjust protection intensity, effectively lowering episiotomy and severe-laceration rates. Due to insufficient experience and strong risk-avoidance awareness, junior midwives are prone to excessive episiotomy.

4.2. Multiple practical clinical dilemmas restrict scientific perineal-protection decision-making

Multiple constraints exist in clinical implementation of perineal-protection decision-making. First, insufficient midwifery staffing and heavy workload make meticulous, full-course perineal-protection difficult to achieve, constituting a bottleneck for perineal-injury prevention-and-control in grassroots hospitals. Second, asymmetric doctor-patient perceptions: mothers and family members hold one-sided views regarding perineal-injury and episiotomy risks, excessively interfering with midwifery decisions and increasing midwives' occupational pressure. Third, unified quantitative decision-making criteria are absent. The industry lacks refined grading standards for perineal elasticity and quantitative systems for borderline episiotomy indications, resulting in highly experience-dependent decisions, poor consistency and difficulty guaranteeing operational standardization [9].

4.3. Risk-avoidance mentality induces decision-making bias and impairs midwifery-service quality

Pressure from medical-risk prevention-and-control serves as the main subjective cause for midwives' conservative decisions. Compared with controllable episiotomy, spontaneous-delivery-related irregular lacerations and severe pelvic-floor injuries bring more uncertain prognosis and easily trigger doctor-patient disputes. Under pressure from adverse-event reporting and accountability for medical disputes, midwives commonly adopt risk-avoidance mindsets and prefer episiotomy for borderline conditions. This gives rise to unnecessary invasive operations and aggravates maternal childbirth trauma. Such empirical, risk-oriented decision-making runs counter to the concept of restrictive episiotomy and priority for preserving perineal integrity.

5. Countermeasures and suggestions

5.1. Establish standardized quantitative decision-making systems and unify clinical operational criteria

Hospitals and the midwifery industry shall formulate detailed specifications for perineal-protection and episiotomy decision-making, develop quantitative evaluation criteria for perineal elasticity, perineal length, fetal weight and labor advancement, and define absolute episiotomy indications and relative borderline

indications to reduce arbitrary decisions dominated by personal experience. Formulate tiered operational specifications for midwives of different seniority, narrow decision-making discrepancies and improve clinical homogeneity in perineal management.

5.2. Implement tiered specialized training to improve midwifery decision-making competence

Carry out tiered training tailored to junior, mid-senior and senior midwives. For junior midwives, focus on training in perineal assessment and standardized protection operations to correct misconceptions of overly conservative decision-making. For senior midwives, strengthen cultivation of evidence-based midwifery concepts to prevent errors caused by empirical decision-making.

5.3. Optimize midwifery practice environments and alleviate occupational decision-making pressure

Improve doctor-patient-communication mechanisms. Provide antenatal childbirth-related health education for pregnant women, popularize knowledge regarding perineal protection, episiotomy and perineal injury, correct misconceptions among family members and reduce interferences with clinical decision-making.

5.4. Promote evidence-based midwifery techniques and optimize perineal-protection workflows

Routinely apply evidence-based techniques including antenatal perineal massage in midwife clinics, second-stage-labor perineal hot-compresses and free-position delivery to improve maternal perineal elasticity and lower injury risks at the source. Establish a dynamic labor-evaluation system to timely monitor fetal-head-descending speed and perineal-expansion status, dynamically adjust protective measures and realize personalized, precise perineal-protection decision-making [10].

6. Conclusion

Midwives' perineal-protection decision-making constitutes a complex dynamic process affected by objective medical indications, practical clinical conditions, occupational psychology and doctor-patient relationships. Clinical practice shall establish standardized quantitative decision-making systems, conduct tiered specialized training, optimize midwifery practice environments, promote evidence-based midwifery techniques, standardize decision-making behaviors for perineal protection and episiotomy, reduce rates of unnecessary episiotomy and severe perineal injury, effectively guarantee maternal safety in vaginal delivery, and enhance the refinement, standardization and scientific nature of midwifery services.

Disclosure statement

The author declares no conflict of interest.

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Clinical Implementation of Regional Citrate Anticoagulation in Combined CRRT and ECCO$_2$R Therapy: A Case Report

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Abstract: *Background*: Hypercapnia is a common precipitating factor for multiple organ failure in critically ill patients. The combination of continuous renal replacement therapy (CRRT) and extracorporeal carbon dioxide removal (ECCO$_2$R) represents a targeted pulmonary-renal support strategy; however, anticoagulation management during prolonged treatment remains a clinical challenge. Traditional unfractionated heparin carries risks of bleeding or circuit clotting, while evidence for regional citrate anticoagulation (RCA) in CRRT-ECCO2R combination therapy remains limited, with practical data in high-flow settings particularly lacking. This case report describes a novel anticoagulation regimen combining low molecular weight heparin (LMWH) and 4% citrate, providing a practical alternative for anticoagulation management in this complex therapy. *Case presentation*: A 59-year-old male patient with over a decade of occupational dust exposure (cement plant, gold mine, coal mine) and a history of pulmonary tuberculosis presented with cough, sputum production, and dyspnoea. On admission, oxygen saturation was 30–40%, arterial partial pressure of carbon dioxide ($PaCO_2$) was 142.33 mmHg, and serum potassium was 6.13 mmol/L. Diagnoses included acute exacerbation of chronic obstructive pulmonary disease (AECOPD), sepsis, septic shock, Legionella pneumonia, pulmonary encephalopathy, type II respiratory failure, and acute respiratory distress syndrome (ARDS). Despite initial management with antimicrobial therapy, fluid resuscitation, and mechanical ventilation, persistent hypercapnia ($PaCO_2$ > 100 mmHg) and hyperkalaemia persisted. Combined CRRT-ECCO$_2$R therapy was initiated from 23 May to 5 June 2025 (total 197 cumulative hours), with blood flow rate 300 mL/min, oxygen flow rate 8–10 L/min. Anticoagulation comprised LMWH (2000 U loading dose + 200 U/h continuous infusion), 4% trisodium citrate (200–210 mL/min), and 10% calcium gluconate (2–5 mL/h). After treatment, the patient showed significant reduction in $PaCO_2$, restored pH, improved oxygenation, no clinically significant bleeding events, and stable haemoglobin levels. However, due to financial constraints, the patient was transferred to a local healthcare facility for further care. *Conclusion*: In CRRT-ECCO$_2$R combined therapy, the LMWH + 4% citrate anticoagulation regimen effectively maintained circuit patency

(mean lifespan 65.67 hours) at a high flow rate of 300 mL/min, achieved efficient carbon dioxide clearance (mean clearance rate 44.5 mL/min), rapidly corrected acid-base imbalance, and demonstrated good safety. This approach overcomes limitations of conventional anticoagulation, offering a novel therapeutic option for critically ill hypercapnic patients at bleeding risk, with promising clinical utility and cost-effectiveness.

Keywords: Continuous renal replacement therapy (CRRT); Extracorporeal carbon dioxide removal ($ECCO_2R$); Regional citrate anticoagulation (RCA); Low molecular weight heparin (LMWH)

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1. Introduction

Hypercapnia is defined as arterial partial pressure of carbon dioxide ($PaCO_2$) exceeding 45 mmHg. It most commonly arises from upper airway obstruction, chronic obstructive pulmonary disease (COPD), thoracic and pleural disorders, or respiratory centre-depressant medications. Hypercapnia can reduce myocardial contractility, induce vasodilation, and increase cerebral blood flow, potentially causing impaired consciousness in severe cases. Although permissive hypercapnia is sometimes employed to reduce ventilator-induced lung injury (VILI), persistent severe hypercapnia remains a major driver of multiorgan dysfunction in critically ill patients [1].

To minimize VILI, improve respiratory failure, shorten mechanical ventilation duration, and facilitate early extubation, the combination of CRRT and $ECCO_2R$ has emerged as a targeted lung-kidney support strategy [2]. CRRT-$ECCO_2R$ employs two circuit configurations: arteriovenous (V-A) and venovenous (V-V), with the V-V configuration generally preferred as it maintains arterial integrity while offering superior haemodynamic stability [3,4]. Compared to venovenous extracorporeal membrane oxygenation (VV-ECMO), ECCO2R offers a lower technical threshold, less haemodynamic impact, reduced vascular injury, smaller catheter size, and lower cost, making it an attractive option for centres without advanced ECMO capabilities [5–7].

Animal studies have validated the efficacy of $ECCO_2R$ in controlling hypercapnia. Godet et al. using an infant-sized oxygenator in hypercapnic porcine models showed that CO_2 clearance ranged from 35 to 75 mL/min, with clearance maintained even at the lowest blood flow rates regardless of oxygen flow [8]. Christian et al. demonstrated that with modern low-flow oxygenators, post-membrane PCO_2 could be controlled within 10–25 mmHg when oxygen flow rate was ≥ 6 L/min [9].

Long-term $ECCO_2R$ and CRRT require rigorous anticoagulation management. Early studies predominantly used unfractionated heparin (UFH), but regional citrate anticoagulation (RCA) is now recommended for its reduced bleeding risk and extended filter lifespan [4,9–15]. However, the 2023 review by Tonetti et al. noted that heparin and argatroban remain common options for extracorporeal life support (ECLS), each with drawbacks and unresolved issues [16]. Importantly, no literature has reported the application of RCA in ECLS in high-flow settings. The KDIGO guidelines and some authors caution against RCA use in patients with hypotension, hypoxaemia, or severe liver disease—conditions that are not uncommon in $ECCO_2R$ candidates [17,18].

In this case report, we describe the use of a combined LMWH + 4% citrate anticoagulation regimen in a critically ill patient undergoing CRRT-$ECCO_2R$ therapy. This protocol was implemented after multidisciplinary assessment by the CRRT team at West China Hospital of Sichuan University, with informed consent obtained from the patient's family.

2. Patient information

A 59-year-old male patient presented with a chief complaint of intermittent cough with sputum production persisting for over a decade. He sought local hospital care within the past two months due to worsening dyspnoea. Tracheal intubation was performed and anti-infective therapy initiated owing to persistent desaturation (30–40%) and hypercapnia ($PaCO_2$ 115 mmHg). Post-intervention arterial blood gas analysis continued to demonstrate carbon dioxide retention, prompting transfer to our hospital's Emergency Department for further management. Past medical history includes occupational exposure to cement plants, gold mines, and coal mines (> 10 years), alongside a history of pulmonary tuberculosis treated with unspecified anti-tuberculosis therapy.

Emergency admission vital signs: Temperature 36.4 °C, blood pressure 93/59 mmHg, respiratory rate 20 breaths/min, pulse rate 114 beats/min, oxygen saturation 98%. The patient appeared lethargic, remained intubated, exhibited coarse breath sounds, bilateral moist rales, and no significant abdominal abnormalities.

Key investigations (Huaxi Hospital Emergency Department, 20 May 2025): Chest CT revealed scattered patchy opacities, linear atelectasis, nodular densification, and confluent consolidation predominantly involving the upper lobes. Biomarkers: Procalcitonin 1.77 ng/mL, C-reactive protein 88.4 mg/L, interleukin-6 165.3 pg/mL, Legionella IgG/IgM antibodies positive.

Diagnosis: 1. Acute exacerbation of chronic obstructive pulmonary disease (AECOPD); 2. Sepsis (per SOFA criteria); 3. Septic shock; 4. Severe pneumonia (Legionella); 5. Pulmonary encephalopathy; 6. Type II respiratory failure; 7. Acute respiratory distress syndrome (ARDS).

Initial management: RASS score -3; maintained sedation/analgesia (propofol 150mg, 0.05mg/kg/h + midazolam 50mg, 0.06mg/kg/h + remifentanil 2mg, 0.3mg/kg/h IV infusion). Vasopressor support included: 32mg noradrenaline in 5% glucose solution (total 50mL) infused at 1-2μg/kg/min; 12U vasopressin in normal saline (total 48mL) infused intravenously at 3mL/h. Mechanical ventilation (A/C-PRVC mode): respiratory rate 30 breaths/min, tidal volume 380–400 mL, positive end-expiratory pressure 5–8 cm H_2O, inspired oxygen concentration 60–70%. Anti-infective therapy: Meropenem 1 g every 8 hours. Adjunctive therapy included ambroxol/salbutamol for bronchodilation/mucus clearance, enteral nutrition, and intravenous immunoglobulin for immunomodulation.

Clinical progression: On 23 May 2025, combined continuous renal replacement therapy (CRRT) with extracorporeal carbon dioxide removal ($ECCO_2R$) was initiated due to refractory hypercapnia ($PaCO_2$ > 100 mmHg) and hyperkalaemia (K^+ 6.0–7.0 mmol/L). CRRT (Baxter Gambro machine/prismaflex, Gambro circuitry) employed post-dilution calcium-containing haemofiltration (prescribed rate 2 L/h; replacement fluid: dialysate = 1:1). $ECCO_2R$ (Xijian ECMO system, infant membrane oxygenator, surface area 0.5m²) was initiated via a right femoral vein-placed Bard® dialysis catheter (National Medical Device Registration Certificate No.: 20183101940), with oxygen flow rate 8–10 L/min. Anticoagulation therapy: Low molecular weight heparin (LMWH) initial loading dose 2000 U, followed by continuous intravenous infusion at 200 U/h; regional citrate anticoagulation (4% trisodium citrate 200–210 mL/min; 10% calcium gluconate 2–5 mL/h). The $ECCO_2R$ circuit membrane was replaced three times during the 9-day treatment period. Outcome: Arterial blood gas analysis demonstrated significant reduction in $PaCO_2$, improved oxygenation, and restoration of pH to normal levels. However, owing to financial constraints and poor prognosis, the patient was discharged against medical advice to a local healthcare facility.

3. Results

3.1. Carbon dioxide clearance

Carbon dioxide clearance ($^{\Delta}PCO_2$) was calculated using the following formula: $^{\Delta}PCO_2$ = (PCO_2 pre-filtration

- PCO_2 post-filtration) × blood flow rate (mL/min) [9]. The mean PCO_2 clearance rate (total $^{\Delta}PCO_2$ divided by total minutes) was 44.5 mL/min (526,294.8 mmHg·mL / (197 hours × 60 min/hour). Mean $PaCO_2$ reduction was 51.2 mmHg, mean pH increased by 0.32, and mean circuit lifespan was 65.67 hours. **Figure 1** illustrates the trends in pre- and post-filtration PCO_2 and pH values during the combined therapy.

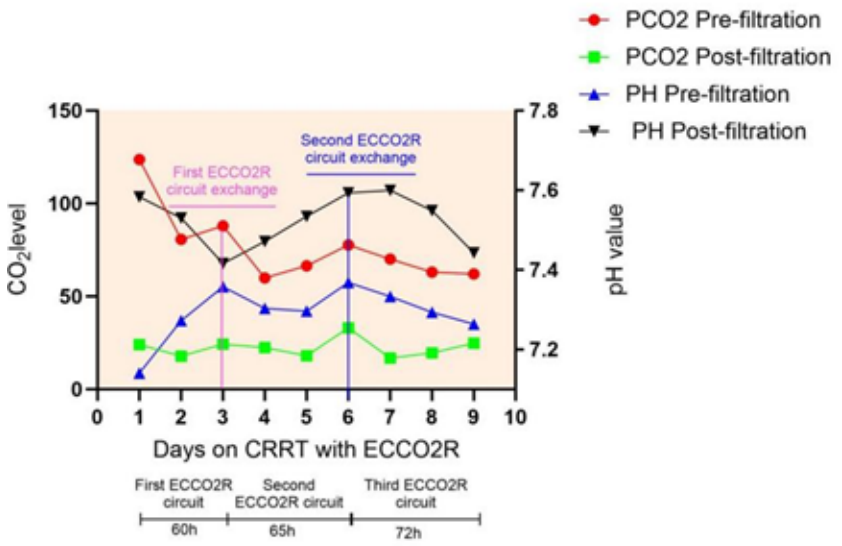


Figure 1. Trends in pre- and post-filtration PCO2 and pH values during the combined therapy.

3.2. Oxygenation improvement

The mean increase in PO_2 was 428.52 mmHg (95% confidence interval: 402.1–454.9). **Figure 2** shows the trend in pre- and post-filtration PO.

Ionised calcium monitoring:

The mean Pre-filtration ionised calcium (Ca^{2+}) was 1.08 mmol/L (SD ± 0.12), and post-filtration Ca^{2+} was 0.48 mmol/L (SD ± 0.07). **Figure 3** shows the trends during therapy.

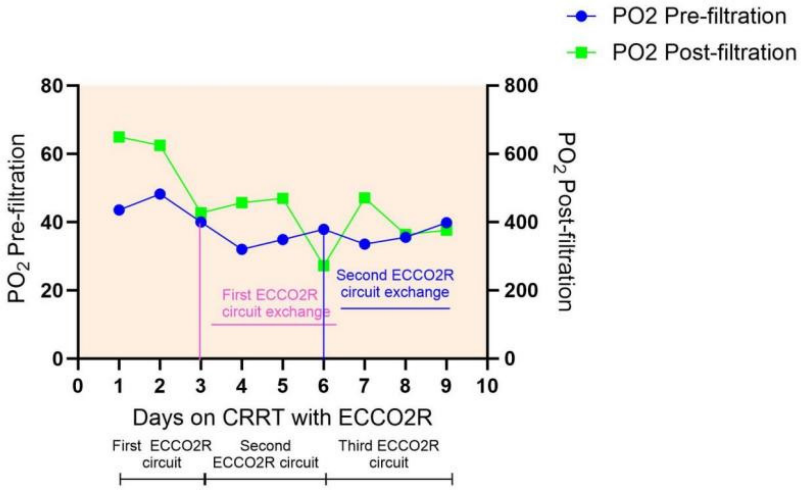


Figure 2. Trend in pre- and post-filtration PO_2 during combined therapy.

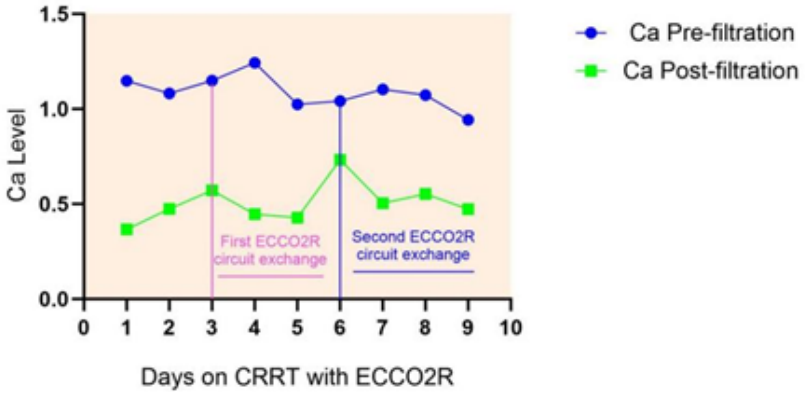


Figure 3. Trends in pre- and post-filtration ionized calcium levels during combined therapy.

Table 1. Pre-filtration blood gas analysis during combined CRRT-ECCO₂R therapy (daily measurements)

Days	Time	Blood gas analysis	PH Mean ± SD	PO_2 Mean ± SD	PCO_2 Mean ± SD	Be Mean ± SD	Ca Mean ± SD	Lac Mean ± SD	Circuit Configuration	Anticoagulation Protocol	Blood flow rate
1	2025-05-23 05:02:01.000	Pre-filtration VBG	7.14 ± 0.05	43.55 ± 23.8	123.66 ± 18.73	10.09 ± 1.5	1.15 ± 0.09	3.06 ± 0.88	Standard calcium reinfusion	LMWH + RCA	300
2	2025-05-24 03:28:43.000	Pre-filtration VBG	7.27 ± 0.08	48.22 ± 14.67	80.66 ± 14.26	7.85 ± 1.24	1.08 ± 0.07	2.46 ± 0.57	Standard calcium reinfusion	LMWH + RCA	300
3	2025-05-25 04:37:36.000	Pre-filtration VBG	7.36 ± 0.04	40.03 ± 8.01	70.9 ± 5.14	11.97 ± 1.22	1.15 ± 0.05	1.83 ± 0.29	Standard calcium reinfusion	LMWH + RCA	300
4	2025-05-31 04:28:20.000	Pre-filtration VBG	7.3 ± 0.02	32.02 ± 1.52	59.89 ± 2.5	2.21 ± 1.34	1.24 ± 0.17	1.42 ± 0.3	Standard calcium reinfusion	LMWH + RCA	300
5	2025-06-01 04:59:10.000	Pre-filtration VBG	7.3 ± 0.03	34.9 ± 2.73	66.46 ± 1.93	4.46 ± 2.47	1.02 ± 0.04	1.55 ± 0.08	Standard calcium reinfusion	LMWH + RCA	300
6	2025-06-02 04:20:15.000	Pre-filtration VBG	7.37 ± 0.01	37.91 ± 3.82	62.74 ± 0.84	8.91 ± 0.71	1.04 ± 0.02	1.62 ± 0.34	Standard calcium reinfusion	LMWH + RCA	300
7	2025-06-03 00:04:10.000	Pre-filtration VBG	7.33 ± 0.02	33.56 ± 2.42	70.06 ± 4.14	9.04 ± 0.46	1.1 ± 0.03	2.05 ± 0.5	Standard calcium reinfusion	LMWH + RCA	300
8	2025-06-04 04:13:31.000	Pre-filtration VBG	7.29 ± 0.04	35.59 ± 4.48	63.1 ± 3.23	2.61 ± 2.82	1.07 ± 0.03	2.44 ± 0.53	Standard calcium reinfusion	LMWH + RCA	300
9	2025-06-05 04:02:02.000	Pre-filtration VBG	7.26 ± 0.02	39.83 ± 0.3	62.02 ± 1	-0.15 ± 1.96	0.94 ± 0.1	2.5 ± 0.79	Standard calcium reinfusion	LMWH + RCA	300

Table 2. Post-filter blood gas analysis during combined CRRT-ECCO₂R therapy (daily measurements)

Days	**Time**	**Blood gas analysis**	**PH Mean ± SD**	**PO_2 Mean ± SD**	**PCO_2 Mean ± SD**	**Be Mean ± SD**	**Ca Mean ± SD**	**Lac Mean ± SD**
1	2025-05-23 07:29:39.000	Post-filtration VBG	7.58 ± 0.02	649.97 ± 56.79	24.08 ± 2.07	0.85 ± 1.42	0.37 ± 0.08	2.65 ± 0.94

2	2025-05-24 03:57:01.000	Post-filtration VBG	7.73 ± 0.08	624.86 ± 106.26	17.82 ± 2.25	3.84 ± 2.99	0.47 ± 0.03	2.51 ± 0.2
3	2025-05-25 04:19:58.000	Post-filtration VBG	7.72 ± 0.07	427.32 ± 27.3	21.3 ± 2.51	6.55 ± 2.39	0.57 ± 0.04	1.78 ± 0.21
4	2025-05-31 04:34:35.000	Post-filtration VBG	7.57 ± 0.08	457.3 ± 91.42	22.45 ± 6.75	-1.77 ± 1.77	0.85 ± 0.32	1.51 ± 0.28
5	2025-06-01 05:07:19.000	Post-filtration VBG	7.53 ± 0.23	272.46 ± 190.27	33.12 ± 17.29	-0.72 ± 1	0.43 ± 0.13	1.59 ± 0.19
6	2025-06-02 04:25:16.000	Post-filtration VBG	7.69 ± 0.05	469.23 ± 95.44	18.08 ± 2.91	1.72 ± 0.18	0.47 ± 0.02	1.61 ± 0.18
7	2025-06-03 00:07:09.000	Post-filtration VBG	7.7 ± 0.02	470.86 ± 86.11	16.84 ± 0.52	1.36 ± 0.54	0.5 ± 0.02	1.94 ± 0.39
8	2025-06-04 04:16:21.000	Post-filtration VBG	7.55 ± 0.06	363.76 ± 62.37	19.57 ± 1.06	-4.26 ± 2.35	0.55 ± 0.06	2.55 ± 0.63
9	2025-06-05 03:59:10.000	Post-filtration VBG	7.44 ± 0.06	376.53 ± 48.54	24.83 ± 2.31	-6.32 ± 1.59	0.47 ± 0.06	2.38 ± 0.5

4. Discussion

$ECCO_2R$ is an evolution of ECMO that operates by connecting a membrane oxygenator to a blood pump. Compared to VV-ECMO, $ECCO_2R$ achieves equivalent CO_2 removal at markedly lower blood flow rates (0.5–1.5 L/min vs. 3–7 L/min), reducing haemodynamic impact, vascular injury, and cost [7]. Combining $ECCO_2R$ with CRRT is therefore a practical, cost-effective multi-organ support option.

Based on prior findings that with oxygen flow ≥ 6 L/min, post-membrane PCO_2 can be controlled within 10–25 mmHg, we used an infant-sized oxygenator with blood flow 300 mL/min and oxygen flow 8–10 L/min. This configuration maintained post-filtration PCO_2 between 10–25 mmHg and achieved a CO_2 clearance of 44.5 mL/min, consistent with reported ranges of 35–75 mL/min [8,19].

The main challenge in prolonged $ECCO_2R$-CRRT is anticoagulation. The KDIGO guidelines caution against RCA in hypotension or severe liver disease, yet our patient required vasopressors throughout treatment [17]. Nevertheless, the LMWH + 4% citrate regimen was safe and effective: circuit lifespan averaged 65.67 hours, with no clinically significant bleeding and stable haemoglobin.

To our knowledge, this is the first report demonstrating the feasibility of RCA-based anticoagulation in CRRT-$ECCO_2R$ at a blood flow of 300 mL/min. This regimen addresses previous concerns about RCA safety in hypotensive patients and provides a practical option for centres without advanced ECMO capabilities. However, the single-case nature and loss to follow-up are limitations; larger studies are needed to validate these findings.

5. Conclusions

In CRRT-$ECCO_2R$ therapy, the anticoagulation regimen of LMWH + 4% citrate effectively maintained circuit patency (mean lifespan 65.67 hours) at a high flow rate of 300 mL/min, achieved a mean CO_2 clearance of 44.5 mL/min, and rapidly corrected refractory hypercapnia (mean $PaCO_2$ reduction 51.2 mmHg). No clinically significant bleeding occurred, and ionized calcium remained controllable. This protocol overcomes key limitations of conventional unfractionated heparin, validates the feasibility of RCA in high-flow $ECCO_2R$-CRRT, and offers a practical option for critically ill hypercapnic patients with bleeding risk.

Ethics statement

Consent was obtained from the patient's family for the treatment regimen and for publication of this case report. The study was conducted in accordance with the principles of the Declaration of Helsinki (version 2013, October; available at www.wma.net) and with Chinese laws regarding human-based research.

Author contributions

Qiongxing Bu designed the work. Qiongxing Bu, Yuejun Liu, and Wei Yang collected and analysed the data. Qiongxing Bu, Yuejun Liu, Wei Yang, Zhifeng Zhou, and Ling Zhang drafted and substantially revised the manuscript. All authors read and approved the final manuscript.

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Disclosure statement

The authors declare no conflict of interest.

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Research on Formative Assessment Based on Learning Communities in the Development of Clinical Competency for Internal Medicine Nursing Students

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Abstract: *Objective*: To explore the effect of formative assessment based on a learning community on cultivating job competency among nursing students in internal medicine. *Methods*: Nursing students rotating in the neurology department from April 2024 to April 2025 were selected and assigned into a control group (admitted for internship from April to September 2024) and an experimental group (admitted from October 2024 to April 2025) according to their rotation periods using a concurrent non-randomized controlled design. The control group received conventional teaching and summative evaluation at the end of the rotation, while the experimental group was provided with a learning community framework and implemented continuous formative assessment throughout the rotation. Job competency, theoretical examination scores at the end of the rotation, and teaching satisfaction were compared between the two groups. *Results*: There was no statistically significant difference in job competency scores between the two groups before intervention ($p > 0.05$). After intervention, the experimental group showed significantly higher scores in all dimensions and total job competency scores than the control group ($p < 0.001$), as well as higher theoretical examination scores and teaching satisfaction ($p < 0.05$). *Conclusion*: Formative assessment based on a learning community can provide timely feedback on students' learning processes, enhance job competency and theoretical knowledge among nursing students in internal medicine, and improve teaching satisfaction.

Keywords: Learning community; Job competency; Clinical nursing education

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1. Introduction

Clinical internship is a crucial phase in nursing education that bridges theory and practice, during which students develop job competency that directly influences their professional adaptation and the quality of clinical care [1]. The National Nursing Development Plan (2021–2025) explicitly calls for establishing a nurse training system centered on job competence, thereby setting higher demands for clinical nursing education.

Neurology patients often experience rapid changes in condition, frequently presenting with consciousness disturbances, swallowing difficulties, and motor impairments, placing high demands on nursing students' abilities in patient observation, clinical judgment, and communication and collaboration [2]. Currently, most clinical internship assessments rely on summative evaluations at the end of rotations, which fail to identify learning issues promptly and hinder timely teaching feedback and continuous improvement [3]. Formative assessment emphasizes collecting information throughout the learning process and providing immediate feedback through various methods such as self-assessment, teacher evaluation, and peer assessment. A learning community refers to an organized group where members collaborate and progress together toward shared goals. Integrating these two approaches provides formative assessment with a stable organizational structure and active participants for peer evaluation, while using evaluation feedback to sustain the ongoing development of the community. This article combines formative assessment and learning communities in clinical instruction for nursing students in neurology, aiming to offer practical insights into enhancing students' job competence in internal medicine. The following presents the application and outcomes.

2. Materials and methods

2.1. General information

Seventy nursing students who completed their clinical internship in the Department of Neurology at our hospital from April 2024 to April 2025 were selected as participants. Inclusion criteria included full-time undergraduate or higher-level nursing students currently enrolled in an academic program, having completed a four-week rotation in neurology, and providing informed consent to voluntarily participate in this study. Exclusion criteria included those who took more than three cumulative days off during the internship period, or those who withdrew midway or transferred to another department. Based on the time of admission for clinical training, students were divided into a control group (admitted between April and September 2024) and an experimental group (admitted between October 2024 and April 2025). Upon admission, students were randomly assigned to learning groups by drawing lots, with each group consisting of 3–4 members, forming a total of 20 groups—10 groups per cohort, each containing 35 students. No dropouts occurred during the study. The control group consisted of 4 males and 31 females, aged 19–24 years (mean age: 21.46 ± 1.12 years); educational background: 19 with bachelor's degrees and 16 with associate degrees. The experimental group included 3 males and 32 females, aged 19–24 years (mean age: 21.63 ± 1.05 years); educational background: 18 with bachelor's degrees and 17 with associate degrees. Comparisons of gender (Fisher's exact test, $p = 1.000$), age ($t = 0.655$, $p = 0.515$), and education level ($\chi^2 = 0.057$, $p = 0.811$) between the two groups showed no statistically significant differences, indicating comparability. This study was approved by the Medical Ethics Committee of our hospital.

2.2. Method

2.2.1. Joint teaching method by two groups

Both groups of nursing students completed a four-week rotation in neurology, using the same teaching syllabus and curriculum content, with identical criteria for instructor qualifications. The teaching nurse manager and chief instructor developed a four-week training plan based on the syllabus and specialty characteristics of neurology, implementing one-on-one bedside teaching. Instructors were required to have at least five years of experience in neurology, hold a title of nurse or higher, and possess hospital-recognized

teaching qualifications. Each instructor followed the department's training plan to complete a detailed teaching task list, which included nursing care for common conditions such as stroke, epilepsy, myasthenia gravis, and Parkinson's disease; specialized skills like consciousness and pupil assessment, swallowing function screening, nasogastric feeding, proper positioning, fall prevention, and pressure injury prevention; patient-nurse communication; health education; and documentation of nursing records. The chief instructor delivered weekly mini-lectures and organized one teaching ward round per semester.

2.2.2. Control group

The control group received standard teaching and assessment methods based on the above-mentioned instruction. During the internship, instructors randomly provided guidance to nursing students without structured phased evaluations or feedback sessions. At the end of the internship, the chief instructor organized a unified theoretical examination and job competency assessment for all students in the group, which served as a summative evaluation.

2.2.3. Experimental group

Based on the collaborative teaching approach, the experimental group implemented formative assessment supported by a learning community, as detailed below.

(1) Establish a learning community

Form learning communities based on groups randomly assigned, including the corresponding teaching instructors. Each group appoints a team leader, a recorder, and a presenter, with these roles rotating weekly among members to ensure every student takes on different responsibilities such as organizing, recording, and presenting. On the first day of the rotation, the chief instructor organizes an introductory meeting for the community to explain internship objectives and evaluation methods, guiding each group to set individualized group learning goals and weekly plans according to their specific learning needs, thereby fostering a shared vision. The chief instructor utilizes a " personalized training platform" to serve as a resource-sharing and online communication hub for the community, regularly posting specialized nursing knowledge, procedural videos, and typical case studies.

(2) Evaluation of task list nodes

Each time a nursing student completes a task from the teaching task list, a formative assessment is conducted. The student performs self-evaluation using the task list evaluation record form, summarizes the operational procedures and knowledge mastery, reflects on personal shortcomings, and the preceptor provides specific feedback and demonstration guidance based on the student's self-assessment and observed issues. The preceptor also acknowledges and encourages the student's strengths demonstrated during nursing practice. Based on the feedback, the student develops improvement measures and undergoes re-evaluation in subsequent similar operations, thus forming a closed loop of evaluation, feedback, improvement, and re-evaluation.

(3) In-class instruction with immediate assessment and peer evaluation among groups

Weekly mini-lectures are conducted through group presentations combined with teacher-led instruction, incorporating classroom questioning and online instant assessments during the lecture to promptly gauge nursing students' understanding of key concepts, thereby adjusting teaching focus and pace accordingly. After each session, groups conduct mutual evaluations focusing on presentation content, accuracy of

knowledge, and team collaboration. Outstanding aspects are acknowledged and promoted, while areas needing improvement receive constructive feedback.

(4) Online interaction and self-directed learning

The lead instructor posts one online assignment per week via the " Individualized Training Platform," including case analyses, nursing care plan development, and knowledge quizzes. Group members first complete the assignments independently, then discuss within their groups to reach a consensus answer before uploading it. The instructor provides feedback within 48 hours, and common issues are addressed collectively during the next group session.

(5) Group reflection and phase evaluation

A group reflection meeting is held every Friday at 3:00 PM, during which members share their learning achievements and challenges of the week, and with the assistance of a recorder, submit the minutes to the supervising teacher. A mid-term evaluation is conducted in the second week of internship, where the supervising teacher provides a comprehensive assessment of nursing students based on task completion, online assignments, and peer evaluation results, and jointly identifies key areas for future learning with the students.

(6) Summative assessment

At the end of the internship, both the experimental group and the control group underwent theoretical examinations and evaluations of job competency simultaneously.

2.2.4. Quality control

All preceptors received standardized training prior to the study, covering the organization methods of learning communities, implementation procedures for formative assessment, feedback techniques, and the use of evaluation tools. Only those who passed the assessment were allowed to participate in mentoring. During the study, the lead preceptors conducted weekly spot checks on the completion of evaluation record forms to ensure that formative assessment proceeded as planned. The two groups of nursing students were mentored by different preceptors to minimize interference between groups.

2.3. Observation indicators

(1) Job competency

The nursing student job competency assessment scale was used to evaluate participants on the first day of admission (pre-intervention) and upon discharge (post-intervention). This scale, originally developed by Hu Bo et al. and revised by Liu Chunbo, consists of 36 items across five dimensions: personal traits, clinical nursing skills, support and interpersonal communication abilities, critical clinical thinking, and professional development and self-improvement. It uses a 5-point Likert scale, with scores ranging from 5 (fully competent) to 1 (not competent), resulting in a total score between 36 and 180. Each dimension is represented by the mean item score, with higher scores indicating stronger job competency. Evaluation was conducted jointly by two senior teaching instructors who had undergone standardized training and were unaware of group assignments; the average of their ratings was taken. In this study, the Cronbach's α coefficient for the scale was 0.927.

(2) Theoretical assessment score upon departmental discharge

Exams were uniformly designed according to the teaching syllabus and conducted as closed-book tests,

with a maximum score of 100 points. The exam consisted of three sections: basic theory, specialized theory, and case analysis. Both groups of nursing students took the test simultaneously on the day of discharge.

(3) Teaching satisfaction

An anonymous survey on teaching satisfaction was conducted at the end of the rotation using a self-developed questionnaire by the department. The survey covered 10 aspects, including teaching content, teaching methods, timeliness of feedback, learning atmosphere, teamwork, and improvement in personal skills, with responses categorized into four levels: very satisfied, satisfied, neutral, and dissatisfied. Satisfaction rate = (number of very satisfied + number of satisfied) / total number of respondents × 100%. The content validity index of the questionnaire was 0.912.

2.4. Statistical analysis

Data were entered after double-checking by two individuals and analyzed using SPSS 22.0 statistical software. Continuous variables with normal distribution were expressed as mean ± standard deviation ($\overline{x} \pm s$), and group comparisons were performed using independent samples *t*-test; when variances were unequal, the *t*-test was applied. Categorical data were presented as frequencies and percentages, and group comparisons were conducted using χ^2 test; Fisher's exact probability method was used when expected frequencies were less than 5. A p value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of job competency scores between the two groups of nursing students before intervention

There was no statistically significant difference in the scores of each dimension and the total score of job competency between the two groups of nursing students before intervention ($p > 0.05$), as shown in **Table 1**.

Table 1. Comparison of job competency scores between the two groups of nursing students before intervention ($\overline{x} \pm s$, points)

Group	n	Personal traits	Clinical nursing competence	Support and interpersonal communication skills	Critical clinical thinking ability	Professional development and self-improvement capabilities	Total score
Experimental group	35	3.39 ± 0.44	3.08 ± 0.43	3.17 ± 0.48	2.96 ± 0.45	2.99 ± 0.46	113.12 ± 13.27
Control group	35	3.42 ± 0.41	3.05 ± 0.46	3.21 ± 0.45	2.93 ± 0.47	3.02 ± 0.49	113.46 ± 12.83
t-value		-0.295	0.282	-0.360	0.273	-0.264	-0.109
P-value		0.769	0.779	0.720	0.786	0.793	0.914

3.2. Comparison of job competency scores between the two groups of nursing students after intervention

After the intervention, the scores for each dimension and the total score of job competency in the experimental group were higher than those in the control group, with statistically significant differences ($p < 0.001$), as shown in **Table 2**.

Table 2. Comparison of job competency scores between the two groups of nursing students after intervention ($\overline{x}$ ± s, points)

Group	n	Personal Traits	Clinical Nursing Competence	Support and interpersonal communication skills	Critical clinical thinking ability	Professional development and self-improvement capabilities	Total score
Experimental group	35	4.21 ± 0.36	4.05 ± 0.38	4.12 ± 0.35	3.86 ± 0.41	3.91 ± 0.40	146.58 ± 10.47
Control group	35	3.84 ± 0.39	3.62 ± 0.42	3.71 ± 0.40	3.38 ± 0.44	3.47 ± 0.43	131.73 ± 11.62
t-value		4.124	4.491	4.564	4.722	4.432	5.617
p-value		< 0.001	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

3.3. Comparison of theoretical assessment scores between the two groups of nursing students upon completion of the rotation

The theoretical assessment scores in basic theory, specialty theory, case analysis, and the total score of the experimental group were all higher than those of the control group, with statistically significant differences ($p < 0.05$), as shown in **Table 3**.

Table 3. Comparison of theoretical assessment scores between the two groups of nursing students upon department discharge ($\overline{x}$ ± s, points)

Group	n	Fundamental theory	Specialty theory	Case analysis	Total score
Experimental group	35	34.12 ± 2.87	25.03 ± 2.61	23.74 ± 3.05	82.89 ± 5.92
Control group	35	32.47 ± 3.26	23.18 ± 2.94	20.36 ± 3.41	76.01 ± 6.85
t-value		2.247	2.784	4.371	4.496
p-value		0.028	0.007	< 0.001	< 0.001

3.4. Comparison of teaching satisfaction between two groups of nursing students

The teaching satisfaction in the experimental group was higher than that in the control group, and the difference was statistically significant ($p < 0.05$), as shown in **Table 4**.

Table 4. Comparison of teaching satisfaction between the two groups of nursing students [n (%)]

Group	n	Very satisfied	Satisfied	General	Not satisfied	Satisfaction
Experimental group	35	20 (57.14)	13 (37.14)	2 (5.71)	0 (0.00)	33 (94.29)
Control group	35	11 (31.43)	14 (40.00)	8 (22.86)	2 (5.71)	25 (71.43)
χ^2 value						6.437
p-value						0.011

4. Discussion

4.1. Formative assessment based on the development of a learning community helps enhance the job competency of nursing students in internal medicine.

The study results indicate that, after the intervention, the experimental group scored higher than the control group in all dimensions and the total score of job competency. This suggests that formative assessment based on a learning community can effectively enhance the job competence of nursing students in internal

medicine. Traditional summative assessment is conducted only at graduation, leaving nursing students with fragmented and unsystematic feedback during clinical practice. Problems are often identified only when they leave the department, missing the optimal window for correction and reinforcement [4]. In this study, formative assessment was implemented using teaching task checklists as milestones. After completing each task, students underwent self-assessment, teacher evaluation, feedback, and re-evaluation, enabling timely identification and improvement of weak points in their learning and continuous consolidation of clinical nursing skills. A significant difference was observed between the two groups in the dimension of critical clinical thinking, which may be related to the inclusion in the experimental group of online case analysis assignments, group discussions, and peer evaluations. Neurological patients often exhibit subtle changes in condition, requiring nursing students to detect early signs through careful observation of consciousness, pupils, muscle strength, and vital signs. By discussing real clinical cases, group members present diverse perspectives, challenge each other, and engage in argumentation, fostering habits of proactive thinking and comprehensive judgment. Role rotation within the learning community, establishment of shared goals, and group reflection promotes the development of communication, listening, and coordination skills among students, thereby enhancing their supportive and interpersonal communication abilities. Improvements in professional development and self-growth stem from the processes of self-assessment and reflection. Through continuous self-examination, nursing students gradually clarify their professional roles and career directions, cultivating awareness of proactive learning and self-improvement.

4.2. Formative assessment based on learning communities helps improve nursing students' theoretical knowledge.

The theoretical assessment scores in each section and the overall scores of the experimental group were higher than those of the control group, with a particularly significant difference observed in the case analysis section [5]. Formative assessment emphasizes the supportive role of evaluation in learning. Immediate assessments conducted during weekly lectures allow instructors to clearly understand students' grasp of key knowledge points, enabling timely adjustments to teaching priorities and preventing disconnection between teaching and learning. Online assignments require nursing students to complete tasks independently before discussing and formulating group answers through collaborative discussion. This process encourages students to consult resources and exchange perspectives, deepening their understanding of the subject matter. Instructors can then address common misconceptions collectively, helping to fill knowledge gaps. Case analysis questions assess students' ability to apply theoretical knowledge to clinical problems. The experimental group's clear advantage in this area demonstrates that formative assessment based on a learning community not only strengthens knowledge retention but also promotes the transfer of knowledge into clinical practice, effectively bridging the gap between academic education and clinical job requirements.

4.3. Formative assessment based on the development of a learning community helps enhance nursing students' satisfaction with teaching

The satisfaction level of the experimental group was higher than that of the control group. Nursing students newly entering clinical practice often face various pressures, such as unfamiliar environments, role transitions, and patient-nurse communication, which can lead to feelings of anxiety and helplessness. A learning community provides nursing students with a stable peer support system, where mutual encouragement and sharing of experiences during collaborative learning tasks help reduce psychological

stress and enhance a sense of belonging. In formative assessment, instructors not only point out shortcomings but also acknowledge students' strengths [6]. This feedback approach helps correct mistakes while motivating students, making them feel respected and valued, thereby increasing their enthusiasm and engagement in learning. The evaluators have shifted from the single instructor to include the students themselves, peers, and instructors, enabling students to transition from passive recipients of evaluation to active participants. This shift reflects the students' central role in the learning process and increases their acceptance of the teaching process. Notably, implementing formative assessment increases the workload for instructors. Clinical teaching managers should provide time support through flexible scheduling and reasonable distribution of teaching responsibilities, and incorporate the implementation of formative assessment into instructor quality evaluations to ensure the sustainable operation of this model.

4.4. Limitations of this study

This study is single-center research with a small sample size, involving nursing students on neurology rotation; therefore, the generalizability of the findings requires further validation. The two groups of nursing students were from the same department and used a concurrent non-randomized control design, which may introduce potential confounding factors such as time effects between groups. Assessment of job competency relied primarily on subjective evaluations by preceptors, introducing some bias. This study only observed short-term outcomes after the internship ended. Future studies could adopt a multi-center, large-sample design, extend to other internal medicine specialties, use objective evaluation tools such as Objective Structured Clinical Examinations (OSCEs), and conduct longitudinal follow-up of nursing students to explore the long-term effects of this assessment approach.

5. Conclusion

In summary, formative assessment based on learning communities integrates teamwork and process-oriented feedback, enabling dynamic monitoring of nursing students' learning progress. It effectively enhances the clinical competence and theoretical knowledge of medical-surgical nursing students, improves their satisfaction with clinical teaching, and offers valuable insights for reforming clinical nursing education evaluation.

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Disclosure statement

The authors declare no conflict of interest.

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Family Resilience Experiences in Adolescents with Inflammatory Bowel Disease: A Qualitative Study

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Abstract: *Objective*: To explore the experiences of family resilience among adolescents with Inflammatory Bowel Disease (IBD), in order to provide a foundation for the development of effective clinical nursing intervention programs. *Methods*: Twenty-two adolescents with IBD were recruited using purposive sampling. In-depth, semi-structured interviews were conducted between July and August 2025. Interview data were analyzed using Colaizzi's seven-step method. *Results*: Four themes and ten subthemes were identified: (1) family stress and challenges brought by IBD, including changes in the family environment, imbalanced family communication, and pressure associated with acute symptoms; (2) family support, including a sense of security, empowerment for personal growth, and emotional connection; (3) support outside the family, including online connections and social support; and (4) growth through adversity, including reshaped family health values and strengthened family cohesion. *Conclusion*: Healthcare professionals should place great emphasis on the negative impacts of IBD and actively utilize various support systems to enhance patients' positive emotional experiences, thereby helping patients and their families achieve effective adjustment and adaptation.

Keywords: Inflammatory bowel disease; Adolescents; Family resilience; Social support; Qualitative research.

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1. Introduction

Inflammatory Bowel Disease (IBD) was once seen as a rare disease [1]. However, in the past 30 years, with the changes in eating habits, lifestyles, and environment, the incidence of IBD has increased gradually [2]. According to the international data, nearly 20% patients develop symptoms before adulthood [3]. Besides, compared to adults, adolescents are more likely to have severe intestinal lesions and rapid progression of this disease [4]. The chronic process and reasons for IBD remain uncertain, which not only affects the physical

and mental health of the patients, but also reduces the quality of life of their families. Long-term care for most patients is mainly undertaken by family members in China as well as many Southeast Asian countries [5,6]. Since the family serves as the key supportive system of adolescents, the family's response to a crisis directly affects the prognosis of the patient [7]. Given such a context, the functions of family resilience are gaining more and more attention [8]. Family resilience refers to the capacity of a family, through collaborative efforts, to recover from trauma, gain strength and growth from within, and become more powerful than before [9]. According to research, strong family resilience not only helps improve disease management but also enhances the mental health and overall well-being of family members [10]. It should be noted that adolescents' subjective perception of family resilience is positively related to their personal resilience, which indicates that the one who believes their family has resilience exhibits stronger personal resilience when facing stressful scenarios with relatively low levels of anxiety [11]. Yet in China, the clinical research on IBD patients is mainly focused on the middle-aged group and young adults [12]. In July 2025, the WHO announced a partnership with Noora Health, with the explicit goal of "strengthening support for family caregivers". This indicates that integrating nursing services with family care remains a key priority on the WHO's current agenda. Nursing practice is shifting from individual intervention towards family system support. Therefore, this study aimed to explore experiences of family resilience among adolescents with IBD through semi-structured interviews, with a view to informing future family-focused nursing interventions.

2. Methods

2.1. Design

This study utilizes a descriptive qualitative design, which uses everyday language to directly describe participants' experiences or present an event, to explore the underlying family resilience experiences, psychological responses, and adaptation strategies of adolescents with inflammatory bowel disease (IBD). Conducting in-depth semi-structured interviews facilitates a thorough understanding of the adolescents lived experiences and cognitive traits, aligning closely with the objectives of this research.

2.2. Sample

This study uses purposive sampling to recruit adolescent IBD patients from participants who attended the youth family summer camp hosted by Zhejiang Love & Relief Foundation, with the inclusion criteria as follows:

(1) Adolescents aged 10 to 19 years and diagnosed with IBD [13];
(2) Who are voluntary participate with consent from their family members;
(3) Who are in a family where at least one family members are available to take care of them.

In addition, the exclusion criteria are as follows:

(1) Patients who have severe physical or mental diseases;
(2) Patients unable to effectively communicate or accept interviews, e.g., hearing or speech dysfunctions;
(3) Families who have already participated in similar research to avoid duplicate data.

The sample size was undetermined prior to data. The researcher will periodically review the interview transcripts to assess if data saturation had been achieved. Data saturation was considered reached when new interviews merely echoed previous data and no new themes or information emerged.

2.3. Data collection

Data were collected between July 2025 and August 2025 through audio-recorded, face-to-face, semi-structured interviews. The interview guidance is censored by two psychiatric and psychological experts and one qualitative methodology expert, and further revised after a pilot interview with 4 participants, ensuring its rigor and applicability. It should be noted that these 4 participants are not included in the formal interview. The core questions in the interview are as follows:

(1) Could you describe your feelings after being diagnosed with the disease?
(2) What changes has the diagnosis brought to you and your family?
(3) What measures have you and your family taken to adapt to the changes?
(4) Apart from family members, what other support have you gained?
(5) What positive changes in your family encourage you?

The interviews were conducted in a tranquil room at a hospital in REDACTED, with Chinese as the medium of communication. All interviews were conducted by a postgraduate nursing student (HY.N.) under the guidance of his master's advisor (QF.M.). To adequately prepare for the study, HY.N. engaged in reading extensively about qualitative research and took relevant online courses. QF.M. has over 30 years of experience treating adolescents with depression. he has completed training in qualitative research and has published several peer-reviewed qualitative studies.

Before commencing the interviews, all participants and their parents or guardians signed informed consent forms. The interviews were conducted with only the adolescents in the room to create a more open and relaxed atmosphere that encouraged free expression, while their parents waited outside with prior consent.

During the interview process, two researchers actively encouraged participants to fully express themselves and used a variety of interviewing techniques, such as follow-up questions, feedback, and clarifications, to ensure the thoroughness and precision of the data collected. Each interview lasted between 30 to 45 minutes and was audio-recorded with the consent of the participants, allowing the researchers to capture detailed information and reduce personal bias.

2.4. Data analysis

Within 24 hours after interviews, the researcher scrutinized the recordings and notes, then transcribed the data. Subsequently, the seven-step analysis method of Colaizzi is used, combined with NVivo12.0, for data coding, categorization, synthesis, and theme extraction [14].

Initially, two researchers（HY.N.&X.L.）thoroughly reviewed all interview data multiple times to fully immerse themselves in the material and develop a comprehensive understanding of the participants' interviews and experiences. Subsequently, independent coding was performed using Nvivo 12.0 qualitative analysis software, and coding units were organized according to shared characteristics. Finally, through an interactive and inductive process, similar coding units with higher levels of abstraction were extracted and grouped together, facilitating the identification of subthemes and overarching themes. Concerning disputes that arise during the data analysis process, LL.Y. will organize meetings in which all researchers participate to discuss and critically examine the coding content until consensus is achieved.

2.5. Rigor

To ensure the trustworthiness and rigor of this qualitative research, the study followed the framework proposed by Lincoln and Guba, which encompasses credibility, transferability, dependability, and confirmability [15]. Credibility: The researchers established a trusting, empathetic, and secure environment during the interviews, using emotional support and non-directive questioning to encourage the 22 adolescent participants to freely and authentically express their experiences. All interviews were audio-recorded, supplemented by field notes, and transcribed within 24 hours. Clarification questions (e.g., "Am I interpreting this correctly?") were actively utilized during the process to ensure data precision. Furthermore, the study was guided by a senior advisor (QF.M.) with extensive clinical experience. Transferability A thick, detailed description of the purposive sampling strategy, inclusion/exclusion criteria, participants' sociodemographic profiles, and the hospital-based interview context has been provided, enabling future researchers to evaluate the applicability of these findings to similar clinical cohorts. Dependability: Data analysis strictly adhered to Colaizzi's distinct 7-step method, integrated with NVivo 12.0 software for standardized coding and categorization. To control variability, two researchers (HY.N. & X.L.) performed independent coding after immersing themselves thoroughly in the transcripts. Any analytical disputes or coding discrepancies were systematically reviewed and resolved through research team consensus meetings led by LL.Y. Confirmability: The primary interviewer (HY.N.), a postgraduate nursing student, underwent extensive training in qualitative methodology and maintained continuous self-reflection to minimize personal preconceptions. Potential researcher biases were continuously bracketed, and the final extracted themes and subthemes were fully supported by direct verbatim quotations from the participants (N1 to N22) to guarantee that the findings genuinely reflect the adolescents' perspectives rather than the researchers' subjective biases.

2.6. Ethical considerations

This study was approved by the Ethics Committee of REDACTED (Approval No. 2022062). The participants were fully informed about the purpose of the study and methods before the interviews. The interview was immediately stopped if the participant experienced distressing emotions. Appropriate psychological support was provided to the participants promptly.

3. Results

3.1. Participants

Ultimately, a total of 22 adolescents with inflammatory bowel disease participated in this study. The average age of the 22 participants was 14.45 years (SD = 2.48 years old, range = 11–18 years old), with 54.55% identifying as female and 45.45% as male. Participants in this study were diagnosed with two types of inflammatory bowel disease: Crohn's disease and ulcerative colitis, with Crohn's disease being the most prevalent (68.18%), followed by ulcerative colitis (31.82%). In terms of educational status, the participants exhibited diverse educational backgrounds, including elementary school (Grade 5–6), junior high school (Junior 1–3), senior high school (Senior 1–3), and college freshmen. Some participants had special educational situations such as intermittent attendance or school suspension due to illness. Information on all adolescent patients, including their gender, age, educational status, disease type, and disease course, is shown in **Table 1**. with 22 adolescent IBD patients involved and numbered from N1 to N22; see **Table 1** for their basic information.

Table 1. Basic information of patients

No.	Gender	Age	Education status	Disease type	Disease course
N1	Male	18	Senior 2	Crohn's disease	3 years
N2	Female	14	Junior 3Suspended	Crohn's disease	5 months
N3	Female	15	Senior 1 Intermittent Attendance	Crohn's disease	2 years
N4	Female	17	Senior 2	Ulcerative colitis	4 months
N5	Female	16	Senior 2 Suspended	Crohn's disease	8 months
N6	Male	13	Junior 2	Crohn's disease	6 months
N7	Male	14	Junior 3	Ulcerative colitis	2 years
N8	Female	11	Grade 6	Crohn's disease	2 months
N9	Male	18	College Freshmen	Crohn's disease	3 years
N10	Male	14	Junior 3	Ulcerative colitis	1 year
N11	Female	11	Grade 6	Ulcerative colitis	4 years
N12	Male	16	Senior 1	Crohn's disease	1.5 years
N13	Female	13	Junior 1 Intermittent Attendance	Ulcerative colitis	7 months
N14	Male	17	Senior 3 Suspended	Crohn's disease	2.5 years
N15	Female	12	Grade 5	Crohn's disease	3 months
N16	Male	15	Senior 1 Suspended	Ulcerative colitis	1.2 years
N17	Female	11	Grade 6 Suspended	Crohn's disease	6 months
N18	Female	12	Grade 5	Crohn's disease	8 months
N19	Male	18	Senior 3	Ulcerative colitis	2 months
N20	Female	12	Grade 6	Crohn's disease	1 year
N21	Female	13	Junior 2 Intermittent Attendance	Crohn's disease	1.5 years
N22	Male	18	Senior 3 Suspended	Crohn's disease	4 years

3.2. Themes

3.2.1. Theme 1: Family stress and challenges brought by IBD

(1) Changes in family environment

For patients and caregivers in the family, challenges like unbalanced medical resource allocation and financial pressure force them to adapt to different life environments to share the family responsibility. For instance, there are expressions like *"My mom is having a hard time. She quit her job to take care of me" (N2); "my mom brought me to Hangzhou because of this disease. We don't live here before" (N6); "I came to Shanghai for treatment, but I didn't study or live here. I've been with my dad living here for more than six months" (N10); "my mom helps me a lot, and dad work in another city for higher salary" (N13); and "my dad went to another city to work, for me, for the whole family" (N16).*

(2) Imbalanced family communication

Part of IBD adolescent feel irritated by the role their parents play in disease management. This may be because they are in the key period of growing up with increasing self-awareness, so they would like to have more self-determination and self-control, but the communication between family members, as well as the means of disease management, makes them feel limited. Moreover, some patients even had delayed diagnosis and treatment due to misunderstandings between family members. The expressions as follows are recorded: *"It's so annoying, my family keep urging me to take medicine every day" (N1); "no one knows more than me about this disease, okay" (N5); "I told them I had stomachache not just to avoid school. They don't believe*

me" (N7); "sometimes they remind me but I don't want to respond. It's a bit annoying. I know everything but they keep urging me" (N12); and "they think I'm not telling the truth. They think I just don't have appetite, giving me pressure every day" (N14).

(3) Response pressure from acute symptoms

Acute episodes of IBD are regular in disease courses, featuring intestinal inflammation, accompanied by abdominal pain, diarrhea, hematochezia, fever, and fatigue, as the participants described: *"there's blood coming out of me, and my mom is terrified" (N3); "In that period, I lost around 20 kilos, and the way my dad looked at me made me sad" (N6); "when I was not in a good state, my mom often hid in her room and cried" (N8); "The gastric tube always made me nauseous, and my mother cannot bear looking at me" (N10); and "I felt extremely weak during flare-ups. My mother paced around, but there was nothing she could do for me" (N11).*

3.2.2. Theme 2: Family support

(1) Sense of security

Given that participants are young and exhibit volatile disease symptoms, caregivers in the family are required to persistently observe and care, so as to maintain a close connection with the IBD patients. For adolescent IBD patients, family serves as the key source of their sense of security and belonging, with expressions as follows: *"when I was in hospital, I was not bored and feel secure because I had my parents accompany me" (N7); "I get used to the present diet very soon because I want to eat everything my mom cooks" (N12); "of course my family take care of me. They provide money, or else I cannot be treated" (N13); "my parent will sit next to my bed and I feel very peaceful when they are here" (N14); and "I feel exhausted when symptoms occur and my parent will help me clean my face and feed me water, and they are always patient. It is with their care that I'm able to face this disease" (N16).*

(2) Empowering personal growth

For an adolescent with IBD, constructing meaning in adversity is a significant process of psychological adaptation, which not only helps them deal with the present challenges but also provides them with psychological resilience for future difficulties. With the family support, adolescents with IBD can gradually achieve self-acceptance from "resisting disease" to "accepting disease" and "growing through adversity", which can not be separated from family guidance and empowerment. Some participants note that the understanding and support of family members can affect their psychological status and disease management, as follows: *"My dad often encourages me to be positive. A lot of things don't have to be so heavy. I should mind the present business and not worry too much." (N5); "before, I always worried about my disease deteriorating. My mom keeps accompanying me, and we search for recovery cases and talk. Now, I have found the courage to hold on" (N11); "I used to feel I didn't have a good luck, asking 'why me', but my mom always there for me, making me feel I'm not alone" (N7); "Although it was hard, I learned to cherish and grateful for what I have now, and I understand more about the love from my parents" (N18); and "I used to be very self-abased and afraid of telling my classmates the disease I had, feeling different from others. It is my dad who keeps encouraging me, saying it's not my fault to have this, and I don't have to be self-abased. He even explained the conditions with me to my classmate, which made me feel much better" (N20).*

(3) Emotional connection

The psychological status of adolescents with IBD is easily affected by emotions, and emotional connections in the family accompany are key to addressing the negative emotions of patients. Such

connections are reflected not only in daily care but also in the family's perception, responses, and empathy of the patient's emotions, which makes them feel understood and respected. Related expressions are as follows: *"every time when I'm down, my mom doesn't keep asking me questions but sits next to me and hugs me, making me feel very warm" (N9); "I could not participate in the school sports meetings due to my disease and felt very upset. My dad asked for one day off to have me accompanied. We had a walk in the garden and did some sports that I'm capable of" (N10); and "when I was in hospital, my little sister would come and meet me after school, talking about funny things that happened in school and drawing me some sketches. I felt like I had to recover and get out of the hospital so I could grow up with her. The affection from my family is my motivation to keep on" (N13).*

3.2.3. Theme 3: Support outside of family

(1) Online connections

IBD is a long-term chronic disease, during which patients may feel lonely and separated. Through the internet and support groups, some patient and their families build connections with people with similar experiences to share their experiences and emotions, so as to alleviate the sense of loneliness. Some patients argue that the internet offers a channel for them to outlet emotions, where they can express their fear, anxiety, and depression free of psychological burden, without worrying about being misunderstood by families and friends. Such emotional outlets help to alleviate mental stress, as mentioned follows: *"I saw people with this disease on the internet, and all of them are facing life with a very positive attitude. I feel encouraged by them and try to face this disease in a more positive way" (N4); "I feel the group is warm because people help each other in the group" (N15); "when I haven been diagnosed, I shared my syptoms and doctor's words with them in the group, and they encouraged me and conforted me, maybe because im very young" (N2); "I don't know a lot of friends with this disease, but my mom know some of their parents on the internet" (N7); and "my dad communicate with patents of children with this disease on the internet, such as the new medicine, etc." (N13).*

(2) Social support

Except for family and internet friends with this disease, a lot of patients gain support from other channels, such as school, friends, and society. Teachers in school offer them care and understanding, society provides rich information about their disease as well as platforms for patients' communication, and friends give them encouragement and comfort. Support from various aspects not only helps to relieve their psychological burden but also enhances their resilience in facing the disease, expressed as follows: *"Sometimes, I have a stomachache when running, teachers will allow me to be absent. Because I live in the dorm, they also remind me about my diet" (N16); " I become happy when I chat with my friends on the watch. My bestie helps to smooth my emotion and hangout with me" (N8); "when I was in summer camp, I added contact with a few friends, and we communicate sometimes" (N14); and "people take care of me. They ask me how am I doing recently and what medicine I'm taking" (N15).*

3.2.4. Theme 4: Adversity brings growth

(1) Health value reshaped by family

All participants reported in the interview that their health values are affected to different degrees after getting IBD. During the process of reshaping health values, adolescents with IBD start to put more emphasis

on daily diet and life habits, such as positive changes within the family, which help not only the recovery of the patient but also the cohesion between family members, with descriptions as follows: *"This disease has reshaped my life value. Before, I overworked, and my mom also encouraged me to do so. At that time, I stayed up late every day. Now, my mom tells me to be constrained, including making efforts" (N6); "my mom says nothing matters except health. Besides, I want to learn to cook my favorite dishes from my mom, so I can make them by myself when I recover" (N8); and "this disease has made me realize that health is very precious and now I care about my wellness. My dad also does so, like we will go to bed earlier at the same time and do sports. We are forming better life habits than before" (N9).*

(2) Family reinforcement

Family reinforcement serves as a critical foundation of disease management and psychological adaptation of adolescents with IBD, with its core in cooperation, consistent ideas, and ability improvement of family members, constructing a more solid family support system. It is shown not only in the detailed daily care but also in family members learning disease knowledge together, unify the supportive ideas, and reduce divergences when providing care, making patients feel the family cohesion and solid support. The related expressions are as follows: *"my family form a habit of checking nursing knowledge of IBD every week. My parent and grandparents will learn them together" (N2); "they used to know nothing about this disease, sometimes, they don't take care me in a proper way. Now, they know better about my feelings" (N4); "my parents used to argue about my nursing. As time passes by, they unified the idea and I feel more secured" (N6); "I no longer feel I'm alone facing the disease, but the whole family is working together to defeat this disease" (N8); "my parents bring me to IBD family communication meetings to learn from other families and to encourage me to share my feelings" (N13); and "my little brother even know that I can't eat spicy food of work too much. He even takes care of me voluntarily" (N17).*

4. Discussion

This study, from the perspective of adolescents with IBD, digs deep into the family resilience experienced by the patients when dealing with the disease. In the theme of a comprehensive family support system, this paper shows three key components: family belief system, family organizational pattern, as well as communication and problem-solving capacity, which is consistent with the family resilience theory of Walsh [9]. Besides, the research has clarified that the presence of family resilience should go through a linear process of "encountering adversity, engaging positive supportive responses, and achieving gradual adaptation", and this study exhibits a similar pattern in terms of this aspect.

4.1. Implement targeted interventions to mitigate adverse impacts of IBD

This study found that IBD patients often go through a checkered diagnosis, leading to delayed treatment and exacerbating the mental stress and financial burdens of the family, thereby reducing family resilience [16]. It is suggested that family education be enhanced by nonprofit projects while implementing a layered diagnosis mechanism to relieve financial burdens. Targeting the complex and volatile clinical presentations of IBD, multidisciplinary team (MDT) collaboration needs to be promoted to realize full-cycle disease management and ensure accessible, high-quality medical services [17,18]. It should be noted that currently, specific diets for disease remission remain insufficient [19]. Some adolescents survive an active period of the disease through

medical treatment, but this process may trigger physical and psychological discomfort, requiring more diet intervention research. Additionally, in this research most of adolescents with IBD suffer complex and volatile negative emotions, which are contagious and expandable, consuming the family energy like viruses [20]. Research has pointed out that enhancing family resilience plays an important role in improving family emotional pollution and overall mental health [8]. According to this study, some IBD patients have problems communicating with their families. From the perspective of the family resilience theory model of Walsh, such ineffective communication will directly reduce the family resilience and trigger dysfunction of the family [21]. Besides, communication hinders further results in disorders of the family functions and weakens the overall resilience as well as its capacity to deal with the disease [22]. It is suggested that caregivers adopt the model of Family Health Conversation (FamHC) to improve family resilience through enhancing the internal communication system [23].

4.2. From the perspective of family resilience, integrate and fully utilize diversified support systems

In this study family resilience presents dynamic, evolving characteristics. Foster et al. also emphasized that nursing givers play a critical role in assessing familial protective and risk factors, facilitating domestic communication, and offering social support [24]. It should be noted that this study found that most families have a demand for digital support, so it is suggested to build a layered knowledge platform, such as an online community based on disease courses. By doing so, the precision of information access is satisfied, while forming a network of patient mutual aid. At the same time, public education should be carried out to eliminate the disease stigma and encourage patients who have recovered to participate in popularization through narrating medical practice, enhancing the emotional resonance of the social support system from the perspective of personal experience. The theory of family systems has broken the limitation of parent-child binary relations, regarding family as a dynamic resource network, among which intergenerational support is defined as a latent resource pool by Walsh [25]. Additionally, the longitudinal pioneering research by Werner et al proves that when parents lack support, the compensatory support from grandparents can significantly boost adolescent resilience [26]. Therefore, it is suggested that clinic staff system identify the key caregivers in the patient's family, and activate intergenerational resources through empowering these "resource points", thereby enhancing the family resilience systematically.

4.3. Family resilience enhances disease adaptation among adolescents with IBD

During their struggle with the disease, adolescents with IBD feel deeply the family resilience shown in the process. Meanwhile, they improved in terms of disease management and adaptation ability, which aligns with the results of Wu Danyan's research on breast cancer patients and Fan Yarong's research on family resilience of depressed patients: family members participate in disease management to adapt, including diet adjustment, medicine supervision, emotional comfort, etc [27,28]. In this study, some adolescent patients achieve positive changes like reshaped health values and enhanced psychological resilience, which is consistent with the research of Zhang et al showing adaptive behaviors like actively improving lifestyles [29]. Thus, it is suggested that the medical team reinforce such positive changes through cognitive behavioral therapy. Not only do patients perceive the supportive effect of the family, but also make the family system realize function optimization, including increased cohesion, enhanced quality of intergenerational communication, as well as

supported internet expansion. Participants' accounts suggest that supportive family interactions may facilitate adolescents' adaptation to IBD and strengthen family cohesion.

4.4. Limitations

Firstly, the results of this qualitative study rely heavily on the subjective experiences and memories shared by the adolescent participants. The theme extraction might be influenced by the researchers' subjective interpretations, which could potentially introduce recall or confirmation biases and affect the absolute objectivity of the insights gained.

Secondly, the sample size of this study, consisting of 22 adolescents recruited solely from a single foundation's summer camp, may limit the generalizability of the findings. This specific sample may not fully represent the diverse socioeconomic backgrounds, varied geographic regions, and full clinical spectrum of adolescent IBD patients across the broader population.

Thirdly, the research process exhibits inconsistencies in its reported methodology. While the study explicitly states it utilizes face-to-face interviews conducted in a quiet hospital room in July and August 2025, the rigor section later describes conducting online semi-structured video interviews. This methodological contradiction regarding the data collection environment could introduce confounding variables into the participants' psychological comfort and expression levels.

5. Implications for practice

As a chronic and recurrent physical disease, Inflammatory Bowel Disease (IBD) is characterized by a protracted course and unpredictable flare-ups, which seriously impacts the physical and mental health of adolescent patients and consumes family energy. Because the family serves as the primary support system during this critical developmental stage, nursing staff must pivot from individual-centered interventions toward comprehensive family system support to enhance family resilience. Health professionals should collaborate with multi-disciplinary teams (MDT) to implement full-cycle disease management, ensuring that patients and their families have access to high-quality medical services and targeted dietary and medical care plans.

Short-term nursing goals should focus on helping families cope with the acute symptoms and response pressures of the disease. Nurses need to guide caregivers in adopting the Family Health Conversation (FamHC) model to improve internal family communication, resolve parent-child management conflicts, and eliminate the negative effects of "emotional pollution" within the household. Long-term goals should focus on empowering the entire family unit by activating diversified support networks. This includes building digital support platforms and online peer-to-peer communities stratified by disease courses to facilitate information sharing and precision mutual aid. Furthermore, clinical staff should actively identify key intergenerational caregivers (such as grandparents) and empower these "resource points" to systematically strengthen the family's overall resilience pool. By utilizing cognitive behavioral therapies, healthcare professionals can reinforce positive familial adaptations—such as reshaped health values, optimized lifestyles, and cohesive family reinforcement—thereby helping adolescent patients transition from resisting the disease to achieving positive growth through adversity.

6. Conclusions

IBD poses challenges and threats to adolescent patients and their families. Yet, the positive emotional experiences of patients, the solid support within the family, and the rich resources outside the family play a vital role in the recovery process. While providing professional nursing, the medical team should pay more attention to the negative effects brought by IBD, such as complex psychological activities of adolescents with IBD, the conflicts in family communication, and the dynamic connection between families. Meanwhile, a diverse supportive system should be fully utilized to improve the positive emotional experiences of patients, helping them and their families achieve effective adjustment and adaptation. In the future, a series of interventions could be adopted to enhance the family resilience of adolescents with IBD, thereby preparing them for possible risks and challenges.

Disclosure statement

The authors declare no conflict of interest.

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The Complex Relationship Between Urinary Albumin-to-Creatinine Ratio and Depression

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Abstract: *Background*: One of the main causes of disability in the world is depression. A recent study has found substantial links between metabolic indicators, including serum albumin and uric acid, and depressive symptoms, pointing to the possibility that metabolic-inflammatory pathways are involved in the pathophysiology of depression. The Urinary Albumin-to-Creatinine Ratio (UACR) is an important indicator for evaluating kidney damage and cardiovascular risk; however, its link to depression is not well understood. This research aims to explore the potential association between UACR and depression. *Methods*: Data from NHANES from 2005 to 2018 were used in this study, focusing on individuals 20 years and older with available urine albumin-to-creatinine ratio (UACR) information. The relationship between UACR levels and depression was assessed using weighted multivariate logistic regression, with adjustments for important factors. To determine the strength of this association, subgroup analyses were performed considering various demographic and health-related variables. *Results*: According to the unadjusted analysis, there was a significant relationship between increased UACR and a greater risk of depression. Each unit rise in UACR, after applying a natural logarithmic transformation, was linked to an 18% higher risk of depression (OR: 1.18, 95% CI: 1.14–1.23). Furthermore, individuals in the highest tertile of UACR exhibited a 112% elevated risk of depression relative to those in the lowest UACR tertile (OR:2.12,95% CI: 1.57–2.86). This association between UACR and the risk of depression was consistently observed across diverse demographic subgroups. *Conclusions*: This study's preliminary unadjusted analyses suggested a correlation between elevated UACR, higher proteinuria grades, and an increased risk of depression. However, after thorough adjustment for covariates, these associations were no longer statistically significant. These results imply that the connection between UACR, proteinuria levels, and depression might be intricate and possibly affected by different socioeconomic and lifestyle factors. Further investigation is essential to uncover the basic mechanisms and clinical impacts of this association.

Keywords: American adults; Cross-sectional study; Depression; National health and nutrition examination survey; Urinary albumin-to-creatinine ratio

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1. Introduction

Depression is a prevalent mental disorder, and its global incidence has been on a consistent rise over recent decades [1]. Projections indicate that depression will become the foremost cause of disability by 2030 [2]. The pathogenesis of depression is multifactorial, encompassing genetic, psychological, biological, and environmental risk factors. Recent research indicates a potential association between depression and impaired renal function, but the underlying mechanisms remain unclear [3]. Therefore, it is crucial to investigate the correlation between depression and renal function.

Increased urine albumin levels, known as proteinuria, are viewed as a precursor to early kidney problems [4]. In the beginning stages of kidney damage, urinary albumin reflects reduced glomerular filtration and could influence tubular function through multiple mechanisms [5]. Abnormalities in UACR have been linked to the onset of cardiovascular disease, hypertension, obesity and other diseases [6–10]. For early detection of CKD, UACR is a significant indicator. Depression is a prevalent condition among CKD patients, with a reported prevalence of 39.3% among individuals with end-stage renal disease [11]. An investigation within a Chinese demographic indicated a significant positive correlation between UACR and depressive symptoms [12]. However, research investigating this link within the American population is scarce. To fill this gap, we conducted a large-scale cross-sectional study utilizing data from the National Health and Nutrition Examination Survey (NHANES) spanning the years 2005 to 2018. The goal of this study was to investigate and confirm the relationship between UACR and depression in adults.

2. Methods

2.1. Study population

NHANES is a perpetual program focused on evaluating the health and nutrition status of the American populace. Roughly 5,000 U.S. residents participate each year, delivering detailed data on their demographics, socioeconomic status, dietary habits, and health conditions. Gathering data includes in-person interviews and comprehensive physical evaluations, including physiological measurements and lab tests. The Institutional Review Board at the National Center for Health Statistics approved the study ethically and provided informed consent. Data spanning from 2005 to 2018 from the NHANES database were utilized in this observational research. Initially, 70,190 potential participants were evaluated according to predefined inclusion and exclusion criteria. Exclusion criteria included incomplete or missing PHQ-9 data (33,743), incomplete UACR data (527), or missing data on important covariates (6,694). After these exclusion criteria were implemented, 29,226 individuals were included in the final dataset for analysis. For further details, please refer to **Figure 1**.

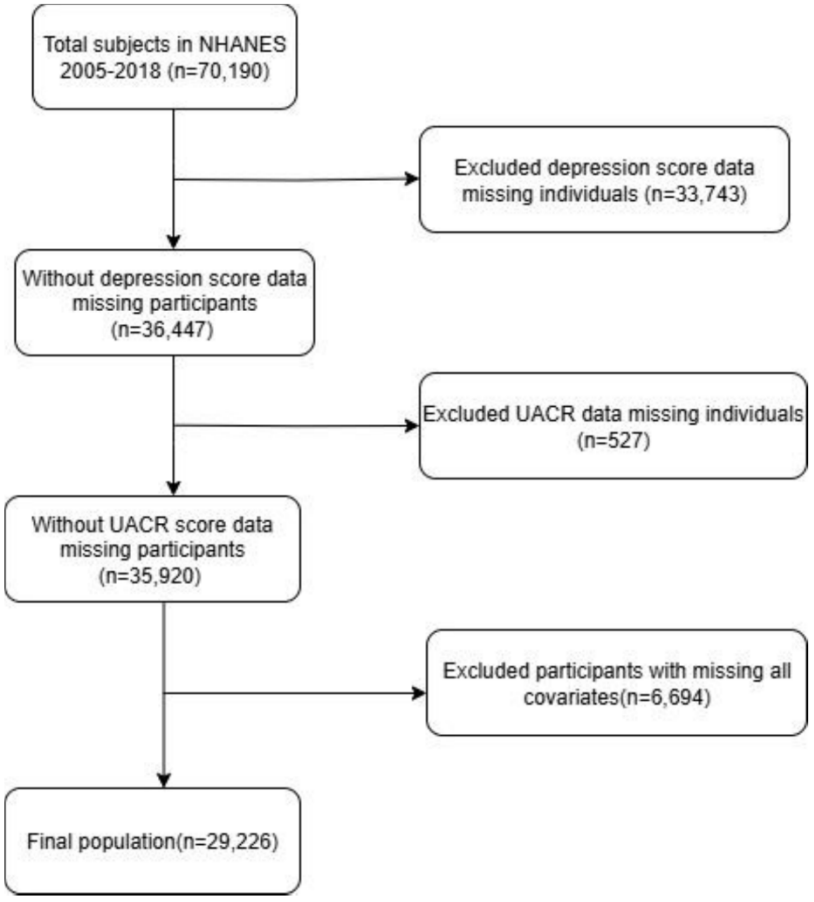


Figure 1. Study's flow diagram.

2.2. Measurement of UACR

To ensure accurate analysis, urine samples were prepared with care and maintained at a temperature of -30 ℃. A solid-phase fluoroimmunoassay was used to detect urinary albumin, whereas urinary creatinine was measured using an enzymatic quantitative technique. A comprehensive overview of the laboratory methodologies is accessible on the NHANES website [13]. Before 2007, the kinetic Jaffe rate reaction method was used to measure urine creatinine levels; after 2007, the enzymatic method was used. Therefore, we adjusted urine creatinine levels from the 2005–2006 cycles using the NHANES-recommended equation. UACR was expressed in milligrams per gram (mg/g), and urinary albumin and creatinine levels were measured and normalized using established gold-standard techniques. In the context of clinical practice, a UACR of 30 mg/g or higher is regarded as proteinuria, with microalbuminuria being defined as a UACR between 30 mg/g and 300 mg/g. A UACR greater than 300 mg/g is considered macroalbuminuria [14].

2.3. Diagnosis of depression

The NHANES used the validated nine-question PHQ-9 to evaluate symptoms of depression. This widely recognized instrument demonstrates a sensitivity and specificity of 88% [15]. The PHQ-9 serves as a highly effective screening tool for depressive symptoms, evaluating symptoms experienced over the preceding two weeks. Technical abbreviations are clarified upon their initial introduction. The questionnaire measures

depressive symptoms in participants over the past two weeks, encompassing issues such as disturbed sleep, loss of appetite, and feelings of loneliness. Every item is evaluated using a 4-point ordinal scale that indicates how often symptoms occur (0, not at all; 1, several days; 2, more than half the days; 3, nearly every day) [16]. The total score for the PHQ-9 is the result of adding the scores of its nine components. Consequently, participants' PHQ-9 scores were categorized into two groups: < 10, indicating no depression, and ≥ 10, indicating the presence of depression.

2.4. Explanation of covariates

Various factors related to UACR levels and the risk of depression were included in the study, organized into demographic, lifestyle, and health-related categories. The research accounted for demographic elements like age, sex, race, marital status, education, and the family income poverty ratio (PIR). Included in lifestyle factors were alcohol drinking habits (yes/no), smoking history (defined by having smoked over 100 cigarettes, categorized as never, former, or current), and Physical activity. [Physical activity was quantified using MET values, weekly frequency, and exercise duration. The formula used was MET-min/week = MET × weekly frequency × activity duration. According to this, participants were grouped into three categories: no PA (0 MET-min/week), low-level PA (1 to 599 MET-min/week), and high-level PA (≥600 MET-min/week)] [17]. Body mass index (BMI), estimated glomerular filtration rate (eGFR), and diseases including diabetes, hypertension, and cardiovascular disease (CVD) were among the health indicators. The data collection process included standardized surveys and medical assessments, and eGFR was calculated via the CKD Epidemiology Collaboration equation [18].

2.5. Analysis of statistics

To guarantee the sample's representativeness, the NHANES dataset's 'Full sample 2-year MEC exam weight' was utilized in accordance with the sampling and weighting guidelines. To guarantee that the results are nationally representative and to account for the bias brought on by the intricate sample design and oversampling of the population. For combining data from multiple survey cycles, we adjusted the weights in accordance with official guidelines, and in this study, data from seven cycles were combined, and the weights were divided by seven.

The Kolmogorov-Smirnov test was employed to verify the normality of continuous variables. Due to the right-skewed distribution of UACR levels, a natural logarithmic transformation was applied to achieve normality. Continuous variables conforming to a normal distribution were reported as mean ± standard deviation (SD), while non-normally distributed continuous variables were summarized using medians and interquartile ranges (IQR). Categorical variables were presented as frequencies and percentages. Comparative analyses of continuous variables between groups were conducted using t-tests, whereas chi-square tests were utilized for categorical variables, as appropriate. Multivariable logistic regression was employed to compute odds ratios (ORs) and 95% confidence intervals (CIs) for the purpose of evaluating the association between UACR and depressive symptoms. All statistical analyses were executed using the R software (http://www.R-project.org, The R Foundation) and Free Statistics software, version 2.2. A two-sided *P*-value of less than 0.05 was considered indicative of statistical significance.

3. Results

3.1. Baseline characteristics of participants

This study analyzed data from 29,226 individuals across seven NHANES cycles spanning 2005 to 2018. The weighted analysis allows sample results to be extrapolated more precisely to the entire target US non-institutionalized civilian population. The demographic summary in **Table 1** shows an average age of 47.27 ± 16.73 years and a gender distribution that is fairly balanced, with 51.2% of the population being female. Depressed individuals are characterized by: The depression group was more likely to be female (63.9% vs 50.1%), black or minority ethnic, less educated (8.0% vs 4.4%), living alone (51.4% vs 34.3%), and low-income (41.0% vs 18.9%) than the non-depression group. In terms of health, the prevalence of smoking (38.8%), obesity (47.6%), lack of physical activity (33.4%), hypertension (37.9%), and cardiovascular disease (15.8%) was significantly higher in the depression group. Importantly, there were no notable differences in age and kidney function metrics between the two groups. These data demonstrate strong associations between depressive status and socioeconomic disadvantage, poor health behaviors, and chronic diseases.

Table 1. Population characteristics by depression category

Variables	Participants*			
	Overall	Non-depression	Depression	*p* value
Age (mean ± SD)	47.27 ± 16.73	47.30 ± 16.81	46.89 ± 15.76	0.359
Sex, n (%)				< 0.001
Male	87981226.5 (48.8)	82918762.1 (49.9)	5062464.4 (36.1)	
Female	92299197.8 (51.2)	83336148.3 (50.1)	8963049.5 (63.9)	
Race, n (%)				< 0.001
Non-Hispanic White	125378377.2 (69.5)	116260296.1 (69.9)	9118081.0 (65.0)	
Non-Hispanic Black	18428061.8 (10.2)	16618550.1 (10.0)	1809511.7 (12.9)	
Mexican American	14561956.2 (8.1)	13486627.7 (8.1)	1075328.5 (7.7)	
Other	21912029.0 (12.2)	19889436.4 (12.0)	2022592.6 (14.4)	
Education, n (%)				< 0.001
Below high school	8486523.3 (4.7)	7371254.5 (4.4)	1115268.9 (8.0)	
High school	59942753.2 (33.2)	53814707.6 (32.4)	6128045.6 (43.7)	
Above high school	111851147.7 (62.0)	105068948.4 (63.2)	6782199.3 (48.4)	
Marry, n (%)				< 0.001
Married or living with partners	115962842.1 (64.3)	109146959.3 (65.7)	6815882.9 (48.6)	
Living alone	64317582.1 (35.7)	57107951.2 (34.3)	7209630.9 (51.4)	
Alcohol, n (%)				0.788
No	36250993.4 (20.1)	33466790.3 (20.1)	2784203.0 (19.9)	
Yes	143927354.4 (79.9)	132725643.4 (79.9)	11201711.0 (80.1)	
PIR, n (%)				< 0.001
Low income	37148809.0 (20.6)	31395759.5 (18.9)	5753049.5 (41.0)	
Medium income	64420718.8 (35.7)	59285523.5 (35.7)	5135195.3 (36.6)	
high income	78710896.4 (43.7)	75573627.3 (45.5)	3137269.0 (22.4)	
Smoke status, n (%)				< 0.001
Never	98523541.2 (54.7)	93211745.9 (56.1)	5311795.3 (37.9)	

Former	45414502.6 (25.2)	42149670.4 (25.4)	3264832.1 (23.3)	
Current	36342380.5 (20.2)	30893494.1 (18.6)	5448886.4 (38.8)	
BMI, n (%)				< 0.001
< 25	52856043.2 (29.3)	49145708.3 (29.6)	3710334.9 (26.5)	
≥ 25 < 30	59551606.0 (33.0)	55913845.9 (33.6)	3637760.1 (25.9)	
≥ 30	67872775.0 (37.6)	61195356.2 (36.8)	6677418.8 (47.6)	
Hypertension, n (%)				< 0.001
No	133647652.1 (74.1)	124942278.3 (75.2)	8705373.8 (62.1)	
Yes	46632772.1 (25.9)	41312632.1 (24.8)	5320140.0 (37.9)	
CVD, n (%)				< 0.001
No	165377770.4 (91.7)	153572512.7 (92.4)	11805257.7 (84.2)	
Yes	14902653.9 (8.3)	12682397.7 (7.6)	2220256.1 (15.8)	
PA (MET-min / week), n (%)				< 0.001
0	37251025.2 (20.7)	32563411.7 (19.6)	4687613.4 (33.4)	
1–599	30469464.2 (16.9)	28149361.4 (16.9)	2320102.9 (16.5)	
≥ 600	112559934.8 (62.4)	105542137.3 (63.5)	7017797.5 (50.0)	
Diabetes, n (%)				< 0.001
No	163405894.6 (90.7)	151492347.1 (91.2)	11913547.5 (85.0)	
Yes	16804945.5 (9.3)	14705570.1 (8.8)	2099375.5 (15.0)	
eGFR (mean ± SD)	93.81 ± 21.88	93.75 ± 21.81	94.58 ± 22.59	0.126
UACR (median [IQR])	6.55 (4.34, 11.72)	6.49 (4.30, 11.54)	7.29 (4.78, 14.66)	< 0.001

Notes: eGFR, estimated glomerular filtration; UACR, Urinary Albumin-to-Creatinine Ratio; SD, standard deviation; IQR, interquartile range.*,Data for categorical variables are presented as weighted numbers (weighted percentages).

3.2. Relationship between UACR and depression

To evaluate the link between the urinary albumin/creatinine ratio (UACR) and depression, we developed four stepwise adjusted models by weighted multivariate logistic regression analysis.

In unadjusted crude models, each natural logarithmic unit increase in the urine albumin-to-creatinine ratio (UACR) was associated with an 18% increase in the risk of depression [95% confidence interval (CI): 1.14–1.23; $p < 0.001$]. With the progressive adjustment for confounding variables, the effect size diminished: the association remained statistically significant in Model 3 (odds ratio [OR] = 1.06, 95% CI: 1.01–1.10), but was no longer significant in the fully adjusted Model 4 (OR = 1.01, 95% CI: 0.97–1.06, $p = 0.63$). The significance of the association in the microalbuminuria group (30–300 mg/g) was lost in Model 3 (OR = 1.09, 95% CI: 0.94–1.26). In the macroalbuminuria group (≥ 300 mg/g), In Model 4, the OR dropped to 1.19(95% CI: 0.86–1.66) as shown in **Table 2**.

Table 2. Association between UACR and depression

Variable	Crude		Model 1		Model 2		Model 3		Model 4	
	OR (95% CI)	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**	**OR (95% CI)**	***p* value**
UACR(In)	1.18 (1.14–1.23)	< 0.001	1.17 (1.13–1.22)	< 0.001	1.08 (1.03–1.13)	0.001	1.06 (1.01–1.10)	0.016	1.01 (0.97–1.06)	0.63

0 < UACR < 30 mg/g	1(Ref)		1(Ref)		1(Ref)		1(Ref)		1(Ref)	
30 ≤ UACR < 300 mg/g	1.44 (1.25–1.67)	< 0.001	1.45 (1.27–1.67)	< 0.001	1.17 (1.01–1.36)	0.036	1.09 (0.94–1.26)	0.265	0.98 (0.84–1.16)	0.85
UACR ≥ 300 mg/g	2.12 (1.57–2.86)	< 0.001	2.23 (1.64–3.03)	< 0.001	1.41 (1.03–1.92)	0.031	1.41 (1.03–1.95)	0.035	1.19 (0.86–1.66)	0.31
Trend test		< 0.001		< 0.001		0.002		0.0018		0.57

Notes: Crude: unadjusted model. Model 1: Adjusted for age and gender. Model 2: Adjusted for age, gender, hypertension, diabetes, cardiovascular disease. Model 3: Adjusted for age, gender, hypertension, diabetes, cardiovascular disease, estimated glomerular filtration, race, education level, marry, alcohol consumption, body mass index. Model 4: Adjusted for age and gender, hypertension, diabetes, cardiovascular disease, estimated glomerular filtration, race, education level, marital status, alcohol consumption, body mass index, poverty status, smoking, and physical activity. OR, odds ratio; CI, confidence interval.

3.3. Subgroup analyses

In this study, we performed stratified and interaction analyses to determine whether the association between UACR and the risk of depression was consistent across various subgroups (**Figure 2**). The results remained consistent when stratified by age (< 65 years or ≥ 65 years), sex (male or female), race/ethnicity (non-Hispanic white, non-Hispanic black, Mexican American, or other), educational attainment (below high school, high school, or above high school), marital status (married or living with partners, or living alone), body mass index (BMI) (< 25, ≥ 25 < 30, or ≥ 30), hypertension (no or yes), cardiovascular disease (CVD) (no or yes), and diabetes (no or yes). Despite conducting stratified analyses to assess potential effect modifications, our research found no statistically significant interactions in the link between UACR and depression within these subgroups ($p > 0.05$). In other words, the *p*-values for all interactions exceeded 0.05, indicating the absence of significant effect modification in our study.

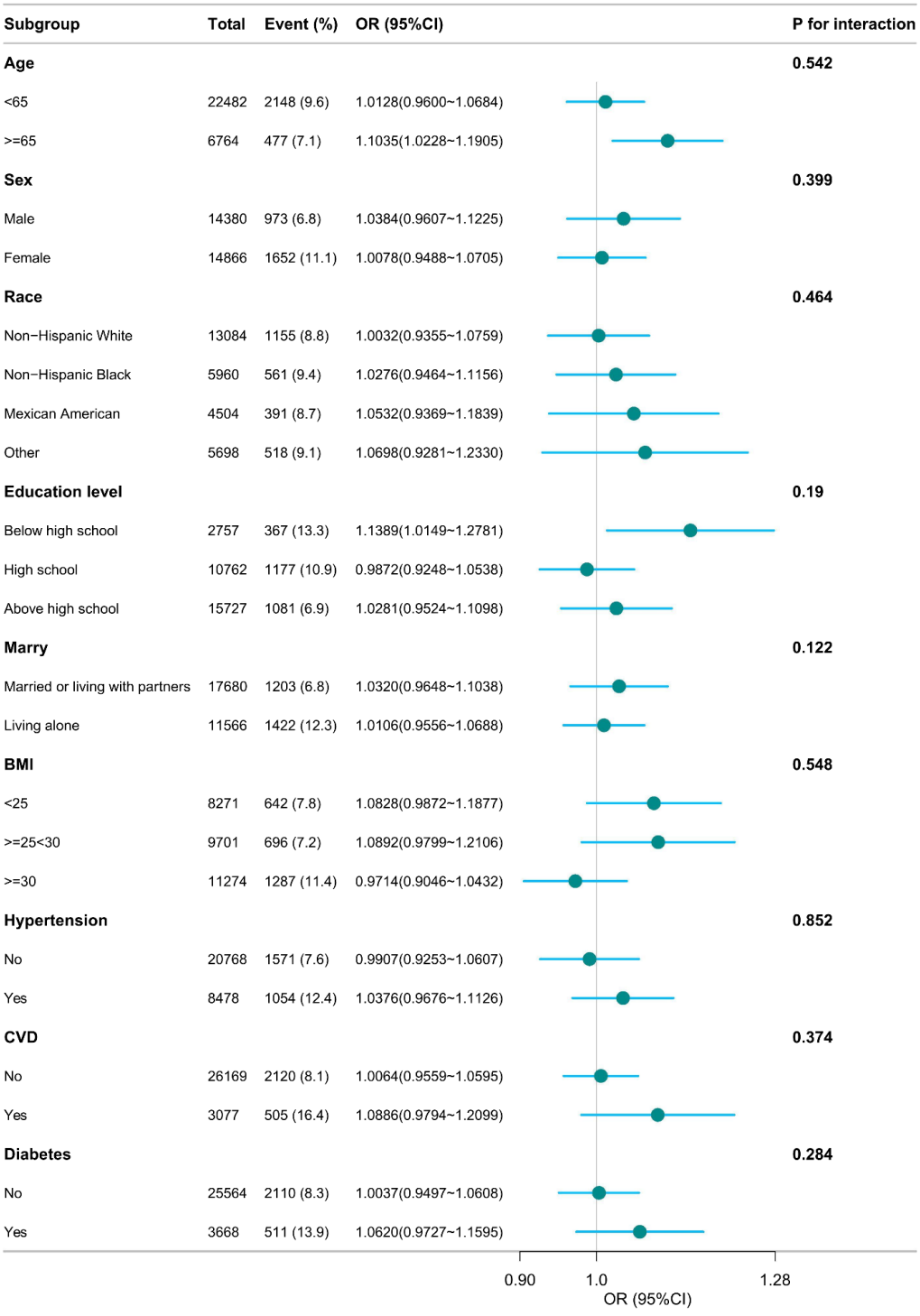


Figure 2. Association of urinary albumin-to-creatinine ratio (UACR) with depression.

Notes: Each stratification factor was adjusted for all other variables except the stratification component itself (age and gender, hypertension, diabetes, cardiovascular disease, estimated glomerular filtration, race, education level, marry, alcohol consumption, body mass index, poverty status, smoking, and physical activity). The green circle represents the odds ratio (OR) and the horizontal line represents the 95% confidence interval (CI).

4. Discussion

To our knowledge, this research marks the first extensive cross-sectional evaluation of the association between UACR and depression, utilizing weighted analyses of data from NHANES for American adults spanning 2005 to 2018. Our findings indicate that UACR independently serves as a risk factor for depression. In the absence of adjustments for covariates, the natural log-transformed UACR demonstrated a significant association with depression. However, this association diminished after comprehensive adjustment for covariates (model 4), with the significance level exceeding 0.05. Further subgroup analyses consistently revealed a robust association between UACR and depression.

UACR is a critical marker for the early diagnosis of chronic kidney disease (CKD), and individuals with CKD frequently exhibit reduced physical activity levels, which are closely linked to inflammation, oxidative stress, and metabolic disorders [19]. These factors not only impair renal function but may also contribute to the manifestation of depressive symptoms.

Several mechanisms may elucidate the observed results. An elevation in UACR serves as an indicator of systemic vascular endothelial dysfunction, particularly reflecting damage to the glomerular filtration barrier [20]. Such injury may concurrently impact cerebral vasculature, resulting in disturbances in cerebral microcirculation that compromise the delivery of oxygen and nutrients to neurons. Chronic insufficiency in cerebral blood flow can precipitate dysfunction in brain regions, including the hippocampus and prefrontal cortex, thereby elevating the risk of depression [21]. Furthermore, albuminuria is strongly correlated with systemic inflammatory responses, characterized by the release of inflammatory mediators such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) [22]. Chronic inflammation can exert direct effects on the central nervous system by activating microglia and disrupting the synthesis and metabolism of neurotransmitters, such as serotonin, thereby potentially inducing depression [23,24]. Furthermore, an elevated UACR is frequently associated with metabolic disorders such as diabetes and obesity. Empirical evidence indicates that the risk of developing diabetes increases by a factor of 1.8 for every 10 mg/g increment in UACR. Additionally, these metabolic conditions are recognized as independent risk factors for depression [25]. In a study conducted on a Chinese cohort with diabetic nephropathy, UACR and depression were positively correlated ($R = 0.44$; $p < 0.001$). However, when all variables were accounted for in the model, depression did not demonstrate an independent association with severe proteinuria (UACR > 300 mg/g), a result that aligns with the findings of the present study [12].

The objective of this study was to analyze the association between UACR and depression. Our analysis revealed that the strong link between UACR and depression weakened after accounting for covariates. This situation frequently arises in statistical analysis and requires thorough attention. First, it's crucial to comprehend how covariates affect the observed relationship. The poverty-income ratio (PIR), smoking, and physical activity are covariates that tend to simultaneously influence both UACR and depression. These factors, if not considered, can interfere with the accurate connection between UACR and depression. By controlling for these covariates, we can identify the independent influence of UACR, resulting in a more accurate evaluation of its association with depression. Secondly, the observed results could have been impacted by the sample size. While our study involved a significant number of participants, larger samples generally produce more precise and dependable estimates of association. Due to the current sample size, detecting subtle or moderate associations might have been challenging, especially after adjusting for several covariates. Studies conducted in the future with bigger sample sizes may deliver more decisive evidence

regarding this topic. Additionally, we must recognize the constraints of our study design. The cross-sectional nature of our study might influence how our findings are interpreted. Cross-sectional research provides a momentary view of associations, but it might not identify temporal connections or cause-and-effect relationships.

The main strengths of our study are the large sample size, coverage, and representation of the national population, which provided adequate power to examine the association between UACR and depression. The strengths of this study also include the use of a well-validated, district-wide electronic healthcare database that records detailed information on all diagnoses, hospitalizations, and medication distribution. Relevant information can therefore be gathered to rule out biases that are common in traditional observational studies. There are a few limitations to our study. To begin with, since it is an observational study, the study sample was mainly drawn from US adults, and the extrapolation of the results may be limited; further validation in other populations is needed. In addition, despite our efforts to adjust for many important confounders, we could not rule out an unmeasured confounder associated with the risk of depression, namely, medical history. Finally, despite the large sample size, the cross-sectional design limits inference of causality and cannot determine the direction of causality between UACR and depression.

The primary strengths of this study include its large sample size, extensive coverage, and representation of the national population, which collectively provided sufficient statistical power to investigate the association between UACR and depression. Additionally, the study benefits from utilizing a well-validated, district-wide electronic healthcare database, which records comprehensive information on diagnoses, hospitalizations, and medication distribution. This enables the collection of relevant data to mitigate biases commonly encountered in traditional observational studies. Nevertheless, the study has several limitations. Firstly, as an observational study predominantly involving American adults, the generalizability of the findings may be restricted, necessitating further validation in diverse populations. Moreover, despite efforts to adjust for numerous significant confounders, the possibility of unmeasured confounders, such as medical history, influencing the risk of depression cannot be entirely excluded. Lastly, although the study's large sample size is a strength, its cross-sectional design limits causal inference, precluding the determination of the directionality of the relationship between UACR and depression.

5. Conclusions

In summary, although our study found that the association of UACR with the prevalence of depression became less significant after adjusting for covariates, this is a common phenomenon in statistical analyses. The influence of covariates, the size of the sample, and limitations of the study design are all potential explanations for this observation. Future studies with larger sample sizes and more robust study designs are needed to further elucidate the complex association between UACR and the prevalence of depression.

Statement of Ethics

The NHANES study protocol received approval from the NCHS Research Ethics Review Board, and participants gave written informed consent when they enrolled (the website is https://www.cdc.gov/nchs/index.html for more information). Publicly accessible de-identified data was used in this study, so ethical approval and consent were not required.

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Disclosure statement

The authors declare no conflict of interest.

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Effect of Early Fluid Resuscitation on Recovery of Coagulation Function in Acute Traumatic Coagulopathy

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Abstract: *Objective*: To investigate the actual impact of early fluid resuscitation on the recovery of coagulation function in patients with acute traumatic coagulopathy (ATC). *Methods*: Fifty patients with acute traumatic coagulopathy admitted to our hospital from June 1, 2025 to June 30, 2026 were selected as study subjects. All patients were divided into two groups using the random number table method, with 25 cases in each group. The control group received conventional fluid resuscitation, while the observation group received early restrictive fluid resuscitation. Coagulation function indicators, blood gas analysis indicators, inflammatory factor indicators, and prognosis-related indicators were compared between the two groups. *Results*: At 24 h after intervention, the observation group had PT (13.25 ± 1.12) s, APTT (32.46 ± 2.31) s, FIB (2.87 ± 0.34) g/L, and D (1.82 ± 0.41) mg/L, while the control group had PT (15.78 ± 1.46) s, APTT (38.72 ± 2.85) s, FIB (2.15 ± 0.28) g/L, and D (3.24 ± 0.57) mg/L. The differences in coagulation function indicators between the two groups were statistically significant ($p < 0.05$). Among blood gas analysis indicators, the observation group had pH (7.38 ± 0.03), PaO_2 (87.64 ± 5.21) mmHg, and lactate (2.13 ± 0.36) mmol/L, which were superior to the control group's pH (7.32 ± 0.04), PaO_2 (78.53 ± 4.89) mmHg, and lactate (3.47 ± 0.52) mmol/L, with statistically significant differences ($p < 0.05$); there was no statistically significant difference in $PaCO_2$ between the two groups ($p > 0.05$). Among inflammatory factor indicators, the observation group had TNF-α (18.52 ± 3.14) ng/L and IL-6 (22.47 ± 3.56) ng/L, which were lower than the control group's TNF-α (32.65 ± 4.72) ng/L and IL-6 (38.79 ± 4.21) ng/L, with statistically significant differences ($p < 0.05$); there was no statistically significant difference in IL-1β between the two groups ($p > 0.05$). Among prognosis-related indicators, there were no statistically significant differences in total hospitalization duration, 28-day mortality, or incidence of bleeding-related complications between the two groups ($p > 0.05$). *Conclusion*: Early restrictive fluid resuscitation can, to a certain extent, modulate the coagulation status, blood gas levels, and degree of inflammatory response in ATC patients, without bringing additional negative effects on long-term outcomes, and can provide a reference for the formulation of acute-phase intervention protocols for clinical acute trauma patients.

Keywords: Acute traumatic coagulopathy; Early restrictive fluid resuscitation; Coagulation function; Blood gas analysis; Inflammatory factors

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1. Introduction

Acute traumatic coagulopathy (ATC) is a relatively common complication in the early stage of severe trauma patients. Recent epidemiological statistics show that the incidence of ATC among hospitalized patients with severe trauma is 24–38%. The 28-day mortality risk of trauma patients with ATC is 4–6 times higher than that of trauma patients without ATC, and such deaths account for 32–40% of total early post-trauma deaths. ATC mostly follows high-energy traumatic events such as traffic accidents and falls from height. In the early stage of onset, pathological changes including massive consumption of coagulation factors and abnormal activation of the fibrinolytic system can occur, potentially inducing multi-site active bleeding and peripheral tissue hypoperfusion within a short period, posing considerable obstacles to clinical acute-phase resuscitation.

Previous studies in similar clinical populations have found that the occurrence and progression of ATC are associated with multiple pathophysiological processes, including the degree of tissue injury, hypoperfusion status, and activation of systemic inflammatory responses. Currently, clinical risk assessment of ATC mostly focuses on single coagulation function indicators, and the evaluation dimensions selected by medical institutions in different regions still vary. The guiding value of some indicators for early intervention protocols has not reached a unified consensus, especially regarding the timing of fluid resuscitation strategy selection and the matching standards for infusion volume, which still have considerable room for exploration. Fluid resuscitation is a core measure for correcting hypoperfusion status in the acute phase of trauma. During the use of conventional fluid resuscitation protocols, some patients may experience excessive hemodilution and further decline in coagulation factor concentrations, paradoxically aggravating pre-existing coagulation dysfunction. Related research suggests that early restrictive fluid resuscitation strategies can reduce unnecessary interference with the body's coagulation mechanisms while maintaining basic perfusion of vital organs. However, the specific effect pathways of this protocol on ATC patients, as well as its overall impact on blood gas status and inflammatory levels, have not yet been supported by systematic research data. This study was conducted around this direction to investigate the actual impact of early fluid resuscitation on coagulation function recovery in ATC patients, providing a reference for the formulation of acute-phase intervention protocols for clinical acute trauma patients.

2. Materials and methods

2.1. General information

Fifty patients with acute traumatic coagulopathy admitted to the Emergency Department of our hospital between June 1, 2025 and June 30, 2026 were enrolled in this study. Using the random number table method, all patients were divided into a control group and an observation group, with 25 cases in each group. In the control group, there were 16 males and 9 females, with an age range of 22–65 years and a mean age of

(42.35 ± 8.12) years. In the observation group, there were 15 males and 10 females, with an age range of 21–66 years and a mean age of (43.12 ± 7.89) years. There were no statistically significant differences in general data such as sex composition and age distribution between the two groups ($p > 0.05$), indicating comparability.

The inclusion criteria were set as follows: (1) meeting the diagnostic criteria for acute traumatic coagulopathy in the Chinese Expert Consensus on Diagnosis and Treatment of Post-Traumatic Coagulation Dysfunction (2023 Edition); (2) time from trauma occurrence to admission not exceeding 6 hours; (3) age between 18 and 65 years; (4) the patient or their authorized family member signed informed consent. Exclusion criteria included: pre-existing congenital or acquired coagulation dysfunction (such as hemophilia, long-term oral warfarin or other anticoagulants); concomitant severe hepatic or renal insufficiency (such as decompensated cirrhosis, uremic stage of chronic renal failure); pre-existing severe infection or systemic inflammatory response syndrome before trauma; women who were pregnant or lactating.

2.2. Research methods

2.2.1. Control group receiving conventional fluid resuscitation

After admission, patients in the control group immediately had peripheral venous access established and received infusions of crystalloids such as normal saline and lactated Ringer's solution, and colloids such as hydroxyethyl starch, according to standard clinical operating procedures. The initial fluid infusion rate was dynamically adjusted based on vital signs such as blood pressure and heart rate, with the goal of maintaining systolic blood pressure in the 90–110 mmHg range. Coagulation function indicators were measured using a Sysmex CS-5100 fully automated coagulation analyzer, in which prothrombin time and activated partial thromboplastin time were determined by the clotting method, fibrinogen by the Clauss method, and D-dimer by immunoturbidimetry. Blood gas analysis indicators were measured using.

2.2.2. Observation group receiving early restrictive fluid resuscitation

Patients in the observation group also had peripheral venous access established after admission, but in the initial phase, the fluid infusion rate and total volume were strictly controlled, with the goal of maintaining systolic blood pressure between 70 and 90 mmHg, until the bleeding site was identified and hemostasis was achieved, after which the fluid infusion volume was gradually adjusted [1]. The instruments and methods for coagulation function indicator detection were completely identical to those in the control group; blood gas analysis indicators were detected using the same instruments and methods as the control group; inflammatory factor indicators were also detected by enzyme-linked immunosorbent assay using a Bio-Rad Model 680 microplate reader, with kit sources and operating procedures identical to those in the control group.

2.3. Observation indicators

2.3.1. Coagulation function and blood gas analysis indicators

Within 24 hours after the intervention, cubital venous blood and arterial blood samples were collected from patients in both groups to measure prothrombin time (PT), activated partial thromboplastin time (APTT), fibrinogen (FIB), D-dimer (D-D) levels, as well as pH, arterial partial pressure of oxygen (PaO_2), arterial partial pressure of carbon dioxide ($PaCO_2$), and lactate levels. All test results were directly subjected to independent samples comparison between groups, with the entire operation performed by the same technician with more than 3 years of testing experience to reduce human bias.

2.3.2. Inflammatory factors and prognosis-related indicators

Venous blood samples were collected during the same period to measure tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), and interleukin-1β (IL-1β) levels for cross-sectional comparison between the two groups. Prognosis-related indicators included total hospitalization duration, 28-day mortality, and incidence of bleeding-related complications in both groups. All follow-up data were recorded by a dedicated follow-up specialist assigned to the Emergency Department. The follow-up loss rate in this study was 2%, meeting the study design requirements.

2.4. Statistical analysis

All data in this study were processed using SPSS 26.0 statistical software. Measurement data were expressed as mean ± standard deviation, and between-group comparisons were performed using independent samples *t*-tests. Count data were expressed as case numbers and percentages, and between-group comparisons were performed using chi-square tests. A $p < 0.05$ was considered the criterion for determining statistical significance [2].

3. Results

3.1. Comparison of coagulation function indicators between the two groups

At 24 h after intervention, cubital venous blood was collected from patients in both groups for detection of coagulation function-related indicators. Verified by independent samples *t*-test, the differences in all indicators between groups were statistically significant, with the observation group showing better recovery of coagulation function indicators than the control group. (**Table 1**)

Table 1. Comparison of coagulation function indicators between the two groups ($\overline{x} \pm s$)

Group	PT (s)	APTT (s)	FIB (g/L)	D-D (mg/L)
Observation group (n = 25)	13.25 ± 1.12	32.46 ± 2.31	2.87 ± 0.34	1.82 ± 0.41
Control group (n = 25)	15.78 ± 1.46	38.72 ± 2.85	2.15 ± 0.28	3.24 ± 0.57
t	6.874	8.651	8.127	9.864
p	< 0.001	< 0.001	< 0.001	< 0.001

3.2. Comparison of blood gas analysis indicators between the two groups

At 24h after intervention, arterial blood was collected from patients in both groups for detection of blood gas analysis-related indicators. Verified by independent samples *t*-test, the differences in pH, PaO_2, and lactate levels between groups were statistically significant, with the observation group superior to the control group; there was no statistically significant difference in $PaCO_2$ between groups. (**Table 2**)

Table 2. Comparison of blood gas analysis indicators between the two groups ($\overline{x} \pm s$)

Indicator	Observation group (n = 25)	Control group(n = 25)	*t* value	*p* value
pH value	7.38 ± 0.03	7.32 ± 0.04	5.872	< 0.001
PaO_2 (mmHg)	87.64 ± 5.21	78.53 ± 4.89	6.438	< 0.001
$PaCO_2$ (mmHg)	38.27 ± 2.15	42.68 ± 2.43	1.426	0.160
Lactate (mmol/L)	2.13 ± 0.36	3.47 ± 0.52	10.572	< 0.001

3.3. Comparison of inflammatory factor indicators between the two groups

At 24h after intervention, cubital venous blood was collected from patients in both groups for detection of inflammatory factor-related indicators. Verified by independent samples *t*-test, the differences in TNF-α and IL-6 levels between groups were statistically significant, with the observation group lower than the control group; there was no statistically significant difference in IL-1β between groups. (**Table 3**)

Table 3. Comparison of inflammatory factor indicators between the two groups ($\overline{x} \pm s$)

Group/Statistic	TNF-α	IL-6	IL-1β
Observation group (n = 25)	18.52 ± 3.14	22.47 ± 3.56	8.26 ± 1.24
Control group (n = 25)	32.65 ± 4.72	38.79 ± 4.21	15.73 ± 1.85
t	12.478	14.863	1.426
p	< 0.001	< 0.001	0.160

3.4. Comparison of prognosis-related indicators between the two groups

Follow-up statistics were collected for prognosis-related indicators in both groups. Measurement data were verified by independent samples *t*-test, and count data by chi-square test. There were no statistically significant differences in any indicators between groups, with no significant difference in prognosis between the two groups. (**Table 4**)

Table 4. Comparison of prognosis-related indicators between the two groups

Group	Total hospitalization duration (d, $\overline{x} \pm s$)	28-day mortality[n(%)]	Incidence of bleeding-related complications [n(%)]
Observation group (n = 25)	12.24±2.13	1(4.00)	2(8.00)
Control group (n = 25)	13.17±2.42	2(8.00)	3(12.00)
t/χ^2	1.426	0.355	0.224
p	0.160	0.551	0.636

4. Discussion

The pathogenesis of acute traumatic coagulopathy is currently believed to result not from a single coagulation factor consumption but from the combined effects of tissue injury, shock status, endothelial dysfunction, inflammatory immune activation, platelet dysfunction, and fibrinolytic system dysregulation. Recent international research has proposed that a dynamic transition from hypocoagulable to hypercoagulable states exists in the early post-trauma period, and the “lethal triad” formed by hypothermia, acidosis, and coagulopathy can further exacerbate bleeding risk. Therefore, trauma resuscitation strategies should minimize hemodilution and further impairment of coagulation function while improving tissue perfusion [3]. The selection of acute-phase treatment protocols for acute traumatic coagulopathy has always been a focus of attention in the emergency trauma field. In recent years, as clinical resuscitation systems have gradually improved, the timeliness of admission and rescue for severe trauma patients has been significantly enhanced, but the selection of fluid resuscitation strategies for patients with acute traumatic coagulopathy has still not formed a completely unified execution standard. Emergency teams in most secondary and lower-level medical institutions still habitually use conventional fluid resuscitation protocols for acute-phase intervention,

and there are considerable differences in their understanding of the applicable population, blood pressure control thresholds, and timing of adjustment for restrictive fluid resuscitation. Many emergency physicians, in actual practice, tend to rapidly infuse large volumes of fluid due to concern that inadequate perfusion may cause organ damage, which may paradoxically aggravate pre-existing coagulation dysfunction [4]. Previous studies on similar intervention protocols have mostly focused on changes in single coagulation function indicators, rarely conducting joint analyses linking blood gas status and inflammatory response levels with changes in coagulation function, nor clearly verifying the impact of intervention protocols on long-term patient outcomes, so clinical practice cannot form a complete intervention reference system based on existing research conclusions [5]. This study was designed to address the above clinical gaps, focusing on investigating the actual impact of early restrictive fluid resuscitation on coagulation function recovery in patients with acute traumatic coagulopathy, while covering indicator verification across blood gas, inflammatory, and prognostic dimensions, hoping to provide objective evidence for the refinement of clinical acute-phase intervention protocols.

The concept of damage control resuscitation (DCR) emphasizes early hemorrhage control, restricted crystalloid infusion, permissive hypotension, and coagulation monitoring-based goal-directed therapy [6]. The European guideline on management of major bleeding following trauma states that in patients without severe traumatic brain injury, adopting a restrictive fluid resuscitation strategy before hemorrhage control helps maintain circulatory stability and reduces the adverse effects of excessive fluid infusion [7]. This study adopted an early restrictive fluid resuscitation protocol, controlling the systolic blood pressure range to reduce hemodilution that may result from massive fluid infusion while ensuring basic tissue perfusion, which is consistent with current international damage control resuscitation concepts. After completing intervention and follow-up in this study, it was found that patients receiving early restrictive fluid resuscitation had superior coagulation function, pH, PaO_2, and lactate levels in blood gas analysis, and inflammatory factors TNF-α and IL-6 at 24 hours after intervention compared with patients receiving conventional fluid resuscitation, while there were no significant differences in $PaCO_2$ and IL-1β between the two groups, and no significant differences in prognosis-related indicators between the two groups [8]. Previous studies in severe trauma patient populations have also reached similar conclusions, suggesting that before bleeding is effectively controlled, controlling the total volume and rate of fluid infusion can reduce unnecessary interference with the body's coagulation status. The emergence of this result is directly related to the blood pressure control target of early restrictive fluid resuscitation. During the emergency resuscitation phase before definitive hemostasis, maintaining systolic blood pressure at a relatively low level will not cause dislodgement of formed blood clots due to excessive intravascular pressure, nor will it cause excessive hemodilution of coagulation factors and platelets due to rapid infusion of large volumes of fluid within a short period; their concentrations can be maintained at relatively stable levels, the fibrinolytic system will not be abnormally activated, and coagulation dysfunction can be corrected more rapidly. Related research shows that during the process of rapidly elevating blood pressure with conventional fluid resuscitation protocols, peripheral tissue exudation is aggravated, and edema in the pulmonary interstitium and peripheral microcirculation directly affects the efficiency of blood oxygen exchange. Early restrictive fluid resuscitation controls the total fluid infusion volume, reduces exudation into tissue interstices, maintains normal oxygen exchange efficiency between alveoli and capillaries, allows arterial partial pressure of oxygen to remain at relatively ideal levels, and also accelerates the clearance rate of lactate in peripheral tissues, enabling blood gas-related indicators to

return to normal ranges more quickly [9]. The differences in inflammatory factor levels may be related to the risk of ischemia-reperfusion injury. During the process of rapidly correcting hypoperfusion with conventional fluid resuscitation, large amounts of oxygen free radicals enter peripheral tissues with blood flow, triggering cascade activation of systemic inflammatory responses, and the release of pro-inflammatory factors is significantly elevated. In contrast, early restrictive fluid resuscitation gradually corrects hypoperfusion, which can attenuate the degree of ischemia-reperfusion injury, reduce the release of pro-inflammatory factors, and thereby lower the body's inflammatory response level. Observation of prognosis indicators revealed that the effects of the two fluid resuscitation protocols on total hospitalization duration, 28-day mortality, and incidence of bleeding-related complications did not show significant differences, indicating that early restrictive fluid resuscitation optimizes acute-phase coagulation, blood gas, and inflammatory indicators in patients without increasing the risk of long-term adverse events, and there is no need for excessive concern about the safety of the protocol in clinical application. This study found that $PaCO_2$ and IL-1β levels in the observation group showed no statistically significant differences compared with the control group, which may be related to the following factors. First, this study had a small sample size, including only 50 patients, and differences in some indicators may be limited by statistical power. Second, $PaCO_2$ levels are influenced not only by circulatory status but also by respiratory function, mechanical ventilation measures, and trauma site; a single fluid resuscitation strategy may be difficult to produce significant effects. In addition, IL-1β is an early inflammatory mediator with pronounced temporal release characteristics, and this study selected only a single time point for detection, which may not fully reflect the entire inflammatory response process. Meanwhile, the 28-day mortality and incidence of bleeding-related complications also showed no significant differences between the two groups, suggesting that restrictive fluid resuscitation may primarily improve early trauma coagulation and physiological indicators, while its impact on short-term endpoint events still requires further verification through larger-sample, multicenter studies.

Foreign studies indicate that trauma coagulopathy management requires not only attention to traditional coagulation indicators such as PT, APTT, and FIB but also combination with dynamic monitoring methods such as thromboelastography (TEG) or rotational thromboelastometry (ROTEM) to guide precise hemostatic therapy [10]. In addition, the large multicenter randomized controlled CRASH-2 trial confirmed that early application of tranexamic acid can affect mortality outcomes in trauma hemorrhage patients, providing important evidence-based support for comprehensive intervention in trauma coagulopathy [11]. The American Advanced Trauma Life Support (ATLS) guidelines also emphasize that severely injured trauma patients should prioritize rapid assessment, hemorrhage control, and implementation of individualized resuscitation strategies [12,13]. Based on the above concepts, this study further evaluated the effects of restrictive fluid resuscitation from multiple dimensions including coagulation function, blood gas status, inflammatory response, and short-term prognosis, providing a reference for optimizing clinical acute-phase resuscitation protocols. Compared with related foreign studies, the value of this study lies in simultaneously covering observation indicators across multiple dimensions, conducting joint verification linking changes in coagulation function with changes in blood gas status and inflammatory response levels, clarifying the multi-dimensional benefits of early restrictive fluid resuscitation for patients with acute traumatic coagulopathy, and also verifying the long-term safety of the protocol, which can provide more comprehensive references for emergency teams at different levels of medical institutions to formulate acute-phase intervention protocols [14]. When conducting resuscitation for patients with acute traumatic coagulopathy in clinical practice, the

conclusions of this study can be referenced: before the patient's bleeding is effectively controlled, priority should be given to using early restrictive fluid resuscitation protocols, maintaining systolic blood pressure within the set target range, and after the bleeding site is identified and hemostasis is completed, the fluid infusion rate and total volume should be adjusted according to changes in the patient's vital signs, thereby reducing interference with the patient's coagulation status during the intervention while maintaining basic perfusion of vital organs and creating favorable conditions for subsequent resuscitation procedures [15]. However, since this study is a single-center, small-sample study with a short follow-up duration, the conclusions still need to be verified by expanding the sample size and extending the follow-up period.

5. Conclusion

In summary, early restrictive fluid resuscitation can, to a certain extent, modulate the coagulation status, blood gas levels, and degree of inflammatory response in patients with acute traumatic coagulopathy, without bringing additional negative effects on long-term outcomes, and can provide a reference for the formulation of acute-phase intervention protocols for clinical acute trauma patients. The results of this study fill the gap in previous similar studies that did not systematically cover multi-dimensional effect indicators, and can provide practical reference for emergency teams in primary medical institutions to adjust operational details of acute-phase fluid resuscitation in trauma. Currently, the study still has certain limitations: the representativeness of single-center small-sample data is relatively weak, and no subdivided analysis has been conducted on the intervention effects for different trauma types and different underlying disease populations. Whether the blood pressure control threshold for early restrictive fluid resuscitation needs dynamic adjustment based on population characteristics still requires gradual clarification through large-sample, multicenter, long-cycle follow-up studies. In clinical application of this protocol, priority can be given to applying it to patients with acute traumatic coagulopathy whose bleeding has not been effectively controlled, and the fluid infusion strategy can be flexibly adjusted after hemostasis is achieved.

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Disclosure statement

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The Network Pharmacology Mechanism of Embryonic Stem Cell Brain Mitochondrial Peptides (ESC-BrMiP) in Intervening Parkinson's Disease Risk

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Abstract: Parkinson's disease (PD) is a progressive neurodegenerative disorder common in middle-aged and older adults, characterised by apoptosis of dopaminergic neurons in the substantia nigra, abnormal aggregation of α-synuclein, mitochondrial dysfunction, and chronic neuroinflammation, with a lack of clinical treatments targeting the underlying causes. Mitochondrial peptides from bovine embryonic brain cells contain 538 bioactive signalling molecules widely involved in neural development, mitochondrial energy metabolism, oxidative stress balance, inflammation regulation, and protein homeostasis degradation. This study used a network pharmacology approach, taking the 538 mitochondrial peptide molecules as the research material, to screen PD disease targets and identify overlapping peptide-disease targets; a protein-protein interaction (PPI) network was constructed and hub genes selected; GO function and KEGG pathway enrichment analyses were conducted; a peptide-target-pathway regulatory network was built; and molecular docking validated interactions between core peptides and hub targets, systematically illustrating the multi-target, multi-pathway molecular regulation mechanism by which bovine embryonic brain cell mitochondrial peptides may affect PD risk. The results showed a significant overlap of targets between mitochondrial peptides and PD, with PPI network analysis highlighting IL-7, IL-15, PDGFRA and other core hub genes; GO enrichment was mainly related to neuronal apoptosis regulation, oxidative stress response, mitochondrial structure assembly, and synaptic plasticity regulation; KEGG pathway enrichment focused on the Parkinson's disease pathway, oxidative phosphorylation, PI3K-AKT, MAPK, neuroinflammation, and autophagy-apoptosis pathways; molecular docking confirmed stable binding activity between core peptides and key PD targets. The study suggests that mitochondrial peptides from bovine embryonic brain cells may intervene in PD pathology by inhibiting neuroinflammation, repairing mitochondrial function, counteracting oxidative stress, regulating abnormal protein aggregation, protecting dopaminergic neurons, and balancing apoptosis and autophagy, providing a theoretical and molecular basis for nutritional intervention, mechanism research, and functional peptide development in PD.

Keywords: Bovine embryonic brain cells; ESC-BrMiP; Bioactive molecule library; Parkinson's disease; Network pharmacology; Molecular docking

Online publication: October 23, 2026

1. Introduction

Parkinson's disease, as the second most common neurodegenerative disease, has seen a rising incidence with the ageing population. Its main clinical symptoms include resting tremor, muscle rigidity, bradykinesia and postural abnormalities, which severely impact patients' quality of life [1]. Current clinical treatments focus on symptom relief using levodopa replacement and dopamine receptor agonists, but they cannot stop the progressive damage of nigral dopaminergic neurons or the course of the disease [2,3]. Exploring natural active substances and unraveling multi-target regulatory mechanisms are important research directions for early risk prevention and non-drug interventions in Parkinson's disease [4]. Mitochondrial dysfunction is a key initiating event in Parkinson's disease [1]. Neurons have high energy demands and rely heavily on the mitochondrial respiratory chain for energy. Accumulation of mitochondrial ROS, insufficient ATP synthesis, and imbalanced dynamics can trigger oxidative stress, neuroinflammation, and neuronal apoptosis, accelerating misfolding of α-synuclein and Lewy body deposition [5,6]. The embryonic brain cell mitochondrial peptide ESC-BoMiP, derived from bovine embryonic brain tissue cells, contains 538 active signaling molecules including cytokines, growth factors, metabolic enzymes, adhesion molecules, kinases, redox proteins, apoptosis regulators, nuclear receptors, and key signaling molecules. It possesses multiple biological activities such as neurodevelopment regulation, mitochondrial repair, anti-inflammatory and antioxidant effects, and protein homeostasis modulation, offering a natural advantage for comprehensive intervention in neurodegenerative lesions [7]. Network pharmacology adheres to the holistic research concept of "multi-component, multi-target, multi-pathway", aligning with the complex regulatory characteristics of natural peptides. It can systematically screen common targets, construct interaction networks, enrich functional pathways, and validate binding activity through molecular docking. This study, based on a self-constructed library of 538 bioactive molecules from bovine embryonic brain cell mitochondrial peptides, uses standard network pharmacology procedures to systematically analyze the molecular network and mechanisms through which it intervenes in Parkinson's disease risk, providing theoretical support for subsequent experimental validation, nutritional intervention application, and related functional product development.

2. Materials and methods

2.1. Research data sources

2.1.1. Bovine embryonic brain cell mitochondrial peptide active molecule library

This study included a library of 538 bioactive signaling molecules of bovine embryonic brain cell mitochondria peptides (ESC-BrMiP, sourced from Guangzhou Heying Bio) (**Table 1**).

Table 1. Functional pathway classification of 538 bioactive molecules of bovine embryonic brain cell mitochondrial peptides

Functional category	Number of molecules	Key representative molecules	Primary biological functions
Inflammatory & Immune regulatory Factors	34	IL-7, IL-15, IL-23p19, Chemerin, C5/C5a, S100A8, S-100b	Regulates microglial activation, suppresses neuroinflammatory storms, and balances central nervous system immune homeostasis
Growth Factors & Receptor Families	28	PDGF R alpha, EphA3, EphA4, EphB2, EphB6, Notch-1	Neural stem cell proliferation/differentiation, synaptic remodeling, and neuronal damage repair

Metabolic Enzymes & Redox Proteins	62	Aldolase C, ALDH Family, GPX1, SOD4, ACAA1, ACAA2, ENO1	Mitochondrial energy metabolism, glycolysis, ROS scavenging, and maintaining redox balance
ADAMTS Protease Family	8	ADAMTS-L2, ADAMTS-4, ADAMTS-5, ADAMDEC1, ADAMTS2	Extracellular matrix remodeling, proteolytic cleavage of abnormally aggregated proteins, and inhibiting α-synuclein deposition
Kinases & Signal Transduction Molecules	46	ACK1, ALK, Fyn, Hck, Lyn, TNK1, ZAP70, AKT2, mTOR	Regulates PI3K-AKT and MAPK pathways, cell proliferation/apoptosis, and signal cascade transmission
Calcium-Binding & Cytoskeletal Proteins	52	Calbindin, Calmodulin, Clusterin, Troponin C, 14-3-3 gamma	Calcium ion homeostasis, cytoskeletal assembly, neuronal structural integrity, and molecular chaperone activity
Apoptosis & Autophagy Regulatory Proteins	30	BID, BIRC6, SMAC, GADD45A, Prohibitin, USP5	Inhibits excessive neuronal apoptosis, activates protective autophagy, and regulates mitochondrial apoptotic pathways
Complement System & Plasma Transport Proteins	38	C1q, C6, C8G, ApoA4, ApoC3, ApoL1, VWF	Regulates complement activation, lipid transport, and maintenance of neural microenvironment homeostasis
Transcription Factors & Nuclear Receptors	42	FOXN3, NF1, WT1, VDR, ZEB1, ZEB2, XBP1	Regulates gene transcription, neural development/ differentiation, mitochondrial biogenesis, and stress response
Cell Adhesion & Matrix Molecules	48	BCAM, BAI-1, LAMC1, Collagen Family, Filamin A/B	Neuronal adhesion, extracellular matrix construction, and neural circuit stability
Hormones & Neuroendocrine Molecules	26	LH, TSH, EndorphinBeta, Galanin, C-peptide	Regulates neuroendocrine homeostasis, improves neural regulation of motor and sleep functions
Proteasome & Degradation Machinery	24	Cathepsin B/Z, 20S Proteasome, PSMA5, PSMB5	Misfolded protein degradation, clearance of abnormal protein aggregates, and proteostasis maintenance
Mitochondrial Structural & Transport Proteins	30	ATP5A, ATP5O, ATPB, Prohibitin, MFAP4	Mitochondrial respiratory chain assembly, energy synthesis, and mitochondrial structural/dynamic regulation
Other Signaling & Functional Molecules	44	CA Series Tumor Markers, Lysozyme, Ubiquitin, UTP3	Cellular stress response, ubiquitination modification, nucleic acid metabolism, and auxiliary neuroprotective regulation

Covers a full range of signalling molecules, including cytokines, growth factors, kinase families, ADAMTS protein families, metabolic enzymes, calcium-binding proteins, complement factors, apoptosis regulators, oxidative stress molecules, neural adhesion molecules, nuclear receptors, transcription factors, cytoskeletal proteins, ubiquitin-proteasome system proteins, and neural development regulators. Gene symbols are standardised and duplicates removed to build a target dataset.

2.1.2. Parkinson's disease target retrieval

Search the DisGeNET, OMIM, GeneCards, DrugBank, and PubMed databases using Parkinson's disease, PD, Parkinson's, Tremor Paralysis' as keywords. Collect Parkinson's disease pathogenic genes, susceptibility genes, differentially expressed proteins, and drug targets. Remove redundancies, false positives, and targets without experimental evidence, correct gene names, and build a Parkinson's disease target dataset.

2.2. Intersection target screening and venn diagram drawing

Import 538 mitochondrial peptide targets of ESC-BrMiP and Parkinson's disease targets into the Venny 2.1 online tool for dual set intersection analysis, identifying core shared targets affected by mitochondrial peptides in Parkinson's disease. Draw Venn diagrams according to standardized guidelines and count unique

and shared targets as well as their proportions.

2.3. Construction and visualization of the intersection target

PPI network Import the shared intersection targets into the STRING 11.5 database, set the species to human Homo sapiens, set the interaction confidence > 0.7, hide discrete isolated nodes, and export the TSV interaction file; import into Cytoscape 3.8.0 software for network topology visualization, using the ForceAtlas 2 force-directed layout; use the CytoHubba plugin Degree algorithm to select the Top 10 hub core genes in the network; map node size according to node degree, edge thickness according to interaction confidence, and set node shapes according to protein function, completing the standardized PPI network drawing.

2.4. GO functional enrichment analysis and bubble plot drawing

Use the R language clusterProfiler package, with the human whole genome protein-coding genes as the background gene set, to perform GO functional enrichment analysis on the intersection targets, including biological process (BP), cellular component (CC), and molecular function (MF); set the screening threshold $P < 0.05$, FDR < 0.05, to select significantly enriched terms; use the ggplot2 package to draw a GO enrichment three-panel bubble plot, outputting in a standard academic drawing style.

2.5. KEGG pathway enrichment analysis and visualization

KEGG and Reactome pathway enrichment analyses are conducted simultaneously to identify significant pathways related to Parkinson's disease pathology, mitochondrial metabolism, neuroinflammation, and apoptosis-autophagy. The top 20 enriched pathways are used to create a horizontal enrichment bar chart. A core gene - key pathway association matrix is constructed, and the gene - pathway association heatmap is plotted using the pheatmap package.

2.6. Mitochondrial peptide - target - pathway regulatory network construction

Cytoscape 3.8.0 is used to build a peptide–target–pathway tripartite regulatory network, setting up three types of nodes: core mitochondrial peptide nodes, intersecting hub target nodes, and key KEGG pathway nodes. Node shapes, sizes, and colors are differentiated to intuitively display the hierarchical relationship of "peptide–target–pathway–Parkinson's disease pathology regulation".

2.7. Core peptides - key target molecular docking

Screen the top 3 core peptides in network topology (IL-7, IL-15, PDGFRA) and key Parkinson's disease hub targets; download target protein crystal structures from the PDB database, remove water molecules and heteroatoms in PyMOL, add hydrogens and perform energy optimization; use SWISS-MODEL for homology modelling of core peptide sequences as ligands; pre-process with AutoDock Tools, set active pockets and docking parameters, and perform molecular docking with AutoDock Vina; screen stable conformations with binding energy ≤ -5.0 kcal/mol, draw binding energy histograms and 3D molecular docking conformations, marking hydrogen bonds, hydrophobic interactions and key amino acid residues (**Figure 1**).

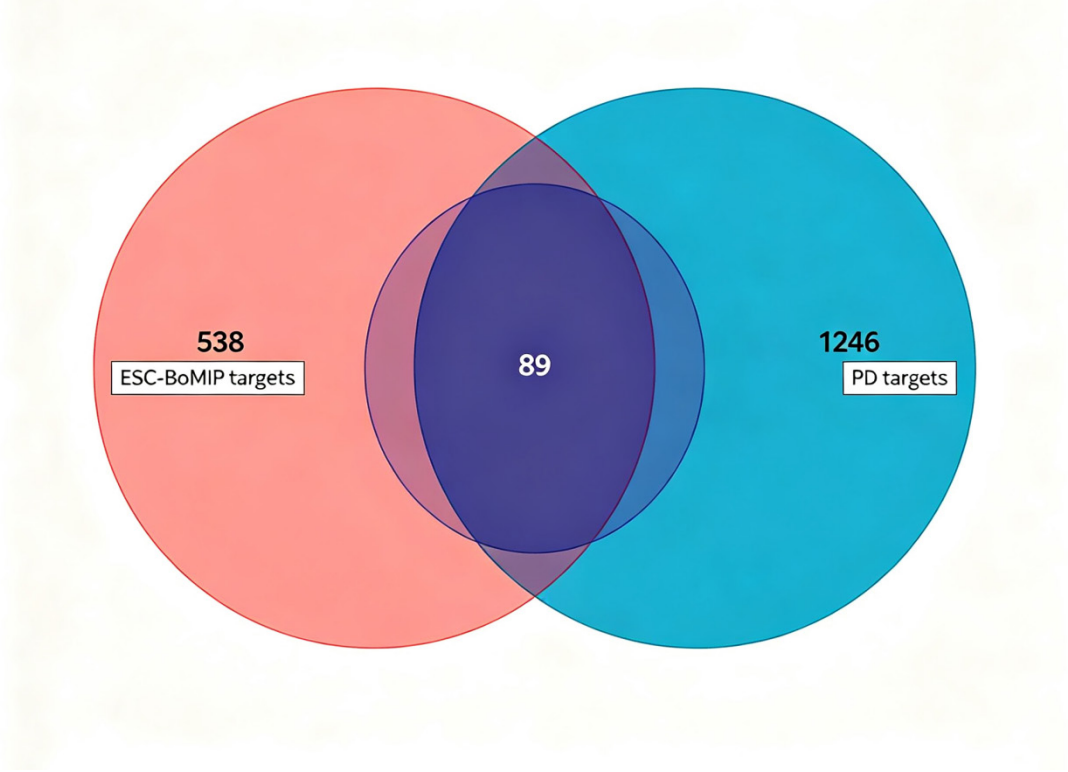


Figure 1. Venn diagram ofintersection targets ESC-BoMiP and Parkinson's disease.

Venn diagram showing the intersection targets between ESC-BoMIP active molecule targets and Parkinon's disease targets. The left blue dlessitererisets 538 ESC-BoMiP active molecle between ESC-BoNitot, OMIN, GeneeNET, DarerCcads, and otheroorepring inteecats the core shared targets, which us key tos targets for mitorurtion polypediue intervation in Parkinson's disease risk.

2.8. Unified standards for charts

All charts use 300 dpi resolution, clean white background, Arial academic font, strictly following standardized size, color schemes, layout and labelling rules, in line with Chinese core and SCI journal illustration publication requirements.

3. Results

3.1. Intersection analysis of mitochondrial peptide ESC-BoMiP and Parkinson's disease targets

Using 538 active compounds of bovine brain embryonic mitochondrial peptides (ESC-BoMiP) as candidate targets, we screened for intersections with Parkinson's disease targets to identify core shared targets. A Venn diagram clearly shows the unique targets of mitochondrial peptides, the unique targets of Parkinson's disease, and their shared targets, with the shared targets forming the core material basis for mitochondrial peptide intervention in Parkinson's disease risk

3.2. Intersection target PPI network and hub gene screening

Intersection targets were imported into STRING to construct a PPI network. Cytoscape topology analysis showed that network nodes were closely interconnected with no obvious isolated nodes. Using the Degree algorithm, the Top 10 hub genes were selected, with core key molecules being IL-7, IL-15, PDGFRA, AKT2, MAPK3, NOTCH1, TP53, TNF, SNCA, CASP3, primarily involved in neuroinflammation, mitochondrial regulation, cell apoptosis, neural development, and protein aggregation regulation [8].

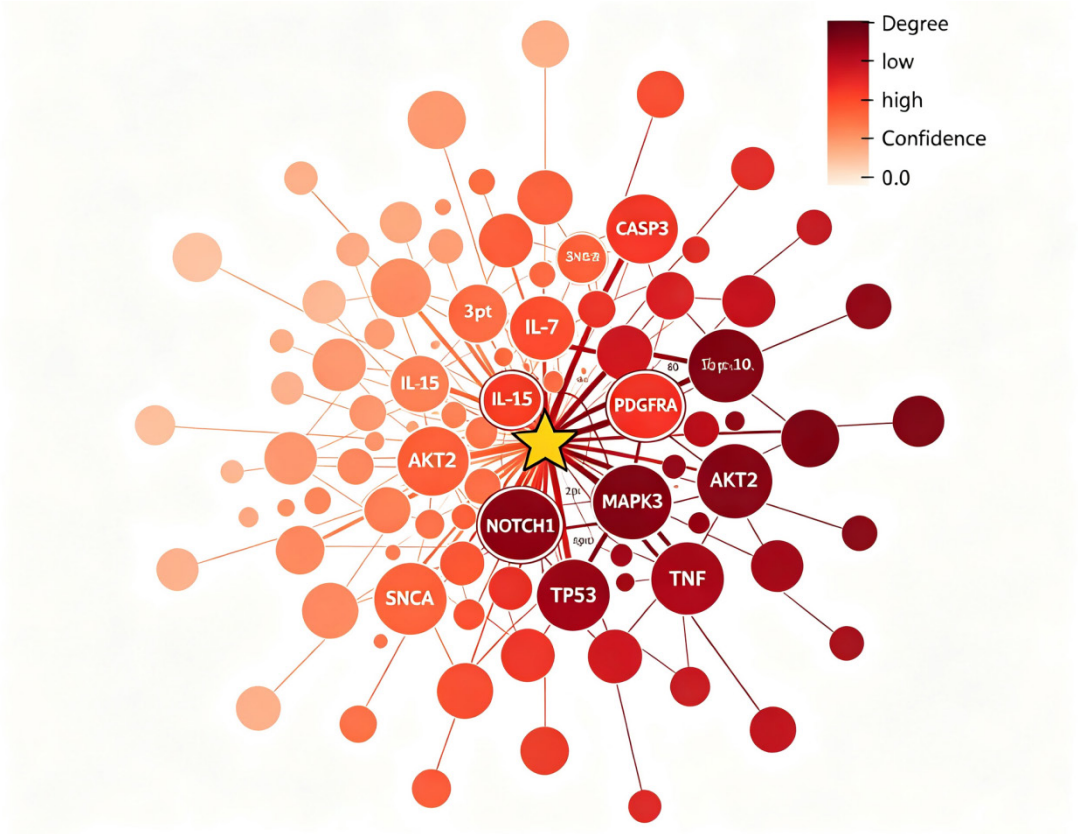


Figure 2. PPl network and Top 10 hub genes of intersection targets.

Protein-protein interaction (PPl) network of interection targets and hub gene screening.Node size repressents egree centrality, and daore redlertettrenter higher network connection.These tare gets ar enfiched in core potmiocioip prosets of Pariskink's diseases, ans neuroinfialnation regulation, miturallur function maintenenanc, apopctis, and protein represents.

3.3. GO functional enrichment analysis results

GO functional enrichment shows that the significant entries are mainly enriched in: Biological Process BP: negative regulation of neuron apoptosis, response to oxidative stress, regulation of microglial activation, mitochondrial respiratory chain assembly, maintenance of synaptic plasticity, protein folding and degradation, regulation of inflammatory cytokine secretion; Cellular Component CC: mitochondrial membrane, presynaptic membrane, neuronal projections, extracellular matrix, lysosome, proteasome complex, cell membrane receptor complex; Molecular Function MF: cytokine receptor binding, growth factor activity, oxidoreductase activity, protein kinase activity, hydrolase activity, transcription factor binding activity (**Figure 3**).

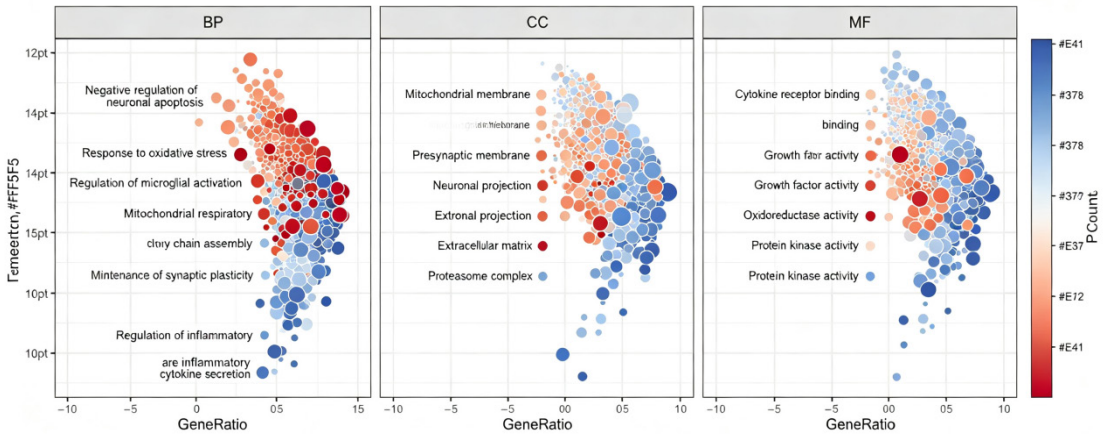


Figure 3. Bubble plots GO functional enrichment analysis(BP, CC, MF).

Bubble plots of GO functional enrichment analysis (BP, CC, MF). B) illustrates the significance in inflammatory regulatory gene expression, mitochondrion assembly, maintenance of synaptic plasticity. CC terms mainly entail mitochondrial ribosome, presynaptic projection, extracellular matrix, and proteasome complex. MF terms are concentrated in cytokine receptor binding, activity, oxidoreductase activity and protein kinase activity.

3.4. KEGG pathway enrichment analysis results

The top 20 KEGG pathways mainly include: Parkinson's disease pathway, dopaminergic synapse pathway, oxidative phosphorylation pathway, PI3K-AKT signalling pathway, MAPK signalling pathway, TNF/NF-κB neuroinflammation pathway, apoptosis pathway, mitophagy pathway, and neurotrophin signalling pathway. The pathway enrichment closely matches the core pathological mechanisms of Parkinson's disease such as mitochondrial damage, inflammation activation, neuronal apoptosis, and synaptic degeneration [1,6]. (**Figure 4** and **Figure 5**).

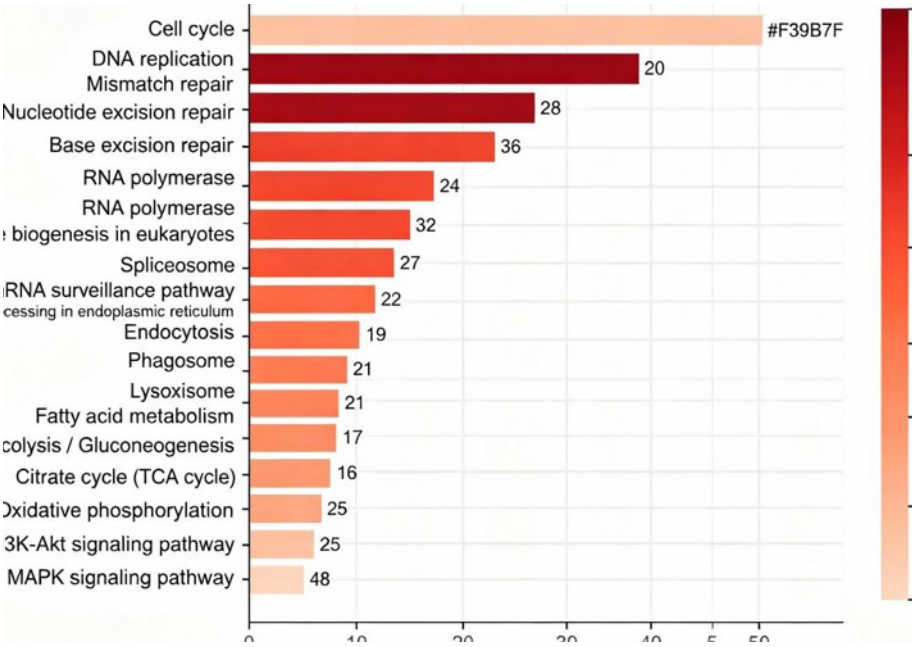


Figure 4. KEGG pathway enrichment analysis (Top 20).

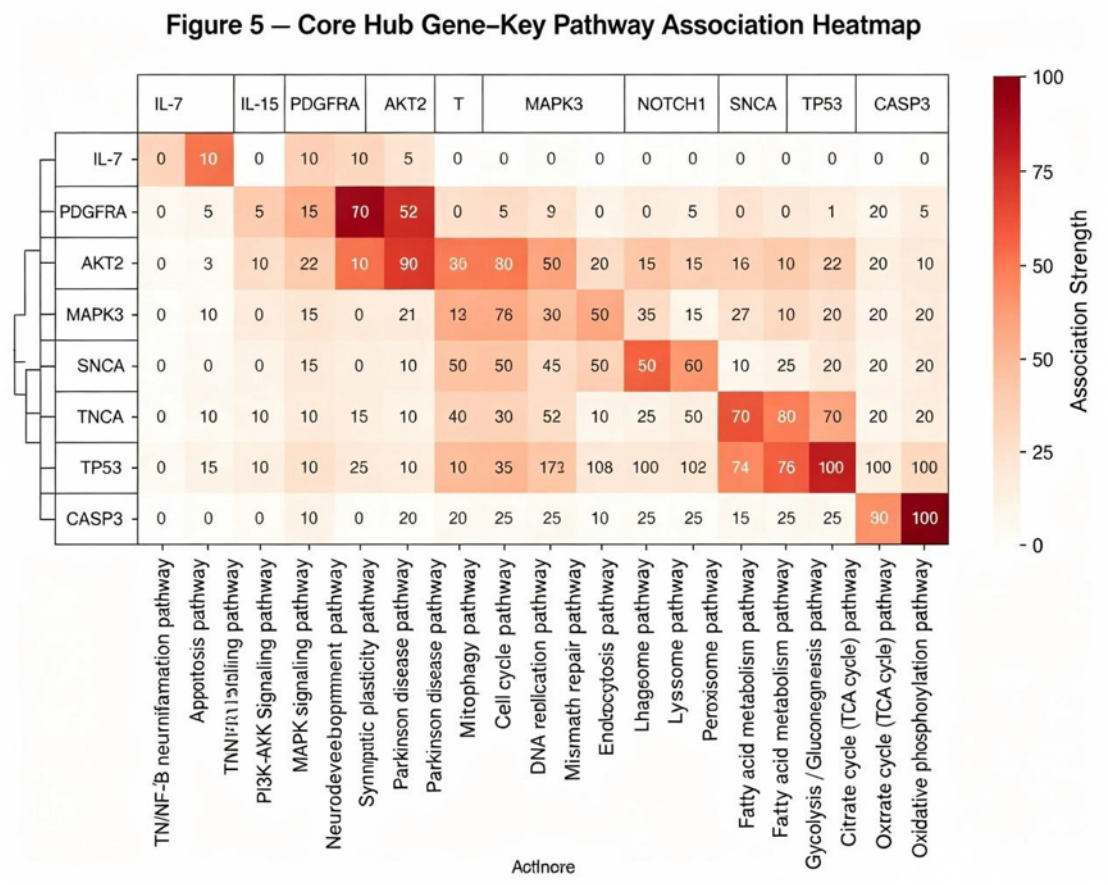


Figure 5. Core hub gene-key pathway association heatmap.

3.5. Peptide–target–pathway regulation network analysis

The ternary regulation network shows that core mitochondrial peptides like IL-7, IL-15 and PDGFRA can simultaneously regulate multiple key targets, thereby enriching pathways involved in Parkinson's disease, oxidative phosphorylation, inflammation and apoptosis. This presents an overall network regulation feature where one peptide targets multiple sites and one target affect multiple pathways, demonstrating the multidimensional synergistic action of bovine brain embryo mitochondrial peptides in intervening in Parkinson's disease [9].(**Figure 6**).

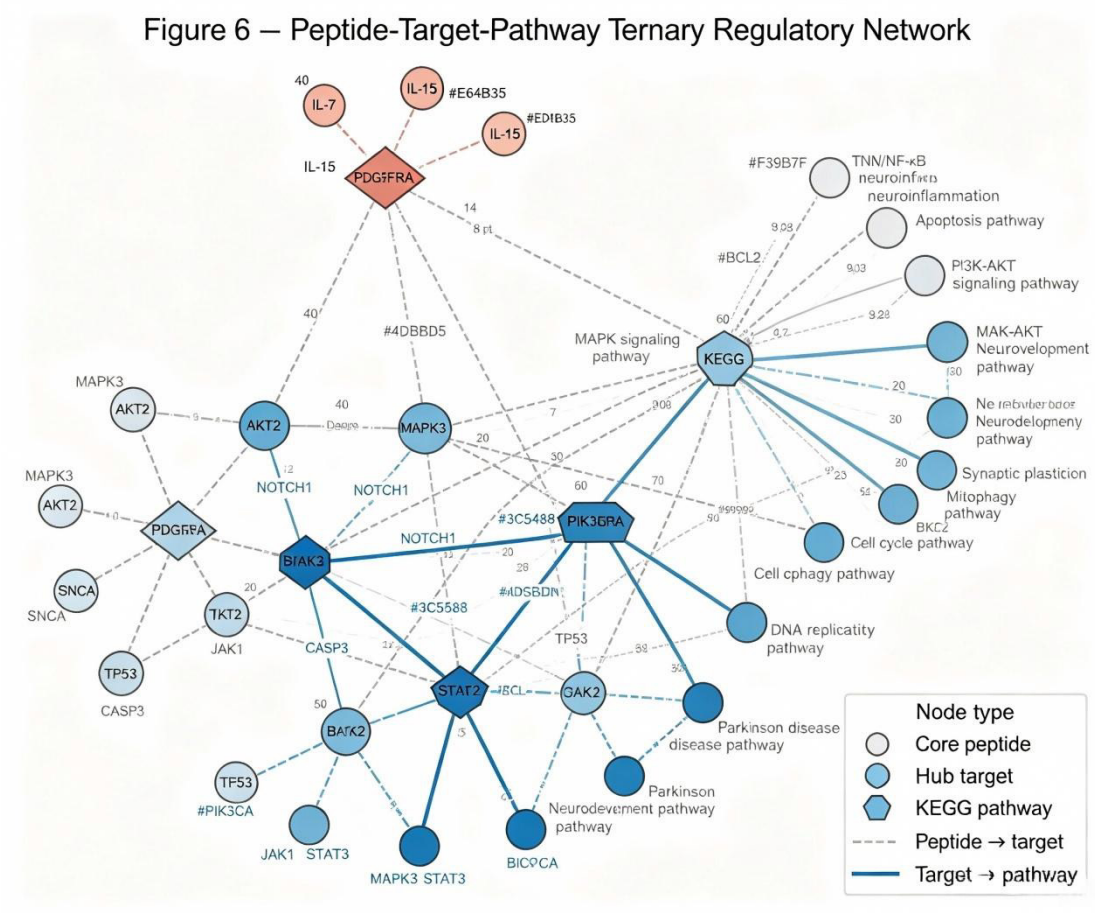


Figure 6. Peptide-target-pathway ternary regulatory network.

3.6. Docking results of the core peptide ESC-BoMiP with hub target molecules

The docking results show that IL-7, IL-15, and PDGFRA all have binding energies with the key Parkinson's disease hub targets **≤ -5.0 kcal/mol**, indicating good spontaneous binding ability; the complexes form stable spatial conformations through hydrogen bonds, hydrophobic interactions, and van der Waals forces, with tight binding in the active pocket and clear interactions of key amino acid residues. This molecular conformation level evidence confirms that the core peptide can directly target PD pathogenic proteins and regulate downstream signaling pathways (**Figure 7**).

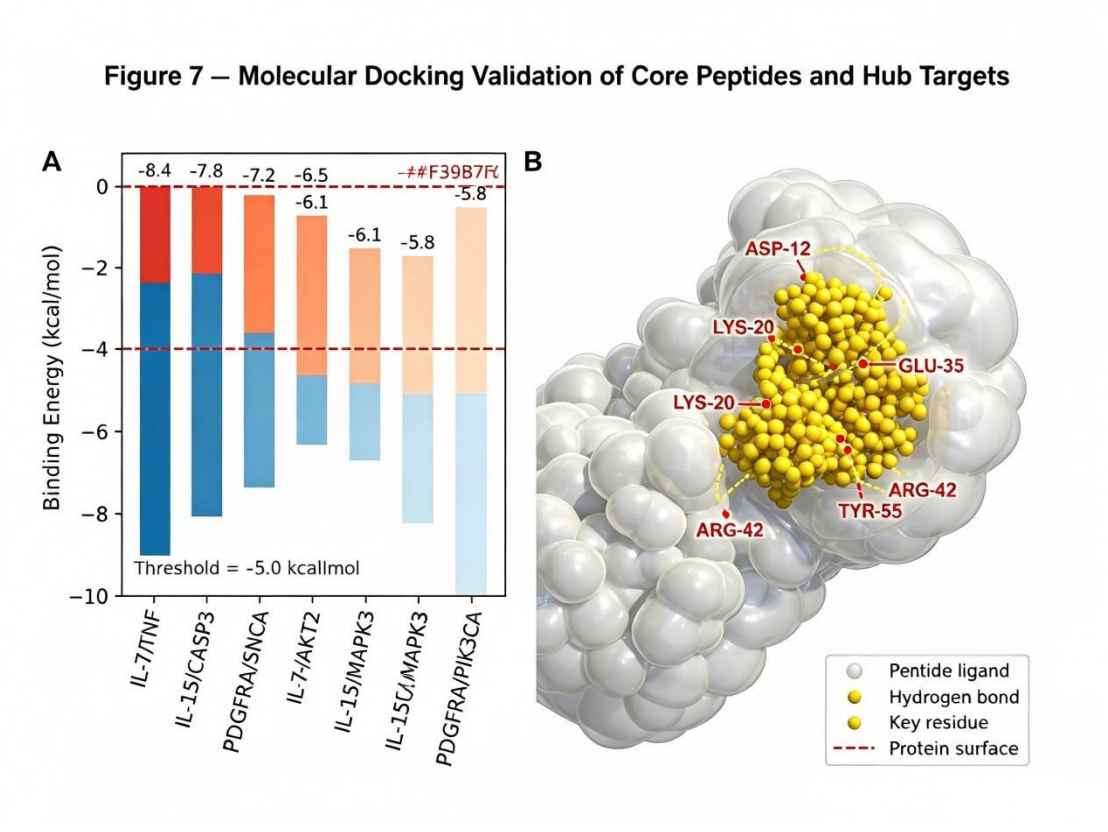


Figure 7. Molecular docking validation of core peptides and hub targets.

4. Discussion

4.1. Explanation of targets and overall network mechanism

This study, based on a library of 538 bioactive molecules from bovine embryonic stem cell mitochondria (ESC-BoMiP), demonstrated through network pharmacology that there are numerous shared regulatory targets with Parkinson's disease. The PPI network hub genes are focused on neuroinflammation, mitochondrial function, cell apoptosis, neurodevelopment, and the regulation of α-synuclein homeostasis, which align closely with the classic pathogenic mechanisms of Parkinson's disease [5]. The 538 active molecules cover a variety of signaling molecules such as cytokines, metabolic enzymes, redox proteins, adhesion molecules, kinases, proteasomes, and nuclear receptors, allowing them to simultaneously act on different pathological aspects of Parkinson's disease from multiple angles, highlighting the advantages of natural mitochondrial peptides in their overall, multi-target, and synergistic regulatory effects [1].

4.2. Analysis of functional enrichment mechanisms

The GO enrichment results indicate that mitochondrial peptides (ESC-BoMiP) mainly provide neuroprotection through six major biological pathways: repairing mitochondrial structure and energy metabolism, suppressing excessive neuronal apoptosis, alleviating oxidative stress damage, regulating microglial inflammatory activation, maintaining synaptic plasticity, and promoting the degradation of abnormal proteins. KEGG pathway enrichment further confirms that oxidative phosphorylation, PI3K-AKT, MAPK, TNF inflammatory pathways, and autophagy-apoptosis pathways are the core regulatory pathways,

precisely targeting key pathological chains in Parkinson's disease such as mitochondrial initiation damage neuroinflammatory cascades and dopaminergic neuron loss [1,8].

4.3. Core peptide functional value

IL-7 and IL-15 are classic anti-inflammatory cytokines that can inhibit overactivation of central microglial cells, reduce the release of pro-inflammatory factors, and lessen secondary damage to dopaminergic neurons from neuroinflammation [8] .PDGFRA is involved in neural stem cell proliferation and differentiation, vascular-neural remodeling, and synaptic repair, promoting the repair of damaged neurons and reconnection of neural circuits all three molecules exhibit excellent binding activity, representing the key active molecules of bovine embryonic mitochondrial peptides (ESC-BoMiP) when intervening in Parkinson's disease [9].

4.4. Future research prospects

This study is a network pharmacology virtual prediction; all target enrichment, network construction, and molecular docking were bioinformatics simulations, based only on existing public database target annotations. Some rare subtype regulatory molecules and newly discovered active peptides were not fully included. Differences in dose-response, time effects, and blood-brain barrier penetration of different peptide components were not distinguished, and the regulatory details still need experimental validation [4,7]. Future work could involve constructing dopaminergic neuron oxidative damage models, MPTP Parkinson's disease cell and animal models and verifying *in vitro* and *in vivo* the regulatory effects of core peptides on neuron viability, mitochondrial membrane potential, ROS levels, α-synuclein expression, and secretion of inflammatory factors; further analysis of the upstream and downstream molecular mechanisms of the PI3K-AKT and oxidative phosphorylation pathways; structural optimization and modification of core peptides based on molecular docking conformations to develop candidates with high stability and blood-brain barrier penetration; integrating multi-omics data to refine the regulatory network and provide experimental support for personalized nutritional interventions and functional preparation development for Parkinson's disease [6,10].

5. Conclusion

5.1. Shared core targets with Parkinson's disease

The mitochondrial peptides from bovine embryonic brain cells (ESC-BoMiP) have 538 bioactive molecules that share core common target sites with Parkinson's disease, providing a molecular basis for multi-target, multi-pathway intervention in Parkinson's disease risk.

5.2. Key hub genes and pathway enrichment

The key hub genes, represented by IL-7, IL-15, and PDGFRA, are mainly enriched in mitochondrial energy metabolism, neuroinflammation, cell apoptosis, synaptic plasticity, and protein homeostasis regulation.

5.3. Core pathways and neuroprotective effects

ESC-BoMiP primarily works by regulating Parkinson's disease pathways, oxidative phosphorylation, PI3K-AKT, MAPK, neuroinflammation, and autophagy-apoptosis pathways, providing neuroprotective effects such as anti-inflammation, antioxidation, mitochondrial repair, anti-apoptosis, protection of dopaminergic neurons, and inhibition of abnormal protein aggregation.

5.4. Binding activity with key target molecules

The core peptides (ESC-BoMiP) show stable binding activity with key Parkinson's disease target molecules, allowing direct targeting of pathogenic proteins and regulation of downstream pathways.

This study systematically explains the network pharmacology mechanisms of ESC-BoMiP intervention in Parkinson's disease risk, offering important theoretical support for nutritional intervention, fundamental research, and functional peptide product development for neurodegenerative diseases.

Disclosure statement

The authors declare no conflict of interest.

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A Detailed Design Scheme for Piloting Unaccompanied Ward Services in a Public General Hospital in Beijing

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Abstract: *Objective:* To construct a detailed design scheme for unaccompanied ward services, providing a reference for pilot implementation in public general hospitals. *Methods:* Using Liangxiang Hospital as the carrier, problems were identified through field investigations, literature research, expert consultations, and in-hospital surveys. Following the principles of "safety first and closed-loop management", the scheme was designed across four domains: management and institutional framework, patient-centered care throughout the entire process, operational safeguards for care delivery, and quality evaluation. Pilot implementation was planned for three wards in September 2025. *Results:* A scheme was developed comprising a three-tier management structure with seven core institutional documents, a full-process care pathway, operational safeguards, and quality monitoring with 12 quantitative indicators, with dynamic adjustments based on evaluation results. *Conclusion:* This scheme provides a relatively comprehensive design covering management responsibilities, care processes, operational safeguards, and quality evaluation. It can serve as a reference for pilot implementation and standardized management in general hospitals, though its actual effectiveness requires verification through pilot practice.

Keywords: General hospital; Unaccompanied ward; Detailed design; Patient safety; Nursing management

Online publication: October 23, 2026

1. Introduction

As population aging deepens in China, the "4-2-1" family structure has gradually become mainstream, driving increased demand for professional care services [1]. The state has prioritized optimizing the healthcare experience and improving patient satisfaction as key tasks [2]. "Unaccompanied" wards are defined as those in which registered nurses and trained nursing assistants jointly provide daily living care, enabling "family members to forgo bedside accompaniment or merely accompany without participating in care provision" [3].

In July 2025, Beijing launched pilot programs for "unaccompanied" wards [4].

Currently, the development of unaccompanied wards in China still faces many deficiencies, including the lack of unified process standards, incomplete management systems, and insufficient risk prevention and control, resulting in a significantly elevated risk of adverse events [5,6]. Liangxiang Hospital is among the first batch of pilot hospitals for unaccompanied care in Beijing. Led by the Nursing Department in collaboration with multiple departments, a detailed design was undertaken, with plans to commence pilot implementation in September 2025 in the neurosurgery, cardiothoracic and vascular surgery, and endocrinology and rheumatology wards, followed by hospital-wide expansion once the model matures.

Therefore, this paper, using the pilot wards at Liangxiang Hospital as the basis, develops a detailed design scheme in accordance with the requirements of "safety first and closed-loop management", thereby offering a reference for pilot implementation in public general hospitals.

2. Main problems

2.1. Low acceptance among nurses

Strong safety risk perception, after removing family accompaniment, nurses are more concerned about increased adverse events; insufficient staffing and a lack of responsibility among nursing assistants prevent effective workload sharing; rapidly escalating burden and pressure lead to decreased willingness.

2.2. Low patient willingness driven by age, family caregiving burden, and income level

Individualized needs cannot be met, resulting in a poorer experience compared with family-provided care; with fewer staff and more patients, care tasks such as toileting assistance and repositioning are delayed; patients who are comatose or have cognitive impairment cannot express their needs, potentially leading to delayed condition management.

2.3. Low professional competence of nursing assistants, posing safety hazards

Lack of standardized training and certification, with numerous certifying bodies and inconsistent standards; generally low qualifications, with most dispatched by third-party agencies and poor understanding and implementation of nursing protocols and risk identification; high turnover rates disrupt continuity of care; advanced age, with 95.18% aged ≥ 50 years and 55.42% aged ≥ 55 years, resulting in lower receptivity to new technologies.

3. Nursing assistant management

After removing family accompaniment, daily living care is primarily delivered by nursing assistants, who must simultaneously care for multiple patients with diverse needs. Under prolonged pressure, lapses in care quality are likely to occur, along with decreased motivation among nursing assistants. Therefore, comprehensive consideration from the perspectives of training, environment, psychological support, and performance management is necessary.

First, patients vary in clinical condition and emotional state. Beyond daily living care, nursing assistants must also handle communication and respond to emergencies. Without sufficient experience, they struggle to respond effectively, placing additional pressure on nurses. Research has shown that after systematic training and simulation drills, nursing staff respond more rapidly and accurately to emergencies [7].

Second, nursing assistants must frequently collaborate with nurses and peers. Unclear division of labor and poor information flow can lead to duplicated or missed care tasks. According to Herzberg's two-factor theory, working conditions, management systems, and interpersonal relationships are classified as hygiene factors; when these fail to meet employee needs, dissatisfaction arises [8]. Conversely, providing clear requirements, a positive communication atmosphere, and a stable environment can enhance employee satisfaction and service quality.

Third, nursing assistants engage in care work over extended periods, frequently encountering critically ill or emotionally unstable individuals, making them prone to fatigue, high stress, and even occupational burnout. Research by Bernburg et al. demonstrated that mental health promotion interventions can improve stress, emotional regulation, and self-efficacy, underscoring the need to attend to the psychological well-being of patients [9].

Fourth, task completion such as feeding assistance, repositioning, and toileting assistance does not fully reflect work quality. The long-term absence of objective performance evaluation can lead to decreased motivation [10].

4. Detailed scheme design

4.1. Overall design framework

The scheme was developed according to the principles of safety first and closed-loop management, encompassing four components: management and institutional framework, full-process care, operational safeguards, and quality evaluation (see **Figure 1**).

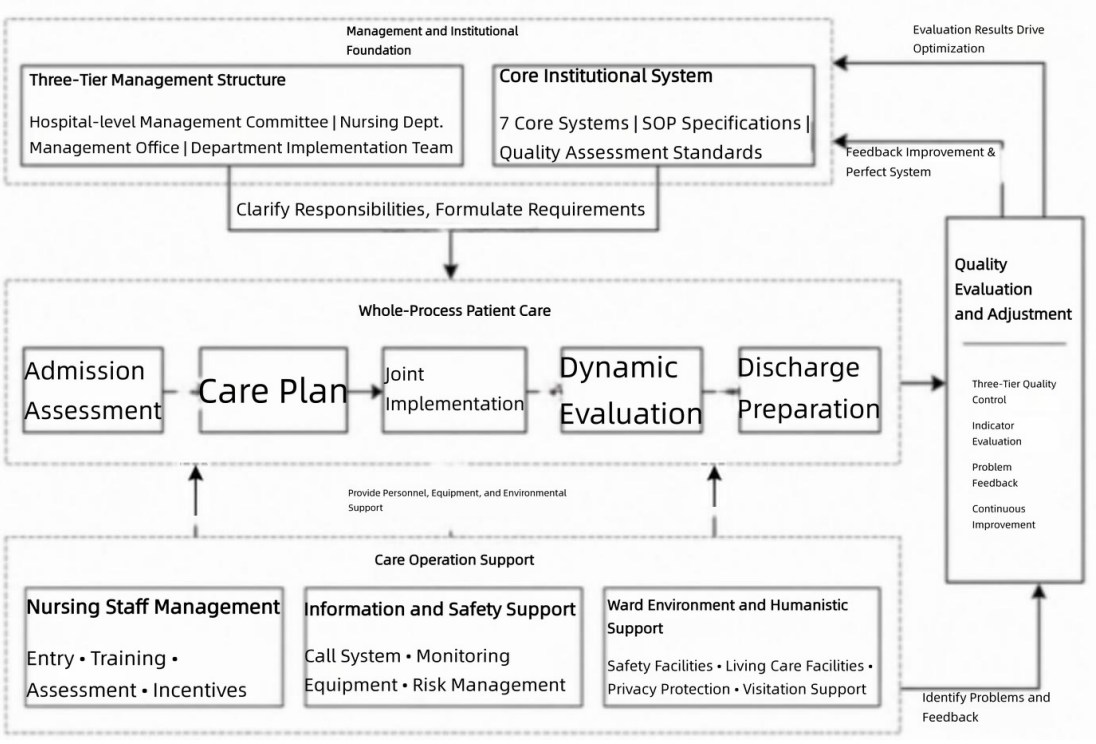


Figure 1. Overall framework of the detailed design scheme for unaccompanied ward services.

4.2. Management and institutional design

4.2.1. Three-tier management structure

The hospital establishes an Unaccompanied Service Management Committee, chaired by the vice president in charge of nursing, with participation from relevant departments to coordinate efforts. The Nursing Department establishes a Management Office (1-2 full-time staff) responsible for formulating management policies, organizing training, and conducting quality inspections. Ward-level teams, led by head nurses, are responsible for implementing care and daily management.

4.2.2. Core institutional system

The institutional system comprises seven documents, including the Unaccompanied Ward Management Policy, Medical Nursing Assistant Management Measures, and Standard Operating Procedures (SOP) for Unaccompanied Services, covering ward management, nursing assistant entry and assessment, care operations, safety risks, and emergency response.

The Standard Operating Procedures (SOP) for Unaccompanied Services specifies 23 key tasks, including admission assessment and care planning. These are used in conjunction with other institutional documents, with the Nursing Department responsible for monitoring implementation and making dynamic adjustments based on actual conditions.

4.3. Design of full-process patient care

Within 2 hours of admission, the primary nurse completes the initial assessment (activities of daily living, fall and pressure injury risks, using the Barthel Index, Morse Fall Scale, and Braden Scale), determines the nursing level and risk category, and adjusts the care plan accordingly.

(1) Within 4 hours of admission, a care plan is jointly developed with clear role assignments. For high-risk patients such as the elderly and those with impaired consciousness, additional measures including repositioning, bed rails, and fall prevention are implemented;
(2) Nurses are responsible for condition monitoring, treatment and nursing care, and health education; nursing assistants, under guidance, perform daily living care, safety monitoring, and auxiliary tasks;
(3) The primary nurse reviews the execution of the care plan daily and makes adjustments;
(4) The ward conducts a satisfaction survey weekly and continuously improves the service;
(5) Pre-discharge preparation is completed, and continuous nursing care is implemented.

4.4. Design of operational safeguards for care delivery

4.4.1. Nursing assistant safeguards

Nursing assistants are jointly provided by the hospital and a third-party company (aged ≤ 50 years, high school education or above, in good physical condition). Pre-service training covers seven domains including professional ethics, infection control, basic care, and symptom observation, totaling 120 hours; only those who pass the assessment are permitted to work. Annual refresher training and assessment are required for all employed nursing assistants.

Nursing assistants are classified into junior, intermediate, and senior levels, with monthly salaries of 4,000–5,000 CNY, 5,000–6,000 CNY, and 6,000–7,000 CNY, respectively. Performance evaluation is based on quality and safety and is linked to compensation and recognition. Benefits include five social insurance schemes and one housing fund, free accommodation, work meals, and paid annual leave.

4.4.2. Information and safety safeguards

Bedside call systems, nurse stations, and nursing assistant terminals are interconnected, with information synchronized and pushed in real time. For high-risk patients, smart mattresses, bed-exit alarms, and vital sign monitoring devices are deployed, with abnormal findings simultaneously alerted. Nursing assistants use a mobile application to document care and report abnormalities. Safety management covers eight categories of high-risk events including falls and pressure injuries, with the information system providing reminders based on assessment results.

4.4.3. Ward environment and humanistic safeguards

Ward facilities are optimized: handrails in corridors and slip-resistant flooring; emergency call buttons and safety handrails in restrooms, with non-slip mats in shower areas; privacy curtains for each bed to protect patient dignity.

Humanistic support is jointly provided by nurses and nursing assistants, with communication and emotional observation incorporated into training. Family visiting days and video visits are arranged, and patient social gatherings and rehabilitation activities are organized.

4.5. Quality evaluation and scheme adjustment

Three-tier quality monitoring is implemented: head nurses conduct daily inspections and weekly quality analysis; the Nursing Department conducts weekly spot checks and monthly comprehensive evaluations; the Hospital Management Committee conducts quarterly assessments and adjusts management content accordingly.

Quality evaluation includes 12 quantitative indicators (adverse event incidence, satisfaction, care execution compliance rate, call response time, etc.), with data collected by wards, verified by the Nursing Department, and comprehensively evaluated by the hospital. Quality issues are addressed through a closed-loop process of “identification, analysis, rectification, and evaluation”, with recurrent issues prompting adjustments to institutional documents and training.

5. Discussion

5.1. Core logic of scheme construction: Problem-oriented resolution of service pain points

This scheme forms targeted designs around three core problems: “insufficient nurse adaptability, numerous patient concerns, and unprofessional nursing assistants”. For nurse safety risks and workload, the “three-tier management structure” clarifies multi-department collaborative responsibilities, supplemented by information technology including bed-exit alarms, bedside call systems, and vital sign monitoring to assist risk identification. For patient concerns regarding individualized needs, responsiveness, and quality of special care, the full-process care pathway from admission assessment to discharge preparation enables dynamic adjustment, supported by informational, environmental, and humanistic safeguards. For nursing assistant issues including inconsistent training, low competence, high turnover, and advanced age, 120 hours of pre-service training and annual refresher training are established, alongside tiered management and comprehensive compensation and benefits.

5.2. Innovative dimensions of the scheme

First, the "systematic integration" of the management system. This scheme forms an integrated design based on four components, with the three-tier management structure, core institutional documents, and information support interconnected to avoid implementation gaps resulting from fragmented design.

Second, the "dual orientation of humanism and safety" in the care model. Addressing the deficiency of existing schemes that emphasize safety while neglecting psychological care, this scheme achieves a balance between safety and experience through "physical environment plus humanistic care": facilities ensure safety, privacy curtains protect dignity, and visiting and rehabilitation activities alleviate loneliness and reduce resistance.

Third, the "scenario-based adaptation" of technology application. Call systems, nurse stations, and nursing assistant terminals are interconnected. For high-risk patients, smart mattresses, bed-exit alarms, and vital sign monitoring devices are deployed. Nursing assistants use a mobile application to document care and report abnormalities, forming a closed loop of "monitoring–early warning–response".

5.3. Practical value of the scheme

This scheme aligns with the characteristics of public general hospitals: collaboration with third-party nursing assistant companies reduces recruitment pressure, and phased pilot implementation mitigates risks. Equipment is selected based on "practicality and essential need" principles, and tiered management facilitates competency-based role assignment. The scheme conforms to national pilot policies for unaccompanied care, establishes seven core institutional documents and quality evaluation indicators, and is amenable to pilot implementation within existing organizational structures.

5.4. Limitations and directions for future optimization

First, insufficient specialty adaptability. The existing "general closed-loop pathway" cannot fully address the special needs of individual specialties. Future efforts should involve collaboration with department directors and head nurses to develop "specialty-specific supplementary care protocols", such as "airway management SOPs".

Second, the absence of cost-benefit analysis. Cost estimation and benefit evaluation were not incorporated. Future work should collect cost data during pilot implementation, conduct cost-effectiveness and cost-benefit analyses, and provide evidence for hospital decision-making and medical insurance payment.

6. Conclusion

Starting from the problems, this paper creates a refined service plan for no-attendant wards in public general hospitals in accordance with the principles of safety first and closed-loop control. It establishes a three-tier management system, seven main systems, and a full care system from admission to discharge, improves the mechanisms for tiered training of nursing assistants, early information alerts, and humanistic care safeguards, and carries out three-tier quality closed-loop control relying on 12 quantitative indicators. This plan is highly systematic and operable, and can provide a reference for the pilot construction of no-attendant wards in general hospitals. This plan also has shortcomings such as low specialty matching and lack of cost-benefit evaluation, which still need to be continuously improved and perfected through pilot programs.

Disclosure statement

The authors declare no conflict of interest.

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Medical Quality Improvement Case Study on Shortening Door-to-Puncture Time for Stroke Patients Undergoing Thrombectomy

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Abstract: *Objective*: To investigate the application effect of the FOCUS-PDCA method in shortening door-to-puncture time (DPT) in patients with acute large vessel occlusion stroke undergoing thrombectomy. *Methods*: A total of 26 patients undergoing thrombectomy admitted to the Department of Neurology II of our hospital from July 2024 to December 2024 were selected as the pre-improvement group, and 28 patients undergoing thrombectomy admitted from January 2025 to June 2025 were selected as the post-improvement group. Interventions included establishing a multidisciplinary team, developing a DPT timeline, optimizing the green channel, and establishing informatization monitoring. *Results*: After improvement, the median DPT decreased from 130 min to 82 min, and the < 90-min compliance rate increased from 10% to 72%. The proportion with good 90-day prognosis (mRS ≤ 2) increased to 52%, and both mortality and average length of hospital stay were significantly reduced. *Conclusion*: FOCUS-PDCA quality improvement can effectively shorten DPT in patients undergoing thrombectomy and improve clinical prognosis, and is worthy of promotion.

Keywords: Acute ischemic stroke; Mechanical thrombectomy; Door-to-puncture time; FOCUS-PDCA; Healthcare quality improvement

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1. Introduction

Thrombectomy for stroke is the most effective recanalization method for acute large vessel occlusion. Door-to-puncture time (DPT), the interval from emergency department arrival to puncture, is a core indicator for evaluating green channel efficiency. Both domestic and international guidelines set DPT ≤ 90 min as the basic target [1,2]. In the second half of 2024, the median DPT of patients undergoing thrombectomy in our department reached 130 min, with a compliance rate of only 10%. One case developed severe postoperative disability due to prolonged in-hospital transfer (138 min), highlighting the urgency of shortening DPT.

This case is based on the quality improvement project "Shortening DPT for Stroke Patients Undergoing Thrombectomy" conducted in the Department of Neurology II of our hospital from July 2024 to June 2025. The FOCUS-PDCA method was used to systematically improve processes, collaboration, preoperative preparation, and informatization [3]. The goal was to increase the < 90-min DPT compliance rate to above 60% and gradually establish a sustainable quality improvement mechanism, providing practical experience for the development of regional stroke centers.

2. Materials and methods

2.1. General data

A total of 26 patients with acute large vessel occlusion stroke who underwent thrombectomy and were admitted to the Department of Neurology II of our hospital from July 2024 to December 2024 were selected as the pre-improvement group, including 16 men and 10 women, with a mean age of 64.2 ± 11.5 years, a median admission NIHSS score of 16 (13, 19), and a median time from onset to admission of 142 (98, 210) min. A total of 28 patients undergoing thrombectomy admitted from January 2025 to June 2025 were selected as the post-improvement group, including 17 men and 11 women, with a mean age of 63.8 ± 10.9 years, a median admission NIHSS score of 15 (12, 18), and a median time from onset to admission of 138 (95, 205) min. Baseline data did not differ significantly between the two groups ($p > 0.05$), indicating comparability.

2.1.1. Inclusion criteria

(1) Large vessel occlusion confirmed by CTA or MRA;
(2) Meeting indications for mechanical thrombectomy;
(3) Time from onset to admission < 6 h.

2.1.2. Exclusion criteria

(1) Severe cardiac, hepatic, and renal insufficiency;
(2) Preoperative mRS > 2;
(3) Family refusal of thrombectomy.

2.2. Improvement methods

2.2.1. Establishment of a multidisciplinary collaboration team

The Emergency Department, Department of Neurology, Department of Imaging, Department of Interventional Radiology, Department of Anesthesiology, Clinical Laboratory, and Nursing Department each designated a fixed liaison. A 24/7 stroke green channel WeChat group was established to provide real-time notification of patient location, estimated arrival time, and materials requiring advance preparation. The responsible person and contact information for each node were clarified. Dedicated staff were assigned for data collection and quality control. Next-day postoperative debriefing and an accountability system for timeout were implemented.

2.2.2. Standardized DPT time management

A target timeline was developed: 0–10 min emergency assessment; 10–20 min CT examination; 20–30 min imaging results; 30–40 min neurology consultation; 40–55 min family discussion and informed consent;

55–70 min catheterization laboratory preparation; 70–90 min puncture initiation. The timeline was posted throughout the process and made into pocket cards for every on-duty physician and nurse. The system provided automatic pop-up reminders for timeout. If the target was exceeded for two consecutive weeks, the department conducted an interview and adjustment.

2.2.3. Optimization of preoperative preparation and the green channel

"Advance discussion" (pre-discussion during the CT examination interval) and "treat first, pay later" were implemented. The catheterization laboratory was activated with one click (arrival within 10 min). The Clinical Laboratory and CT room provided priority or queue-free services for green channel patients, and a transfer elevator was reserved.

2.2.4. Informatization management and training drills

Green channel scanning checkpoints were embedded in the HIS to accurately record time consumption and link it to individual performance. Full-process simulation drills were organized monthly, and problem rectification was implemented. New employees had to pass an assessment on time nodes and the one-click activation process before working independently. Quality control results were included in departmental and individual performance. The monthly DPT compliance rate was calculated and posted at departmental meetings.

2.3. Outcome measures

(1) DPT and < 90-min compliance rate;
(2) Time consumption of each step (informed consent time, catheterization laboratory preparation time, laboratory result waiting time, CT examination time, image interpretation time);
(3) Proportion with 90-day mRS ≤ 2, 90-day mortality, average length of hospital stays;
(4) Completeness and accuracy of data records.

2.4. Statistical methods

SPSS 26.0 software was used for statistical analysis. Normally distributed continuous data were expressed as mean ± standard deviation ($\overline{x} \pm s$), and independent-samples *t* test was used for between-group comparison. Non-normally distributed continuous data (e.g., DPT) were expressed as median (interquartile range), and the Mann-Whitney U test was used for between-group comparison. Categorical data were expressed as counts and percentages (%), and the χ^2 test or Fisher's exact test was used for between-group comparison. $p < 0.05$ was considered statistically significant.

2.5. Quality control

This quality improvement project used a retrospective before-and-after controlled design. Data were obtained from the hospital HIS and the stroke green channel registry. Dedicated staff were responsible for data entry and verification. Each week, 10% of medical records were randomly selected to verify the consistency of time-node records with original physician orders and nursing records. Cases missing key time nodes were excluded. Inclusion and exclusion criteria were consistent before and after improvement, and statistical analysis methods were prespecified to avoid post hoc selective reporting. All interventions were routine departmental management optimizations and did not involve additional invasive procedures, consistent with

hospital quality management requirements.

3. Results

3.1. DPT Was significantly shortened

After improvement, the median DPT decreased to 82 min, and the <90-min compliance rate reached 72% (p = 0.013). Informed consent, catheterization laboratory preparation, and laboratory waiting times were all substantially reduced (**Table 1**). This improvement pathway is consistent with the results of similar quality improvement projects in China and abroad [4].

Table 1. Comparison of key indicators in patients undergoing thrombectomy before and after improvement

Indicator	Pre-improvement group (n = 26)	Post-improvement group (n = 28)	Statistic	p value	Direction of improvement	Remarks
Median DPT (min)	130	82	Z = 3.824	< 0.001	Shortened	Mann-Whitney U
DPT < 90 min compliance rate (%)	10 (38.5)	20 (71.4)	χ^2 = 6.125	0.013	Increased	
Informed consent time (min)	35	15	Z = 4.115	< 0.001	Shortened	
Catheterization laboratory preparation time (min)	28	12	Z = 3.956	< 0.001	Shortened	
Proportion with 90-day mRS ≤ 2 (%)	9 (35)	15 (54)	χ^2 = 2.116	0.146	Increased	Trend
90-day mortality (%)	7 (27)	4 (14)	—	0.283	Decreased	Fisher
Average length of hospital stays (d)	14	11	t = 2.418	0.019	Shortened	

3.2. Improvement in patient prognosis and management efficiency

The proportion with 90-day mRS ≤ 2 increased to 54%, and the average length of hospital stay was significantly shortened (p = 0.019). Multidisciplinary collaboration shifted from being driven by personal relationships to being driven by systems. In the first half of 2025, no complaints caused by DPT delay occurred. Process informatization monitoring eliminated recording bias and effectively reduced response delays during night shifts and weekends.

4. Discussion

4.1. Policy requirements and standardized management

According to the Chinese Guidelines for Diagnosis and Treatment of Acute Ischemic Stroke (2023 Edition) and the National Health Commission's Comprehensive Stroke Prevention and Control Work Plan, thrombectomy DPT should be controlled within 90 min [1,5]. The Expert Recommendations for Medical Quality Evaluation and Improvement of Reperfusion Therapy in Acute Ischemic Stroke, issued by the National Center for Medical Quality Control in Neurological Diseases and the Chinese Stroke Association, also list DPT as a core indicator of stroke care quality, with a basic target of < 90 min and an advanced target of < 60 min [3]. In 2024, our hospital revised the Stroke Green Channel Management System, incorporating

the "DPT < 90 min compliance rate" as a key quality control indicator for the Department of Neurology II. Emergency, imaging, interventional, anesthesiology, laboratory, and nursing departments were required to participate jointly. Operators had to possess thrombectomy credentials. Green channel patients received "treat first, pay later," and a multidisciplinary collaboration and monthly quality control meeting system was established.

4.2. Problem focus and fishbone diagram analysis

Before improvement, from July to December 2024, 26 thrombectomies were performed, with a median DPT of 130 min and only 2 cases with DPT < 90 min, giving a compliance rate of approximately 10%. There was a large gap compared with guideline requirements and advanced peer values [1,3]. The longer DPT is prolonged, the longer the cerebral ischemic time, the less salvageable brain tissue, and the worse the patient prognosis. In-depth analysis showed that low efficiency of multidisciplinary collaboration, prolonged preoperative preparation and informed consent, and lack of standardized processes and informatization support were the main reasons for prolonged DPT. These problems were particularly prominent when the emergency rhythm was tense and human resources were insufficient at night and on weekends.

The main causes in the fishbone diagram analysis were as follows: Man—insensitivity to time nodes, slow discussions, and poor multidisciplinary communication; Machine—mixed scheduling of routine CT, slow catheterization laboratory activation, and no timeout reminders; Material—unfixed locations of thrombectomy devices and emergency drugs; Method—no standardized process, cumbersome informed consent, and lack of supervision and feedback. See **Figure 1**.

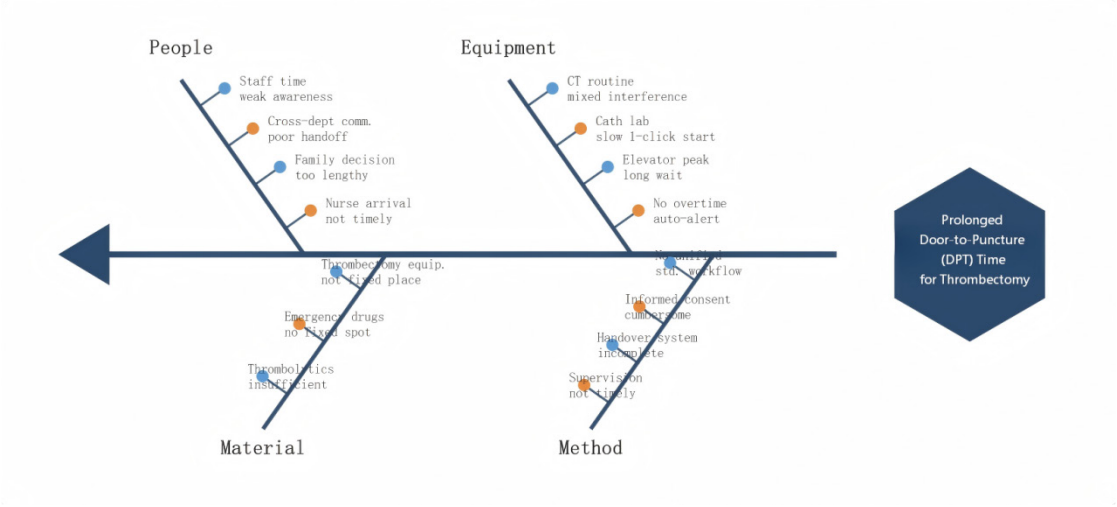


Figure 1. Fishbone diagram of causes of prolonged DPT in thrombectomy.

4.3. Improvement strategies and effects

The improvement strategies included establishing a multidisciplinary collaboration team, standardizing DPT time management, optimizing preoperative preparation and the green channel, and implementing informatization management and training drills. After improvement, the median DPT decreased to 82 min, and the < 90-min compliance rate reached 72%, meeting the project's preset target of above 60%. Informed consent time decreased from 35 min to 15 min, catheterization laboratory preparation from 28 min to 12 min,

and laboratory waiting time from 22 min to 10 min. The proportion with 90-day mRS ≤ 2 increased from 35% to 52%, 90-day mortality decreased from 28% to 16%, and the average length of hospital stay decreased from 14 days to 11 days. This result is consistent with similar studies in China and abroad [3,4,6], indicating that the effectiveness of the quality improvement project is reproducible and valuable for wider application.

4.4. Next-step work plan

The DPT approach will next be extended to DNT time management, incorporating the in-hospital time of intravenous thrombolysis into real-time monitoring. The in-hospital green channel will first be consolidated, and then regional collaboration will be gradually expanded. A collaborative network will be established with tertiary hospitals and primary healthcare institutions in the region to promote the standardized DPT process and form a reproducible clinical pathway. After identifying patients, primary hospitals will notify our hospital in advance and, when necessary, bypass the emergency department and send patients directly to CT to further compress time. A "Stroke Green Channel Quality Monitoring Module" will be embedded in the in-hospital information system to track DPT, DNT, time consumption of each step, and prognosis data in real time. Quality analysis meetings will be held regularly to form a continuous improvement mechanism. Based on this project, applications will be made for municipal or provincial research projects to explore influencing factors and intervention effects of DPT. Physician training and simulation drills will be conducted concurrently to improve team capabilities. An electronic follow-up mini-program will be established to achieve automatic recording of postoperative data and risk warning. Through patient mutual-aid groups and psychological support services, compliance and treatment confidence will be enhanced, promoting stable long-term efficacy. See **Table 2**.

Table 2. Gantt chart of FOCUS-PDCA implementation timeline

Phase	Implementation Content	Participating Departments	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
FFind	Review thrombectomy cases in 2024 and confirm the prolonged DoortoPuncture Time (DPT)	Department 2 of Neurology	Jan											
OOrganize	Set up a multidisciplinary collaboration team and clarify responsibilities for each role	Sevendepartment Collaboration Group	Jan											
CClarify	Calculate median DPT and compliance rate, and set quality improvement targets	Department 2 of Neurology		Feb										

UUnder stand	Analyze major contributing factors from personnel, equipment, materials and procedures via fishbone diagram	All members of collaboration group	Feb Mar	Feb Mar											
SSelect	Determine improvement measures including standardized timeline, preconsent during CT scanning and oneclick cathlab activation	All members of collaboration group		Mar											
PPlan	Formulate implementation plan, quality control indicators and simulation drill arrangements	Department 2 of Neurology · Quality Control Department		Mar											
DDo	Post standardized timeline on wall, record time nodes by system scanning code, and conduct monthly simulation drills	All members of collaboration group			Apr Aug	Apr Aug	Apr Aug	Apr Aug	Apr Aug						
CCheck	Report results in monthly qualitycontrol meetings; publicize and analyze DPTrelated data	Department 2 of Neurology						Jul Sep	Jul Sep	Jul Sep					
AAct	Revise institutional protocols, incorporate outcomes into performance appraisal, and extend successful experience to DoortoNeedle Time (DNT) management	All members of collaboration group									Oct Dec	Oct Dec	Oct Dec		

Note: The horizontal bars indicate the implementation period of each phase; the Do (D) and Check (C) phases partially overlap, reflecting a quality-improvement loop of simultaneous implementation and inspection.

4.5. Experience and reflections

Through this FOCUS-PDCA cycle, we learned the following: First, quality improvement cannot rely solely on the enthusiasm of one individual; it must be supported by the tripartite binding of systems, information systems, and performance. Second, data must be transparent, real-time, and traceable so that everyone can be convinced. Third, training of medical staff and education of patients' families are equally important; failure of either side will cause DPT to rebound. Fourth, improvement goals should be phased and measurable, first meeting targets and then pursuing refinement. Solidifying these experiences into departmental routines and conducting regular reviews are key to preventing the improvement results from rebounding.

4.6. Limitations

This study was a single-center retrospective study with a limited sample size (26 cases before improvement and 28 cases after improvement). Some subgroup results need to be verified with a larger sample. In addition, DPT is affected by multiple factors, including individual patient differences, family decision-making, traffic conditions, and prehospital emergency transport efficiency. Future multicenter large-sample studies are needed for further confirmation, combined with collaborative optimization of the prehospital emergency system. The study data were obtained from the medical record system, and some time nodes relied on manual scanning, which may introduce recording bias.

5. Conclusion

FOCUS-PDCA quality improvement can effectively shorten DPT in patients undergoing thrombectomy, improve clinical prognosis, and enhance the operational efficiency of the stroke green channel. This model has strong operability, generalizability, and value for continuous improvement, and is worthy of promotion and application in stroke centers of primary and above hospitals.

Disclosure statement

The author declares no conflict of interest.

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Effect of Intraoperative Temperature Protection Nursing on Postoperative Complications in Cardiac Surgery Patients

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Abstract: *Objective*: To observe the impact of intraoperative body temperature protection nursing on the occurrence of postoperative complications in patients undergoing cardiac surgery. *Methods*: A total of 120 patients who underwent cardiac surgery in our hospital from February 2024 to February 2026 were selected as the research subjects. They were randomly divided into the control group and the observation group using the random number table method. The 60 patients in the control group received routine intraoperative nursing for cardiac surgery, while the 60 patients in the observation group received intraoperative body temperature protection nursing in addition to the routine care. This study compared the differences in core body temperature levels at different time points during the operation, the incidence of postoperative complications, nursing satisfaction, and the changes in various postoperative recovery indicators between the two groups. The effect of intraoperative body temperature protection nursing on the intervention of patients undergoing cardiac surgery was evaluated. *Results*: The core body temperature levels of the observation group at 30 minutes, 60 minutes, and at the end of the operation were all higher than those of the control group ($p < 0.05$), and the incidence of postoperative complications such as arrhythmia, incision infection, and shivering in the observation group was lower than that in the control group ($p < 0.05$). The nursing satisfaction rate of the observation group was higher than that of the control group ($p < 0.05$), and the postoperative awakening time, ICU stay time, and hospital stay time of the observation group were shorter than those of the control group ($p < 0.05$). *Conclusion*: The application of intraoperative body temperature protection nursing can effectively maintain the stability of core body temperature at all time points during cardiac surgery, and can specifically reduce the risk of postoperative complications such as arrhythmia, which is conducive to the postoperative recovery of patients, can improve patients' satisfaction with nursing intervention, and has high clinical application value.

Keywords: Intraoperative body temperature protection nursing; Cardiac surgery; Postoperative complications

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1. Introduction

Clinically, congenital heart diseases such as atrial septal defect, tetralogy of Fallot, ventricular septal defect,

and acquired heart diseases such as coronary heart disease, constrictive pericarditis, and heart valve diseases all fall within the scope of cardiac surgery treatment. Moreover, vascular diseases such as aortic aneurysm and aortic dissection also require cardiac surgery for symptomatic intervention. Clinically, various surgical procedures such as heart valve replacement, bypass surgery, heart transplantation, and mediastinal tumor resection are commonly used for symptomatic intervention for the aforementioned diseases. Based on the individual patient's condition and disease type, a reasonable surgical treatment approach is selected to help patients avoid the harm of the diseases and ensure their physical health and life safety [1]. However, due to the common characteristics of cardiac surgery, such as large trauma, long operation time, wide exposure of organs, and high rate of extracorporeal circulation usage, the incidence of perioperative hypothermia in patients undergoing cardiac surgery is higher than that of patients undergoing general surgery [2]. Relevant statistics indicate that patients undergoing cardiac surgery without standardized temperature protection have a risk of intraoperative hypothermia exceeding 60%. For humans, the normal physiological range of core body temperature is 36.0–37.5 ℃. However, due to the combined influence of factors such as the low temperature environment in the operating room, extensive skin disinfection and heat dissipation, open thoracic exposure, and extracorporeal circulation blood cooling, the core body temperature of patients undergoing cardiac surgery will rapidly decrease, making intraoperative hypothermia highly likely [3]. The occurrence of intraoperative hypothermia not only inhibits the body's coagulation function, increases the risk of intraoperative and postoperative bleeding, but also significantly reduces the activity of immune cells, thereby increasing the risk of postoperative infection [4]. In addition, intraoperative hypothermia can also stimulate the sympathetic nerve, thereby increasing myocardial oxygen consumption, significantly increasing the risk of arrhythmia and other adverse cardiac events, and seriously threatening the patient's life safety [5]. Therefore, ensuring the intraoperative temperature protection of patients undergoing cardiac surgery is of great significance for the smooth progress of the surgery and the prognosis of postoperative recovery. For this reason, this article specifically observed the impact of intraoperative temperature protection nursing on the occurrence of postoperative complications in patients undergoing cardiac surgery, with the aim of providing certain practical basis for the temperature protection of patients undergoing cardiac surgery, and the content is reported as follows.

2. Materials and methods

2.1. General information

The Medical Ethics Committee of our hospital has approved the conduct of this study. From February 2024 to February 2026, 120 patients who underwent surgical treatment in our hospital's cardiac surgery department were selected as the research subjects. They were divided into the control group and the observation group using the random number table method, with 60 subjects in each group for comparative study. **Table 1** shows that there was no statistically significant difference in gender, age, and primary disease type between the two groups of research subjects ($p > 0.05$), allowing for the comparison of various observation indicators.

Table 1. Comparison of general data among groups

Item	Control group (n = 60 cases)	Observation group (n = 60 cases)	t/χ^2 value	p value
Gender (Male/Female)	33/27	31/29	0.1339	0.7144

Item		Control group (n = 60 cases)	Observation group (n = 60 cases)	t/χ^2 value	*p* value
Age (years)		53.68 ± 6.42	54.25 ± 6.37	0.4882	0.6263
Operation duration (hours)		4.12 ± 1.05	4.08 ± 1.12	0.2018	0.8404
Operation type	Heart valve replacement surgery	22 (36.67)	21 (35.00)	0.0362	0.8490
	Coronary artery bypass surgery	20 (33.33)	19 (31.67)	0.0380	0.8455
	Congenital heart disease correction surgery	13 (21.67)	14 (23.33)	0.0478	0.8270
	Aortic dissection surgery	5 (8.33)	6 (10.00)	0.1001	0.7517

2.1.1. Inclusion criteria

(1) Meets the indications for cardiac surgery, and is undergoing the first open-chest heart surgery;
(2) Age between 30 and 76 years old, with basically stable vital signs before the surgery;
(3) Preoperative core body temperature is 36.0–37.5 ℃, without history of fever or hypothermia-related diseases;
(4) Normal cognitive function, able to cooperate with perioperative care and postoperative follow-up;
(5) Complete clinical data, without any withdrawal from the study during the course of the study.

2.1.2. Exclusion criteria

(1) Patients with severe liver or kidney failure, coagulation disorders, autoimmune diseases, or severe lung diseases are excluded;
(2) Patients with preoperative arrhythmia, infectious diseases, or abnormal body temperature are excluded;
(3) Patients with severe sudden adverse events such as massive bleeding or cardiac arrest during the operation are excluded;
(4) Patients with mental disorders or cognitive impairments who cannot cooperate with nursing interventions are excluded;
(5) Patients with a history of previous cardiac surgery or those undergoing a second surgery are excluded;
(6) Patients who transfer to another hospital midway, give up treatment, or have missing clinical data are excluded.

2.2. Methods

2.2.1. Control group (Conventional cardiac surgery intraoperative nursing)

Before the operation, the medical staff conducted routine visits to the patients, provided detailed explanations of the surgical process and relevant precautions to the patients, and patiently answered their questions to enhance the patients' cooperation. During the operation, the medical staff closely monitored the changes in the patients' vital signs such as heart rate, blood pressure, and blood oxygen saturation, and ensured proper intraoperative cooperation to guarantee the smooth progress of the surgery. After the operation, the medical staff completed hemostasis, suturing, anti-infection and other treatments in coordination and sent the patients to the ICU ward for monitoring.

2.2.2. Observation group (Conventional cardiac surgery intraoperative nursing + intraoperative temperature protection nursing)

(1) When medical staff conduct preoperative visits, they should explain in detail to the patients and their

families the hazards of intraoperative hypothermia and the importance of temperature protection. Moreover, 30 minutes before the operation, medical staff should activate the constant temperature system of the operating room, preheat the operating room temperature to 24–26 ℃, and control the humidity to 50–60%, in order to reduce the heat dissipation of the environment. Additionally, medical staff need to preheat the fluids and irrigation solutions to be infused during the operation and maintain a constant temperature of 37 ℃. After the patient enters the operating room, medical staff should complete the preoperative preparations quickly, minimize the patient's skin exposure time, and quickly cover the non-operative areas of the patient with sterile protective materials and insulation blankets.

(2) During the operation, the medical staff should collect the patient's core body temperature data every 15 minutes, closely monitor the changes in the patient's core body temperature, and try to keep the patient's core body temperature within the range of 36.0–37.5 ℃. In addition to covering the exposed skin of the patient with the insulation blanket, they should also help the patient wear cotton insulation sleeves at the extremities of the limbs. By reducing heat loss at the periphery, they can maintain the patient's body temperature. For patients undergoing extracorporeal circulation during the operation, they must strictly follow the principle of uniform temperature rise and drop, and control the cooling and rewarming rates within 0.5 ℃/min. Finally, during the operation, the medical staff should promptly remove the accumulated fluid and blood in the surgical area, avoid accelerating heat loss with wet dressings, and replace the dry and sterile dressings regularly.

(3) After the surgery is completed, the medical staff should promptly shut off the ventilation equipment to maintain the stability of the environmental temperature in the operating room and quickly wipe the patient's body surface with blood and disinfectant solution to keep the patient's skin dry. Moreover, the medical staff should immediately cover the patient's entire body with an electric blanket after the surgery to prevent the patient's body temperature from dropping. During the postoperative transfer process, the medical staff also need to use transfer warming beds and insulation quilts for insulation, and try to shorten the transfer time to reduce the influence of the external environment on the patient's body temperature. After the patient is transferred to the ICU, they also need to closely monitor the patient's body temperature changes and adjust the warming plan according to the patient's body temperature to maintain the patient's body temperature within the normal range. And if the patient shows signs of hypothermia such as shivering and cold limbs, timely symptomatic intervention measures should be taken to avoid the occurrence of postoperative hypothermia-related complications.

2.3. Evaluation criteria

(1) Core body temperature levels at different time points during the operation

Record the core body temperature (nasopharyngeal temperature) of both groups of patients at the time of entering the operating room, 30 minutes after the operation, 60 minutes after the operation, and at the end of the operation. Compare the differences in body temperature at different time points.

(2) Postoperative complication rate

Count the occurrence of complications within 7 days after the operation for both groups of patients, including arrhythmia, incision infection, postoperative hypothermia, chills, thoracic bleeding, and pulmonary infection. Calculate the total complication rate.

(3) Nursing satisfaction

Use the self-developed perioperative nursing satisfaction scale of our hospital. Conduct a survey before the patients are discharged. The scale has a full score of 100 points. 90–100 points are considered very satisfied, 70–89 points are considered satisfied, and less than 70 points are considered unsatisfied. The total satisfaction rate = (number of very satisfied cases + number of satisfied cases) / total number of cases × 100%.

(4) Postoperative recovery indicators

Record the recovery time after the operation, ICU stay time, and total hospital stay time for both groups of patients. Compare the rehabilitation efficiency of the two groups.

2.4. Statistical methods

The data from this study were analyzed and processed using SPSS 26.0 statistical software. Measurement data (body temperature, recovery time, etc.) were expressed as mean ± standard deviation ($\overline{x} \pm s$), and comparisons between groups were conducted using *t*-tests; count data (complication incidence rate, satisfaction rate) were expressed as rates (%), and comparisons between groups were performed using χ^2 tests; a p value < 0.05 indicated statistically significant differences.

3. Results

3.1. Comparison of core body temperature levels at different time points during the operation between the two groups

Table 2 shows that the core body temperature levels of the patients in the observation group at 30 minutes, 60 minutes after the start of the operation, and at the end of the operation were all higher than those of the control group ($p < 0.05$).

Table 2. Comparison of core body temperature levels at different time points during surgery between the two groups ($\overline{x} \pm s$)

Group/Category	Number of examples	When entering the room	Surgery: 30 minutes	Surgery: 60 minutes	At the conclusion of the procedure
Observation group	60	36.82 ± 0.35	36.45 ± 0.36	36.22 ± 0.39	36.51 ± 0.35
Control group	60	36.79 ± 0.38	35.76 ± 0.42	35.41 ± 0.45	35.63 ± 0.41
t	-	0.4498	9.6619	10.5364	12.6448
p	-	0.6537	0.0000	0.0000	0.0000

3.2. Comparison of postoperative complication rates between the two groups

Table 3 shows that the rates of postoperative complications such as arrhythmia, incision infection and chills in the observation group were all lower than those in the control group ($p < 0.05$)

Table 3. Comparison of postoperative complication rates between the two groups [n (%)]

Group/ Category	Number of examples	arrhyt hmia	Incision infection	Postoperative hypothermia	shiver	Thoracic hemorrhage	Lung infection	Postoperative complication rate
Observation group	60	1 (1.67)	0 (0.00)	1 (1.67)	2 (3.33)	0 (0.00)	1 (1.67)	5 (8.33)
Control group	60	4 (6.67)	3 (5.00)	5 (8.33)	6 (10.00)	2 (3.33)	2 (3.33)	16 (26.67)

χ^2	-	-	-	-	-	-	-	6.9841
p	-	-	-	-	-	-	-	0.0082

3.3. Comparison of nursing satisfaction between the two groups

Table 4 shows that the nursing satisfaction rate of the patients in the observation group was higher than that of the control group ($p < 0.05$).

Table 4. Comparison of nursing satisfaction between two groups [n (%)]

Group/Category	Number of examples	Very satisfied	Satisfied	Dissatisfied	Satisfaction rate
Observation group	60	42 (70.00)	16 (26.67)	2 (3.33)	58 (96.67)
Control group	60	28 (46.67)	22 (36.67)	10 (16.67)	50 (83.33)
χ^2	-	-	-	-	5.9259
p	-	-	-	-	0.0149

3.4. Comparison of postoperative recovery indicators between the two groups

Table 5 shows that the postoperative awakening time, ICU stay time, and hospital stay time of the observation group were all shorter than those of the control group ($p < 0.05$).

Table 5. Comparison of postoperative recovery indicators between the two groups ($\overline{x} \pm s$)

Group/Category	Number of examples	Postoperative awakening time (hours)	Length of stay in ICU (days)	Total hospitalization duration (days)
Observation group	60	3.25 ± 0.96	2.05 ± 0.62	9.18 ± 1.86
Control group	60	5.86 ± 1.23	3.12 ± 0.85	12.36 ± 2.15
t	-	12.9572	7.8778	8.6644
p	-	0.0000	0.0000	0.0000

4. Discussion

The results of this study show that the core body temperature levels of patients in the observation group at 30 minutes, 60 minutes after the start of the surgery, and at the end of the surgery were all higher than those of the control group ($p < 0.05$), and the incidence of postoperative complications such as arrhythmia, incision infection, and chills in the observation group was lower than that in the control group ($p < 0.05$). The nursing satisfaction rate of patients in the observation group was higher than that of the control group ($p < 0.05$), and the postoperative awakening time, ICU stay time, and hospital stay time of the observation group were shorter than those of the control group ($p < 0.05$). The above research results prove that intraoperative temperature protection nursing plays a superior role in maintaining the intraoperative body temperature level of patients undergoing cardiac surgery and reducing postoperative complications. Through analysis, it is found that intraoperative temperature protection nursing runs through the entire process of patients undergoing cardiac surgery, from preoperative, intraoperative to postoperative. It can reduce the heat loss of patients from the source through preheating of the operating room environment, preheating of fluids during infusion, and reduction of skin exposure, thereby laying a foundation for intraoperative body temperature protection of

patients; while the intervention measures such as continuous monitoring of core body temperature during the operation, insulation of extremities, and uniform cooling of extracorporeal circulation can comprehensively block the heat dissipation pathways of patients, thereby maintaining the stability of the patient's core body temperature during the operation; measures such as maintaining postoperative environmental temperature, covering with insulation blankets, shortening the transfer time, monitoring of body temperature in the ICU, and symptomatic adjustment can effectively avoid the occurrence of postoperative hypothermia and related complications, thereby promoting the postoperative recovery of patients [6].

5. Conclusion

In conclusion, the application of intraoperative body temperature protection nursing can effectively maintain the core body temperature stability of patients undergoing cardiac surgery at all time points during the operation, and can specifically reduce the risk of postoperative complications such as arrhythmia, which is conducive to the postoperative recovery of patients and can enhance patients' satisfaction with the nursing intervention. Therefore, its clinical application value is relatively high.

Disclosure statement

The authors declare no conflict of interest.

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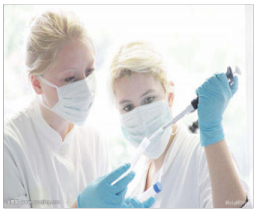


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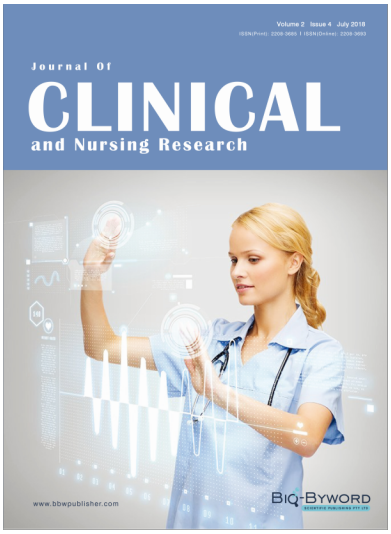
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