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Application of Cluster-Based Anesthesia Management in Painless Gastrointestinal Endoscopy

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Abstract: *Objective:* To investigate the application effect of cluster-based anesthesia management in painless gastrointestinal endoscopy and evaluate its impact on anesthesia safety, procedural quality, and patient recovery. *Methods:* A total of 2000 patients who underwent painless gastrointestinal endoscopy at the Digestive Endoscopy Center of our hospital from January 2025 to January 2026 were randomly divided into two groups, with 1000 cases in each group. The observation group implemented a comprehensive cluster-based anesthesia protocol, while the control group received conventional intravenous sedation anesthesia with basic monitoring. The anesthesia induction time, awakening time, recovery room stay time, intraoperative hemodynamic fluctuations, incidence of adverse events, endoscopic procedure completion rate, and patient satisfaction were compared between the two groups. *Results:* The anesthesia induction time, awakening time, and recovery room stay time in the observation group were significantly shorter than those in the control group (all $p < 0.001$). The fluctuations in systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) at T1, T2, and T3 in the observation group were significantly smaller than those in the control group (all $p < 0.001$). The incidence of intraoperative adverse events in the observation group was significantly lower than that in the control group ($p < 0.001$). The endoscopic procedure completion rate and patient satisfaction in the observation group were significantly higher than those in the control group (both $p < 0.001$). *Conclusion:* Cluster-based anesthesia management can significantly optimize the anesthesia process for painless gastrointestinal endoscopy, shorten anesthesia and recovery times, reduce the risk of intraoperative adverse events, and improve procedural safety and patient comfort, making it worthy of clinical promotion and application.

Keywords: Cluster-based anesthesia management; Painless gastrointestinal endoscopy; Intravenous anesthesia; Safety; Recovery quality

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1. Introduction

Painless gastroenteroscopy has become a core method for screening, diagnosing, and minimally invasive

treatment of gastrointestinal diseases. Its key advantage lies in the administration of intravenous short-acting anesthetics and analgesics to induce general anesthesia, thereby eliminating pain and fear during the examination and improving the quality of endoscopic procedures and patient compliance [1]. However, during the examination, anesthetic drugs can suppress the respiratory and circulatory systems, leading to hypoxemia and hypotension. Additionally, factors such as individual patient differences or procedural stimuli can easily trigger adverse events such as body movement, regurgitation, and aspiration, which can seriously jeopardize safety [2]. Conventional anesthesia management often focuses on intraoperative drug administration, lacking a comprehensive integration of preoperative precise assessment, intraoperative refined monitoring, and postoperative rapid recovery, making it difficult to maximize risk avoidance and efficiency. Bundle management integrates multiple evidence-based and proven effective interventions into a standardized and systematic approach, which, when applied clinically, can significantly improve medical quality and safety. This study systematically evaluates the clinical application value of bundle anesthesia management, aiming to provide evidence-based support for optimizing painless endoscopic anesthesia protocols.

2. Materials and methods

2.1. General information

A total of 2000 patients scheduled to undergo painless gastroenteroscopy at the Digestive Endoscopy Center of our hospital from January 2025 to January 2026 were selected and randomly divided into two groups, with 1000 patients in each group. In the observation group, there were 542 males and 458 females, with an average age of (48.65 ± 12.36) years and a BMI of (23.45 ± 2.87) kg/m². In the control group, there were 536 males and 464 females, with an average age of (49.12 ± 12.58) years and a BMI of (23.62 ± 2.91) kg/m². There were no statistically significant differences in general information between the two groups ($p > 0.05$), indicating comparability.

2.1.1. Inclusion criteria

Age between 18 and 80 years; American Society of Anesthesiologists (ASA) classification < grade II; no severe heart, lung, liver, or kidney dysfunction; no history of anesthesia drug allergies; no mental illness or communication disorders; signed informed consent.

2.1.2. Exclusion criteria

ASA classification ≥ grade III; upper gastrointestinal obstruction, delayed gastric emptying, severe reflux esophagitis; severe obesity (BMI ≥ 35 kg/m²), sleep apnea syndrome, abnormal coagulation function; pregnant or lactating women.

2.2. Methods

All patients were routinely fasted for 8 hours and abstained from clear liquids for 2 hours before the examination. An upper limb venous access was established, and upon entering the examination room, non-invasive blood pressure (BP), heart rate (HR), pulse oxygen saturation (SpO_2), and respiratory rate (RR) were routinely monitored, with nasal cannula oxygen administration (2–3 L/min).

The control group received a conventional intravenous sedation anesthesia protocol. Sufentanil 0.10 μg/kg was administered intravenously, followed by a slow intravenous injection of propofol 1.5–2.0 mg/kg 3

minutes later. The procedure commenced when the patient's eyelash reflex disappeared, and the Modified Observer's Assessment of Alertness/Sedation Scale (MOAA/S) score was ≤ 1. During the procedure, additional doses of propofol 0.5–1.0 mg/kg were administered based on the patient's body movement and depth of sedation to maintain an appropriate level of anesthesia. Only BP, HR, SpO_2, and RR were monitored during the procedure, without routine monitoring of end-tidal carbon dioxide ($PetCO_2$). After the procedure, patients were transferred to the recovery room and discharged only after they were fully awake and their vital signs were stable, without a standardized recovery assessment and intervention protocol.

The observation group implemented a standardized bundle protocol throughout the preoperative-intraoperative-postoperative process, with the following core measures:

(1) Preoperative assessment and education during appointment scheduling

Anesthesiologists assessed the patient's ASA classification and underlying diseases during the preoperative appointment to develop an individualized plan; reinforced education was provided to alleviate patient anxiety, and emergency equipment was prepared in advance for high-risk patients.

(2) Anesthesia induction and maintenance

A low-dose opioid + propofol target-controlled infusion was used for induction, and an appropriate depth of sedation was maintained throughout the procedure. The depth of sedation was adjusted according to the stages of gastroscopy and colonoscopy during combined examinations to minimize circulatory fluctuations.

(3) Intraoperative refined monitoring

Multi-parameter monitoring, including BP and HR, was conducted throughout the procedure, with immediate intervention for any abnormalities to maintain airway patency and promptly address hypotension and hypoxemia (abdominal compression to assist breathing was performed when a continuous decline in predicted blood oxygen saturation was anticipated).

(4) Postoperative recovery and assessment

Infusion was stopped after the procedure, and patients were monitored by dedicated personnel in the recovery room. They were assessed according to standardized discharge criteria, and symptomatic treatment was provided to uncomfortable patients to shorten recovery time.

2.3. Observation indicators

(1) Anesthesia-related times

Anesthesia induction time (from drug administration to disappearance of eyelash reflex), awakening time (from drug discontinuation to opening eyes upon calling and correctly answering name), and recovery room stay time (from drug discontinuation to meeting discharge criteria).

(2) Intraoperative hemodynamics

Systolic blood pressure (SBP), diastolic blood pressure (DBP), and HR were recorded at admission to the examination room (T0), after induction (T1), upon endoscope insertion (T2), and at the end of the examination (T3), and the fluctuation amplitude was calculated.

(3) Incidence of adverse events

Intraoperative hypotension, hypoxemia (SpO_2 < 92%), body movement (requiring additional drugs to affect the procedure), nausea and vomiting, regurgitation and aspiration, and apnea.

(4) Endoscopic procedure indicators

Procedure completion rate, examination duration, and lesion detection rate.

(5) Patient satisfaction

Assessed 24 hours after the examination using a self-made satisfaction scale (100-point system) at our hospital. A score ≥ 90 was considered satisfactory, and the satisfaction rate was calculated.

2.4. Statistical methods

All data were processed using SPSS 27.0 software. Measurement data were expressed as (±s), and comparisons between groups were made using the t-test. Count data were expressed as [n (%)], and comparisons were made using the χ^2 test. A p-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of Anesthesia-Related Times Between the Two Groups

The anesthesia induction time, awakening time, and recovery room stay time in the observation group were significantly shorter than those in the control group (all $p < 0.001$), as shown in **Table 1**.

Table 1. Comparison of anesthesia-related times between the two groups

Group	Induction time (min)	Awakening time (min)	Length of stay in PACU (min)
Observation group (n = 1000)	2.15 ± 0.42	6.32 ± 1.25	15.68 ± 2.76
Control group (n = 1000)	3.46 ± 0.58	9.75 ± 1.83	22.45 ± 3.52
t	57.722	48.934	47.782
p	< 0.001	< 0.001	< 0.001

3.2. Comparison of intraoperative hemodynamic fluctuations between the two groups

The fluctuation ranges of SBP, DBP, and HR at T1, T2, and T3 in the observation group were significantly smaller than those in the control group (all $p < 0.001$), as shown in **Table 2.**

Table 2. Comparison of hemodynamics between the two groups at different time points

Indicator	Group	T0	T1	T2	T3
SBP (mmHg)	Observation group (n = 1000)	126.58 ± 10.25	118.36 ± 9.42	120.45 ± 9.68	124.28 ± 10.12
	Control group (n = 1000)	127.12 ± 10.36	109.52 ± 10.56	112.38 ± 10.75	118.65 ± 10.89
	t	1.150	19.733	17.672	11.960
	p	0.250	< 0.001	< 0.001	< 0.001
DBP (mmHg)	Observation group (n = 1000)	78.65 ± 6.82	73.28 ± 6.56	74.56 ± 6.72	77.32 ± 6.85
	Control group (n = 1000)	78.92 ± 6.91	68.45 ± 7.12	69.86 ± 7.28	72.58 ± 7.36
	t	0.847	15.809	15.002	14.866
	p	0.397	< 0.001	< 0.001	< 0.001
HR (beats/min)	Observation group (n = 1000)	76.85 ± 8.26	72.36 ± 7.85	73.58 ± 8.02	75.62 ± 8.18
	Control group (n = 1000)	77.12 ± 8.35	67.52 ± 8.68	69.25 ± 8.82	71.86 ± 8.95
	t	0.727	13.105	11.486	9.780
	p	0.467	< 0.001	< 0.001	< 0.001

3.3. Comparison of the incidence of intraoperative adverse events between the two groups

The incidence of intraoperative adverse events in the observation group was significantly lower than that in the control group ($p < 0.001$), as shown in **Table 3**.

Table 3. Comparison of the incidence of intraoperative adverse events between the two groups [Cases (%)]

Group	Hypotension	Hypoxemia	Body movement	Nausea and vomiting	Total incidence (%)
Observation group (n = 1000)	42 (4.20)	28 (2.80)	31 (3.10)	53 (5.30)	154 (15.4)
Control group (n = 1000)	115 (11.50)	87 (8.70)	92 (9.20)	126 (12.60)	420 (42)
χ^2					172.887
p					< 0.001

3.4. Comparison of endoscopic procedures and patient satisfaction between the two groups

The completion rate of endoscopic procedures and patient satisfaction in the observation group were 99.70% (997/1000) and 98.90% (989/1000), respectively, significantly higher than those in the control group (97.80% [978/1000] and 93.20% [932/1000], respectively). The differences were statistically significant ($\chi^2 = 14.623$, 42.818; both $p < 0.001$).

4. Discussion

The core objective of anesthesia for painless gastrointestinal endoscopy is to provide a stable depth of sedation for endoscopic procedures while ensuring patient safety and comfort, thereby reducing adverse events, shortening recovery time, and improving medical efficiency [3]. Conventional anesthesia management often relies on the experience of anesthesiologists, lacks standardized procedures, and is prone to issues such as excessive or insufficient sedation, significant fluctuations in circulation and respiration, and delayed recovery. These challenges are particularly pronounced in endoscopy centers with large patient volumes and fast-paced operations, where risk control becomes more difficult. This study, through a randomized controlled trial involving 2,000 cases, demonstrates that bundled anesthesia management can significantly optimize the entire process of anesthesia for painless gastrointestinal endoscopy, with core benefits in safety, efficiency, and comfort.

Bundled anesthesia management reduces anesthesia risks from the source through preoperative precise assessment and individualized plan formulation [4,5]. Preoperative visits and airway assessments can identify high-risk patients, such as those who are obese, elderly, or have sleep apnea, in advance, allowing for targeted adjustments in drug dosages and preparation of airway rescue equipment to avoid severe circulatory fluctuations and airway obstruction during induction due to inadequate assessment. Standardized education alleviates patient anxiety, reduces sympathetic excitation caused by stress responses, and lays the foundation for smooth induction. In this study, the induction time in the observation group was significantly shorter than that in the control group, thanks to preoperative precise assessment and a standardized induction protocol using “low-dose opioids + target-controlled propofol,” which rapidly achieved effective sedation depth while avoiding respiratory and circulatory depression caused by single large doses of propofol.

Intraoperative multi-parameter monitoring and refined regulation are the core components of bundled

management. Conventional monitoring focuses only on SpO_2, BP, and HR, making it difficult to detect early hypoventilation and respiratory depression. $PetCO_2$ can provide early warning of inadequate ventilation before SpO_2 decreases, while BIS monitoring enables quantitative control of sedation depth, avoiding delayed awakening and circulatory depression caused by excessive sedation or body movement and procedure interruption caused by insufficient sedation. In the observation group, continuous target-controlled infusion of propofol was maintained with a BIS of 55–70, combined with real-time $PetCO_2$ monitoring, significantly reducing the incidence of hypotension, hypoxemia, and body movement. The incidence of body movement was only 3.10%, much lower than the 9.20% in the control group, providing a stable operating environment for endoscopists and improving procedure completion rates. Additionally, the use of low-dose sufentanil in combination with propofol reduced the total dosage of propofol and the incidence of adverse reactions such as nausea and vomiting. The incidence of nausea and vomiting in the observation group was 5.30%, significantly lower than the 12.60% in the control group, directly related to the optimized drug regimen [6,7].

Postoperative rapid recovery and standardized discharge assessment are key to improving efficiency and safety in bundled management [8]. Conventional recovery lacks unified standards, often requiring patients to wait for extended periods after awakening. In contrast, the observation group, through dedicated monitoring, regular assessments, and symptomatic interventions, strictly controlled discharge criteria, significantly shortening awakening time and recovery room stay by 3.43 minutes and 6.77 minutes, respectively, compared to the control group. This not only improved the turnover efficiency of the endoscopy center but also reduced adverse events during recovery. In terms of patient satisfaction, bundled management covered the entire process from preoperative education to intraoperative comfort and postoperative rapid recovery, effectively alleviating examination-related fear and achieving a satisfaction rate of 98.90%, significantly higher than the 93.20% in the control group, reflecting a patient-centered medical philosophy [9,10].

This study has certain limitations: it included only ASA I-II patients and did not cover high-risk populations with ASA III or higher, requiring caution in extrapolating the conclusions; long-term follow-up of postoperative cognitive function and other long-term indicators was not conducted; and the details of the bundled protocol (such as drug ratios and monitoring parameter thresholds) could be further optimized. However, the large-sample, prospective, randomized controlled design ensures the reliability of the results. The standardized and refined advantages of bundled anesthesia management throughout the entire process can effectively balance safety, efficiency, and comfort in painless gastrointestinal endoscopy, making it suitable for promotion in endoscopy centers at all levels. Future research could further explore optimized protocols for special populations such as the elderly and obese patients, improve long-term safety assessments, and promote continuous improvements in the quality of painless endoscopic anesthesia.

In summary, bundled anesthesia management significantly shortens anesthesia and recovery times for painless gastrointestinal endoscopy, reduces the incidence of intraoperative adverse events such as hypotension, hypoxemia, body movement, nausea, and vomiting, and improves endoscopic procedure completion rates and patient satisfaction through the integration of preoperative precise assessment, standardized anesthesia induction and maintenance, intraoperative multi-parameter refined monitoring, and postoperative rapid recovery. This protocol is safe, efficient, and replicable, representing an effective strategy for optimizing anesthesia management and improving medical quality in painless gastrointestinal endoscopy, worthy of widespread clinical application.

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Disclosure statement

The authors declare no conflict of interest.

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