

A Study on the Diagnostic Value of Multimodal MRI in Assessing Early Radiation-Induced Brain Injury Following Intensity-Modulated Radiation Therapy for Nasopharyngeal Carcinoma

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Abstract: *Objectives:* Intensity-modulated radiation therapy is the cornerstone of curative treatment for nasopharyngeal carcinoma; however, radiation-induced brain injury has an insidious onset, with no obvious morphological abnormalities in brain tissue in the early stages. It is difficult to detect through routine imaging examinations, making it easy to miss the optimal window for intervention. To investigate the dynamic progression of early radiation-induced brain injury following radiation therapy for nasopharyngeal carcinoma, identify the optimal evaluation window, and determine the correlation between tumor staging and brain injury, this study conducted a dynamic follow-up study using multimodal MRI technology. *Methods:* Thirty patients with newly diagnosed nasopharyngeal carcinoma were enrolled and divided into three groups based on TNM staging: T1/T2, T3, and T4, with 10 patients in each group. All patients underwent radical intensity-modulated radiation therapy. Multimodal MRI scans were performed 1 day before radiotherapy and 1, 3, and 7 weeks after radiotherapy. Changes in the microstructure of the temporal lobe and hippocampal white matter, as well as brain functional network parameters, were quantitatively compared across groups. *Results:* One week after radiotherapy, only physiological fluctuations in brain tissue parameters were observed, with no pathological damage; three weeks after radiotherapy, subclinical white matter structural disorganization and abnormalities in brain functional networks could be consistently detected, representing the optimal time window for assessing early damage; seven weeks after radiotherapy, brain damage showed cumulative worsening in proportion to radiation dose. The overall detection rate of early brain injury in this group was 46.67%. The incidence and severity of brain injury in stage T4 patients were significantly higher than those in patients with early- to mid-stage disease ($P < 0.05$). The FA, ReHo, and ALFF parameters measured in the temporal lobe 3 weeks after radiotherapy demonstrated good diagnostic performance for early brain injury. *Conclusion:* Multimodal MRI can accurately detect occult early-stage radiation-induced brain injury following radiotherapy for nasopharyngeal carcinoma. Abnormal changes in brain function occur earlier than morphological damage to brain tissue, and TNM staging is positively correlated with the severity of brain injury. This technique provides reliable imaging evidence to support the early implementation of neuroprotective interventions and the optimization of individualized radiotherapy regimens.

Keywords: Nasopharyngeal carcinoma; Intensity-modulated radiation therapy; Radiation-induced brain injury; Multimodal magnetic resonance imaging; Early diagnosis

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1. Introduction

Nasopharyngeal carcinoma is a head and neck malignancy with a high incidence in southern China, exhibiting a distinct regional clustering pattern. Intensity-modulated radiation therapy, with its advantages of precise dose delivery to the target area and protection of normal tissues, has become the treatment of choice for curative therapy in newly diagnosed nasopharyngeal carcinoma. Due to the deep anatomical location of the nasopharynx and its proximity to important brain structures such as the bilateral temporal lobes and the hippocampus, scattered radiation and cumulative doses generated during radiation therapy can cause sustained damage to normal brain tissue, leading to radiation-induced brain injury—one of the most common long-term complications following radiation therapy for nasopharyngeal carcinoma, which severely impacts patients' quality of life after surgery ^[1].

Radiation-induced brain injury progresses insidiously and gradually. In the early stages of the disease, there are no specific clinical symptoms, and no macroscopic morphological lesions are visible in the brain tissue; it manifests only as microstructural disruption in the white matter and reduced functional coordination between brain regions, making it difficult to detect effectively with conventional CT and standard MRI. As radiation damage continues to accumulate, patients may gradually develop symptoms such as memory impairment, inattention, and cognitive decline. In severe cases, irreversible pathological changes—such as cerebral softening and brain tissue necrosis—may occur, constituting major risk factors for poor long-term prognosis. Therefore, achieving early and accurate screening and assessment of radiation-induced brain injury holds significant clinical value for improving the long-term prognosis of nasopharyngeal carcinoma patients ^[1,2].

Multimodal MRI, which integrates diffusion tensor imaging and resting-state functional MRI, can quantitatively assess subclinical brain tissue damage at both the microstructural and functional levels, thereby addressing the technical limitations of conventional imaging, which can only observe macroscopic morphological lesions. Currently, most domestic studies focus on retrospective analyses of long-term organic brain damage following radiation therapy; however, there remains a lack of systematic dynamic follow-up studies regarding the dynamic evolution patterns of subclinical damage in the very early stages of radiation therapy, the optimal screening time window, and the impact of different TNM stages on the severity of brain damage. Through dynamic monitoring at multiple time points, this study compares and analyzes the evolutionary characteristics of brain tissue MRI parameters before and after radiotherapy in nasopharyngeal carcinoma patients at different stages to identify specific indicators for early brain injury assessment. The aim is to provide objective radiological data support for the early clinical prevention and control of radiation-induced brain injury and the optimization of radiotherapy protection strategies ^[2,3,4].

2. Materials and methods

2.1. General materials

This study included 30 treatment-naïve nasopharyngeal carcinoma patients diagnosed and treated in the Oncology Department of our hospital between June 2024 and June 2026.

2.1.1. Inclusion criteria

- (1) Diagnosis of primary nasopharyngeal carcinoma confirmed by pathological biopsy of the nasopharynx;
- (2) First-time diagnosis, with no history of cranial surgery or cranial radiation therapy; ③ No underlying

- cranial or brain diseases such as cerebral infarction, intracranial tumors, or encephalitis;
- (3) No contraindications for MRI;
 - (4) Complete clinical and imaging records, with the ability to cooperate in completing the full course of follow-up scans.

2.1.2. Exclusion criteria

- (1) Severe imaging artifacts or missing data rendering the case ineligible for analysis; (2) Patients who dropped out during follow-up or were unable to complete the entire follow-up process.

Patients were grouped according to the TNM staging criteria for nasopharyngeal carcinoma, with 10 cases each in stages T1/T2, T3, and T4. The study included 21 male and 9 female patients, ranging in age from 40 to 75 years, with a median age of 58 years. All patients and their families were informed of the study details and voluntarily signed informed consent forms. This study was approved by our hospital's Medical Ethics Committee. There were no statistically significant differences in baseline characteristics, such as age and gender, among the three groups ($P > 0.05$), indicating that the groups were well-balanced and comparable ^[5].

2.2. Testing methods

All subjects underwent whole-brain scans using our hospital's Siemens Skyra 3.0T medical MRI scanner. Parameters such as slice thickness, field of view, and patient positioning were standardized across all scans to minimize equipment and operational errors. The scanning sequences included 3D-T1 structural imaging, DTI, and rs-fMRI. Scans were scheduled at fixed time points: 1 day before radiotherapy and 1 week, 3 weeks, and 7 weeks after radiotherapy. The same experienced radiologic technologist performed all scans. Prior to scanning, patients were instructed to keep their heads still, remain calm, and rest with their eyes closed to minimize motion artifacts and ensure image quality met the requirements for data analysis.

2.3. Data processing and metric extraction

Import the raw image data into the SPM12 image analysis software and perform image registration, smoothing, denoising, and standardization as part of the preprocessing. The bilateral temporal lobes and hippocampus—areas with a high incidence of radiation-induced brain injury—were selected as regions of interest. Quantitative metrics such as the anisotropy fraction (FA), apparent diffusion coefficient (ADC), regional homogeneity (ReHo), low-frequency amplitude (ALFF), and default mode network (DMN) functional connectivity strength were extracted at each time point. Two senior radiologists with over 10 years of experience independently reviewed the images and compiled the statistics using a double-blind method. In cases of data discrepancies, they jointly reviewed and corrected the results, and invalid samples were excluded to ensure the authenticity and reliability of the data.

2.4. Statistical methods

Data were analyzed using SPSS 26.0 statistical software. Continuous variables are expressed as “mean $\pm$ standard deviation (SD)”; repeated-measures analysis of variance was used to compare measures at different time points within groups, and one-way analysis of variance was used to compare measures at the same time point across groups. Categorical variables are expressed as counts and percentages, and the chi-square (χ^2) test was used for between-group comparisons. Pearson's correlation analysis was used to assess the

correlation among variables. The significance level was set at $\alpha = 0.05$, and a P -value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of baseline characteristics among the three groups of patients

There were no statistically significant differences in age or gender distribution among the three patient groups ($P > 0.05$). Furthermore, baseline levels of temporal lobe and hippocampal brain structure and brain function indicators were essentially consistent across all groups prior to radiotherapy; baseline characteristics were well balanced between groups, and there were no confounding factors. All patients completed four imaging follow-up sessions, with no dropouts or missing data, as shown in **Table 1**.

Table 1. Comparison of general baseline characteristics among the three groups of patients

Indicators	Stage T1/T2 group (n=10)	Stage T3 group (n=10)	Stage T4 group (n=10)	χ^2/F value	P value
Gender (Male/Female, Number)	7/3	7/3	7/3	0.000	1.000
Age (mean $\pm$ SD, years)	57.2 $\pm$ 8.1	58.1 $\pm$ 7.9	58.5 $\pm$ 8.3	0.089	0.915

3.2. Detection rates and temporal patterns of early radiological brain lesions

One week after radiation therapy, the imaging parameters of brain tissue in all three patient groups showed only physiological fluctuations, with no pathological changes such as nerve fiber damage or cerebral dysfunction. Three weeks after radiation therapy, pathological abnormalities in the microstructure of white matter and cerebral function in the temporal lobe and hippocampus regions could be reliably detected, representing the optimal time window for detecting early, latent brain injury. Seven weeks after radiotherapy, the extent of brain tissue damage further expanded and the severity of damage continued to worsen, demonstrating a significant time-dose cumulative effect ^[1,2,6].

In this study, abnormal radiological findings 3 weeks after radiotherapy were used as the criterion for a positive diagnosis of early brain injury. Among the 30 patients, 14 tested positive, resulting in an overall detection rate of 46.67% for early brain injury. Specifically, there were 3 cases (30.00%) in the T1/T2 stage group, 4 cases (40.00%) in the T3 stage group, and 7 cases (70.00%) in the T4 stage group. A comparison of the incidence of early brain injury among the three groups revealed statistically significant differences ($P < 0.05$); patients in the T4 stage had a significantly higher risk of developing early brain injury after radiation therapy than those in the T1/T2 and T3 stages ^[5,7].

3.3. Dynamic changes in brain tissue microstructure and brain function following radiation therapy

Conventional structural MRI results showed that, 3 weeks after radiation therapy, the thickness of the patient's bilateral temporal and frontal cortices and the volume of white matter had decreased significantly compared to pre-treatment levels, and the extent of damage continued to worsen as the follow-up period extended. DTI findings suggest that radiation therapy can cause neurofibrillary edema and disorganization in the temporal lobe and hippocampus, primarily manifested by decreased FA values and increased ADC values. As the injury progresses, this can gradually develop into irreversible organic damage, such as white matter

demyelination and axonal degeneration^[3, 8, 9].

rs-fMRI results indicate that following radiation therapy, patients exhibit a progressive decline in ReHo, ALFF, and DMN functional connectivity in the temporal lobe, with continued impairment in neural synchrony and functional integration across brain regions. Overall, radiation therapy-induced abnormal changes in brain functional networks occur earlier than macroscopic morphological lesions in brain tissue, enabling the effective identification of subclinical, occult brain injury that is difficult to detect with conventional MRI^[3,8].

3.4. Correlation between TNM staging and the severity of brain injury

At the same follow-up time point, the severity of brain damage in patients showed a clear gradient correlation with tumor TNM staging: patients with stage T4 exhibited the greatest degree of abnormal imaging parameters and the most severe brain damage, while those with stages T1 and T2 had the mildest damage, and those with stage T3 fell between the two. Results of Pearson correlation analysis showed that TNM staging was significantly negatively correlated with FA values in the temporal lobe and hippocampus, and significantly positively correlated with the degree of ADC elevation and the severity of brain dysfunction (all $P < 0.05$), suggesting that TNM staging is an independent risk factor influencing the severity of radiation-induced brain injury following radiotherapy for nasopharyngeal carcinoma^[5,7].

3.5. Screening for early-stage specific imaging markers

Based on an analysis of the trends in parameter changes at various follow-up time points, intergroup differences, and data stability, the detection rates of abnormalities in the three temporal lobe parameters—FA, ReHo, and ALFF—were high 3 weeks after radiotherapy; significant intergroup differences were observed; and data stability was good. These parameters demonstrated high sensitivity and specificity for the diagnosis of early, subclinical radiation-induced brain injury and can serve as specific imaging biomarkers for early radiation-induced brain injury following radiotherapy for nasopharyngeal carcinoma.

3.6. Comparison of DTI parameters among patient groups at different time points

Prior to radiation therapy, there were no statistically significant differences in baseline FA and ADC parameters in the temporal lobe and hippocampus among the three patient groups; baseline levels were balanced and comparable. After radiation therapy, FA values continued to decrease and ADC values continued to increase in all groups, demonstrating a clear cumulative effect over time. Specifically, changes in these parameters 1 week after radiotherapy were not statistically significant ($P > 0.05$); however, both pre- and post-treatment comparisons within each group and intergroup comparisons at the same time points 3 and 7 weeks after radiotherapy were statistically significant ($P < 0.05$). Furthermore, the magnitude of abnormalities in imaging parameters was significantly higher in Stage T4 patients than in Stage T1/T2 and Stage T3 patients, as detailed in **Table 2**.

Table 2. Comparison of DTI parameters in the white matter of patients in each group at different radiotherapy time points (mean $\pm$ SD)

Testing Time	Grouping	FA in the temporal lobe	Temporal lobe ADC ($\times 10^{-3}$ mm ² /s)	Hippocampus FA	Hippocampus ADC ($\times 10^{-3}$ mm ² /s)
Before radiotherapy	Stages T1/T2	0.482 $\pm$ 0.021	0.786 $\pm$ 0.032	0.451 $\pm$ 0.018	0.812 $\pm$ 0.029

Before radiotherapy	Stage T3	0.479 ± 0.019	0.789 ± 0.028	0.448 ± 0.020	0.809 ± 0.031
Before radiotherapy	StageT4	0.480 ± 0.022	0.785 ± 0.030	0.449 ± 0.019	0.811 ± 0.028
1 week of radiotherapy	Stages T1/T2	0.475 ± 0.020	0.792 ± 0.031	0.445 ± 0.017	0.818 ± 0.030
1 week of radiotherapy	Stage T3	0.471 ± 0.018	0.798 ± 0.029	0.442 ± 0.019	0.822 ± 0.027
1 week of radiotherapy	StageT4	0.468 ± 0.021	0.803 ± 0.032	0.439 ± 0.018	0.826 ± 0.029
3 weeks of radiotherapy	Stages T1/T2	0.441 ± 0.017 ^{*#}	0.835 ± 0.028 ^{*#}	0.412 ± 0.016 ^{*#}	0.859 ± 0.026 ^{*#}
3 weeks of radiotherapy	Stage T3	0.425 ± 0.015 ^{*#}	0.858 ± 0.025 ^{*#}	0.398 ± 0.014 ^{*#}	0.878 ± 0.024 ^{*#}
3 weeks of radiotherapy	StageT4	0.402 ± 0.016 ^{*#}	0.889 ± 0.027 ^{*#}	0.375 ± 0.015 ^{*#}	0.905 ± 0.025 ^{*#}
7 weeks of radiotherapy	Stages T1/T2	0.410 ± 0.014 ^{*#△}	0.868 ± 0.025 ^{*#△}	0.385 ± 0.013 ^{*#△}	0.886 ± 0.023 ^{*#△}
7 weeks of radiotherapy	Stage T3	0.386 ± 0.013 ^{*#△}	0.895 ± 0.022 ^{*#△}	0.362 ± 0.012 ^{*#△}	0.912 ± 0.021 ^{*#△}
7 weeks of radiotherapy	StageT4	0.358 ± 0.012 ^{*#△}	0.932 ± 0.024 ^{*#△}	0.335 ± 0.011 ^{*#△}	0.948 ± 0.022 ^{*#△}

Note: Compared with pre-radiotherapy, ^{*}*P* < 0.05; compared with 1 week after radiotherapy, [#]*P* < 0.05; compared with 3 weeks after radiotherapy, [△]*P* < 0.05.

3.7. Comparison of changes in brain functional network indicators

Prior to radiotherapy, baseline levels of ReHo, ALFF and DMN functional connectivity in the temporal lobe were balanced across the three patient groups, with no significant differences observed between groups (*P* > 0.05). One week after radiotherapy, only minor fluctuations were observed in the brain functional indicators across all groups, with no statistically significant pathological abnormalities detected (*P* > 0.05); Three weeks after radiotherapy, the ReHo, ALFF and DMN functional connectivity strengths in the temporal lobe of patients in all three groups had decreased significantly compared with pre-treatment levels. Among these, the extent of decline in patients with advanced stage T4 was significantly greater than that in patients with stages T1/T2 and T3, with significant differences between groups (*P* < 0.05). Seven weeks following radiotherapy, the degree of disruption to the brain's functional networks had further increased, with functional synchrony and integrative capacity continuing to deteriorate. Overall, the temporal patterns of brain functional impairment were highly consistent with the progression of microstructural damage in the white matter, confirming the pathological characteristic of radiation-induced brain injury as 'functional abnormalities first, followed by structural damage'. For detailed data, see **Table 3**.

Table 3. Comparison of temporal lobe functional parameters among patient groups at different time points (mean ± SD)

Testing time	Grouping	Temporal lobe ReHo	ALFF in the temporal lobe	DMN functional connectivity strength
Before radiotherapy	Stages T1/T2	0.892 ± 0.035	1.025 ± 0.042	0.915 ± 0.038
Before radiotherapy	Stage T3	0.889 ± 0.032	1.021 ± 0.040	0.912 ± 0.035
Before radiotherapy	StageT4	0.890 ± 0.034	1.023 ± 0.041	0.913 ± 0.036
3 weeks of radiotherapy	Stages T1/T2	0.815 ± 0.030 [*]	0.936 ± 0.038 [*]	0.842 ± 0.032 [*]

Testing time	Grouping	Temporal lobe ReHo	ALFF in the temporal lobe	DMN functional connectivity strength
3 weeks of radiotherapy	Stage T3	0.772 ± 0.028*	0.885 ± 0.035*	0.796 ± 0.030*
3 weeks of radiotherapy	Stage T4	0.721 ± 0.025*	0.824 ± 0.032*	0.735 ± 0.028*
7 weeks of radiotherapy	Stages T1/T2	0.753 ± 0.027* [#]	0.872 ± 0.034* [#]	0.781 ± 0.029* [#]
7 weeks of radiotherapy	Stage T3	0.701 ± 0.024* [#]	0.813 ± 0.031* [#]	0.725 ± 0.026* [#]
7 weeks of radiotherapy	Stage T4	0.642 ± 0.022* [#]	0.745 ± 0.028* [#]	0.658 ± 0.024* [#]

Note: Compared with pre-radiotherapy, * $P < 0.05$; compared with 3 weeks after radiotherapy, [#] $P < 0.05$.

4. Discussion

Intensity-modulated radiotherapy is the standard treatment for the radical treatment of nasopharyngeal carcinoma, enabling precise coverage of the tumour target area and effective control of local lesions. However, due to the anatomical proximity of the nasopharynx to brain structures such as the temporal lobe and hippocampus, the scattered and cumulative doses resulting from radiotherapy can cause persistent damage to normal brain tissue, leading to radiation-induced brain injury. Early-stage manifestations of this complication are extremely subtle, with no obvious morphological or clinical abnormalities, making them difficult to detect through routine imaging examinations. By the time organic lesions such as cognitive decline or cerebral softening become apparent, the damage is already irreversible, severely compromising patients' long-term quality of life. Therefore, establishing a precise early assessment system and clarifying the temporal patterns of damage onset are of significant practical importance for guiding early clinical intervention and reducing the incidence of long-term brain damage^[1,7].

This study established multiple standardised follow-up time points to dynamically track the occurrence and progression of brain damage in nasopharyngeal carcinoma patients following radiotherapy. The results showed that one week after radiotherapy, brain tissue exhibited only temporary fluctuations in physiological parameters, with no pathological or organic damage observed; three weeks after radiotherapy, microstructural disturbances in the white matter of the temporal lobe and hippocampus, as well as imbalances in brain functional networks, could be reliably detected, representing the optimal time point for the assessment and clinical intervention of early, latent brain injury; seven weeks after radiotherapy, functional damage gradually progressed to structural damage such as demyelination and axonal degeneration, with the extent and severity of the damage continuing to worsen, confirming the existence of a clear time-dose cumulative effect in radiation-induced brain injury. The temporal patterns of early damage identified in this study provide data support for the development of personalised follow-up protocols and early neuroprotective strategies in clinical practice^[1,2,10].

The findings of this study suggest that tumour TNM staging is closely associated with the risk of and severity of radiation-induced brain injury. Patients with advanced T4 nasopharyngeal carcinoma have a wider extent of tumour infiltration and a larger radiotherapy treatment field; consequently, the surrounding normal brain tissue is exposed to higher doses of scattered radiation. Compared with patients with T1/T2 or T3 disease, they exhibit a higher incidence of early brain injury and more pronounced abnormalities in imaging parameters. In clinical practice, for patients with advanced nasopharyngeal carcinoma, it is necessary to optimise further radiotherapy planning to minimise the extent of radiation exposure to normal brain tissue, strengthen early postoperative imaging follow-up, and promptly implement neuroprotective interventions to

mitigate the adverse effects of radiation-induced brain injury on patients' long-term prognosis ^[5,7].

Multimodal MRI enables the simultaneous quantitative assessment of white matter microstructure and functional brain networks, effectively overcoming the limitations of conventional imaging examinations. In particular, DTI parameters objectively reflect the integrity of white matter fibre tracts and the extent of microscopic damage, whilst rs-fMRI parameters accurately assess the synchrony of neural activity and the state of functional integration between brain regions. The results of this study confirm that, three weeks following radiotherapy, the FA, ReHo and ALFF parameters in the temporal lobe demonstrate good stability, significant intergroup differences and high diagnostic performance. They can effectively detect subclinical brain damage that cannot be identified by conventional imaging and may serve as specific assessment indicators for early radiation-induced brain damage following radiotherapy for nasopharyngeal carcinoma, providing an objective basis for clinical risk prediction and the individualised adjustment of radiotherapy regimens ^[3,8].

This study has certain limitations: as a single-centre study with a small sample size, there may be a slight selection bias; the follow-up period covered only the early stages following radiotherapy, and did not further track changes in patients' long-term cognitive function or long-term prognostic outcomes. Furthermore, the analysis in this study was based solely on radiological indicators; it did not incorporate neurocognitive scales or serum damage markers for multidimensional validation, and therefore could not establish a precise correlation between radiological abnormalities and clinical cognitive impairment. Future research could involve multicentre, large-sample prospective studies with extended follow-up periods, integrating radiological, neuropsychological and serological indicators to construct multidimensional early prediction models, thereby further refining the system for the early screening and prevention of radiation-induced brain injury.

5. Conclusion

Multimodal MRI enables dynamic, quantitative monitoring of early, subtle changes in the microstructure and function of brain tissue following intensity-modulated radiotherapy for nasopharyngeal carcinoma, and can effectively detect subclinical, occult radiation-induced brain injury that is difficult to identify using conventional imaging. Three weeks after radiotherapy represents the optimal window for the assessment and intervention of early brain injury; furthermore, changes in brain function precede morphological damage to brain tissue, thereby allowing sufficient time for early clinical intervention. There is a positive correlation between the TNM staging of nasopharyngeal carcinoma and the severity of post-radiotherapy brain injury, with patients at an advanced stage being at higher risk of brain injury. The diagnostic performance of FA, ReHo and ALFF parameters in the temporal lobe at three weeks post-radiotherapy is excellent; these can serve as specific imaging biomarkers for early radiation-induced brain injury. They hold significant clinical value for optimising individualised radiotherapy protection strategies for nasopharyngeal carcinoma, guiding early neuroprotective treatment and improving patients' long-term prognosis.

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References

- [1] Tang Y, Chen L, 2022, Recent Advances in the Mechanisms and Early Intervention of Radiation-Induced Brain Injury in Head and Neck Tumours. *Chinese Journal of Radiation Oncology*, 31(04): 361–366.
- [2] Wang C, Liu M, Zhou F, 2023, Diagnostic Value of Multimodal MRI in Early Radiation-Induced Brain Injury Following Intensity-Modulated Radiotherapy for Nasopharyngeal Carcinoma. *Journal of Clinical Radiology*, 42(08): 1245–1249.
- [3] Zhang Y, Li J, Chen J, 2022, An Applied Study on the Assessment of White Matter and Cerebral Functional Network Damage Following Radiotherapy for Nasopharyngeal Carcinoma Using DTI Combined with Resting-State fMRI. *Radiology Practice*, 37(11): 1432–1437.
- [4] Qiu Q, Chen H, Cui Y, et al., 2023, Advances in Imaging Studies of Radiation-Induced Damage to the Skull Base Tissues Following Radiotherapy for Nasopharyngeal Carcinoma. *Chinese Journal of Clinical Medicine*, 16(1): 1–7.
- [5] Chen Q, Lin X, Han L, 2022, Imaging Analysis of Differences in Brain Damage Following Radiotherapy in Nasopharyngeal Carcinoma Patients with Different TNM Stages. *Tumour Imaging*, 31(03): 278–283.
- [6] Lv X, Guo Z, Tang L, 2021, A One-Year Follow-Up Study on Dynamic Morphological Changes in the Cerebral Cortex Following Radiotherapy for Nasopharyngeal Carcinoma Based on Structural MRI. *Quant Imaging Med Surg*, 11(6): 2307–2320.
- [7] Ouyang P, Ma J, Sun Y, 2023, A Study on the Correlation Between the Three-Dimensional Distribution of Radiation Dose in the Temporal Lobe and Radiation-Induced Brain Injury in Nasopharyngeal Carcinoma. *Int J Radiat Oncol Biol Phys*, 115(5): 1291–1300.
- [8] Lv X, Mai H, Qiu Y, 2022, Early Microstructural and Functional Brain Alterations After Intensity-Modulated Radiotherapy in Nasopharyngeal Carcinoma Patients. *J Neuroimaging*, 32(5): 689–696.
- [9] Tang Y, Zhang Y, 2023, Pericyte Dysfunction Mediates Radiation-Induced Brain Injury After Radiotherapy for Head and Neck Cancer. *Sci Transl Med*, 15(698): eabm6543.
- [10] Liu Y, Wang X, 2021, Dynamic Changes of Default Mode Network in Nasopharyngeal Carcinoma Patients with Radiation-Induced Brain Injury. *Radiol Oncol*, 55(3): 312–319.

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