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ORIGINAL

APPLICATION OF 3.0T HIGH-RESOLUTION MAGNETIC RESONANCE IMAGING FOR THE DIAGNOSIS OF STENOTIC VESSEL WALL PLAQUES IN THE MIDDLE CEREBRAL ARTERY: A STUDY ON FITNESS OF PROFESSIONAL ATHLETES

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ABSTRACT

Objective: To investigate the value of 3.0T high-resolution magnetic resonance imaging (HR-MRI) in the diagnosis of plaque in the vessel wall of middle cerebral artery stenosis. **Methods:** 41 Athletic patients with middle cerebral artery stenosis admitted from January 2018 to January 2020 were selected for the study, all of whom underwent HR-MRI, and the diagnostic results of digital subtraction angiography (DSA) were used as the gold standard to compare HR-MRI findings in middle cerebral artery stenosis with DSA diagnostic results. The NWI and responsible plaque heights of non-ischemic stroke and ischemic stroke athletic patients at 6 months, 12 months, 18 months and 24 months after discharge were compared. **Results:** 41 athletic patients were found to have stenosis in 49 middle cerebral arteries by DSA, including 33 cases of unilateral stenosis and 8 cases of bilateral stenosis. The diagnostic accuracy, specificity and sensitivity of HR-MRI in middle cerebral artery stenosis were 93.90% (77/82), 90.91% (30/33), 95.92% (47/49). There was no obvious distinction in NWI and responsible plaque height at 6, 12, 18 and 24 months after discharge in athletic patients with ischemic stroke ($P > 0.05$). When comparing NWI and responsible plaque height at corresponding time points after discharge in non-ischemic stroke patients, the distinctions were not obvious ($P > 0.05$). Compared with the group of ischemic stroke, the non-ischemic stroke group

NWI was lower at corresponding time points (P < 0.05). No obvious distinctions were found between the group of ischemic stroke and the group of non-ischemic stroke in terms of responsible plaque height at 6, 12, 18 and 24 months after discharge (P > 0.05). **Conclusion:** HR-MRI has highly valuable applications in the diagnosis of plaque in the wall of middle cerebral artery stenosis, which can accurately determine the stenosis of middle cerebral artery. Through HR-MRI, it was found that the plaque in the wall of patients with middle cerebral artery stenosis was stable after conventional treatment.

KEYWORDS: 3.0T high-resolution; magnetic resonance imaging; middle cerebral artery stenosis; diagnostic value; vessel wall plaque; responsible plaque height

1. INTRODUCTION

Stroke is a common and frequent disease in the elderly people, which is the second major fatal cause among the elderly worldwide, only after ischemic heart disease, and it is characterized by high morbidity, mortality and disability. And in recent years, the incidence of the population tends to be younger (Lu et al., 2018). Stroke can be divided into two types: ischemic stroke and non-ischemic stroke. Intracranial arterial lesions, including atherosclerosis and arterial stenosis, are the main causes of ischemic stroke (Liu et al., 2020).The middle cerebral artery is an important lesion vessel that contributes to the development of ischemic stroke, and the artery's ipsilateral circulatory atherosclerotic stenosis and altered plaque morphology are the main causes of stroke(Ran et al., 2020). Studies have found that ischemic stroke due to middle cerebral artery lesions accounts for up to 50% of all stroke athletic patients (shan Lu et al., 2018; Vigen et al., 2020). In athletic patients with transient ischemic attack (TIA) or stroke accompanied by intracranial atherosclerotic stenosis, the 2-year recurrence rate can reach 12%-14% despite the administration of statins and antiplatelet agents (Yu et al., 2018). In contrast, the annual incidence of stroke in athletic patients with symptomatic middle cerebral artery stenosis is more than 10%, while that of asymptomatic is about 2.8% (Shi et al., 2020). As research continues, it has been found that the occurrence of ischemic stroke is not only closely relevant to the degree of luminal stenosis, but also has a close correlation with vessel wall remodeling and plaque nature(Liang, Guo, Liu, Shi, & Luo, 2019). Thus, the diagnosis of ischemic disease by assessing the stenosis alone can no longer meet the clinical needs (Zhao et al., 2019). High-resolution magnetic resonance imaging (HR-MRI) is a high-field MRI technique developed in recent years to determine carotid atherosclerotic plaque formation, which can provide a reliable basis for the analysis of plaque composition and characteristics to accurately assess plaque stability and to predict the risk of related diseases (Abe et al., 2018; CHAKRABORTY, YARDI, & SINDHA, 2020). In this study, 41 athletic patients with middle cerebral artery stenosis admitted during January 2018 to January

2020 were chosen to study the application value of 3.0T HR-MRI in the diagnosis of plaque in the vessel wall of middle cerebral artery stenosis, which is reported as follows.

2. DATA AND METHODS

2.1 General information

41 athletic patients with middle cerebral artery stenosis admitted during January 2018 to January 2020 were chosen for research. **Inclusion criteria:** (1) Patients with recent history of TIA, all meeting the diagnostic criteria for TIA in the Chinese Expert Consensus Update on Transient Ischemic Attack (2011); (2) Ischemic stroke lesions detected by transcranial magnetic resonance imaging (MRI); (3) Ischemic stroke lesions confirmed by digital subtraction angiography (DSA), CT angiography (CTA) and other examinations to confirm the diagnosis of middle cerebral artery stenosis; (4) Stenosis rate ≥ 50%; (5) Patient with informed consent; (6) Athletic Patients complete medical records and other information. **Exclusion criteria:** (1) Athletic Patients with combined psychiatric diseases; (2) Athletic Patients with contraindications to MRI examination; (3) Athletic Patients with cerebral hemorrhage and occupying lesions; (4) Athletic Patients with infectious diseases of the brain; (5) Athletic Patients with combined cardiac, hepatic and renal insufficiency. There were 23 men and 18 women cases, aged 45-82 (58.95±2.46) years. Disease type: 18 cases of non-ischemic stroke and 23 cases of ischemic stroke.

2.2 Methods

HR-MRI examination method: All the enrolled athletic patients underwent 3.0T high-resolution MRI examination, and the equipment was selected from Skyra 3.0T superconducting MRI system, provided by Siemens. And the scan sequences were selected from liquid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), T1-weighted imaging (T1WI) and T2-weighted imaging (T2WI). Parameter settings: T1WI sequence: set TR to 440ms, TE adjustment to 2.46ms; T2WI: set TR to 5000ms, TE adjustment to 93ms; FLAIR: set TR to 8000ms, TE adjustment to 93ms; DWI: set TR to 3800ms, TE adjustment to 93ms, layer thickness set to 5mm, set layer spacing to 1mm and the field of view (FOV) to 220mm×220mm. The middle cerebral artery imaging (Figure 1) was performed by high-resolution MR vessel wall imaging with time-of-flight method (TOFMRA) with the following parameters: TOFMRA: set TR to 20ms, TE to 3.6ms, and FOV to 200mm; High-resolution MR vessel wall imaging (black blood sequence) and Parameters: T1WI: adjust TR to 700ms, TE set to 14ms, T2WI: adjust TR to 2500ms, set TE to 67ms, DWI: TR set to 2400ms, TE set to 17ms, FOV set to 80mm, adjust layer thickness to 2mm, layer spacing to 0. Posteriorly, the black blood sequence T1WI, T2WI and DWI were performed perpendicular to the stenotic segment artery. T2WI and DWI were performed (Figure 2), and finally SPACE-CET1WI-enhanced scan and DSC-PWI-enhanced scan were performed. Non-ischemic stroke and ischemic stroke HR-MRI images were shown in Figure 3 and Figure 4.

Image processing: Two radiologists with >8 years of experience reviewed the scans by double-blind method, and if a unified opinion could not be obtained, it was discussed until the opinion was unified. The scanned images were uploaded to the syngo MMWP workstation, and the lumen inner wall area (LA) and total vascular area (TVA) were determined on black blood sequence T2WI using the contouring area calculation tool. The wall normalization index (NWI) and wall area (WA) were calculated, and the height of the responsible plaque was measured at the highest point of the long axis of the plaque (WA=TVA-LA; NWI=WA/TVA). And all study subjects were tracked for 2 years continuously. During the follow-up period, they were instructed to receive conventional treatment, such as oral statins, aspirin for lipid regulation and antiplatelet therapy, as prescribed by their physicians.

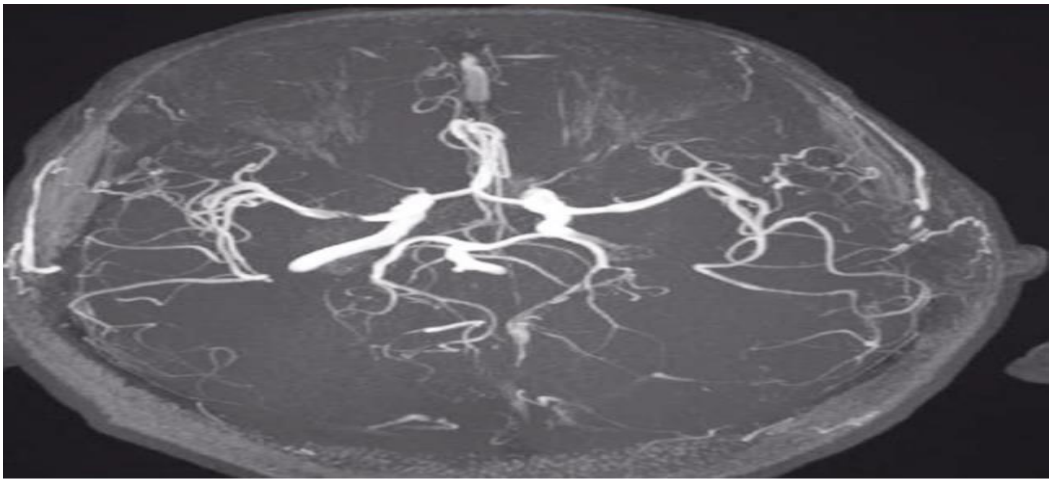

Figure 1. MRI image of right middle cerebral artery stenosis

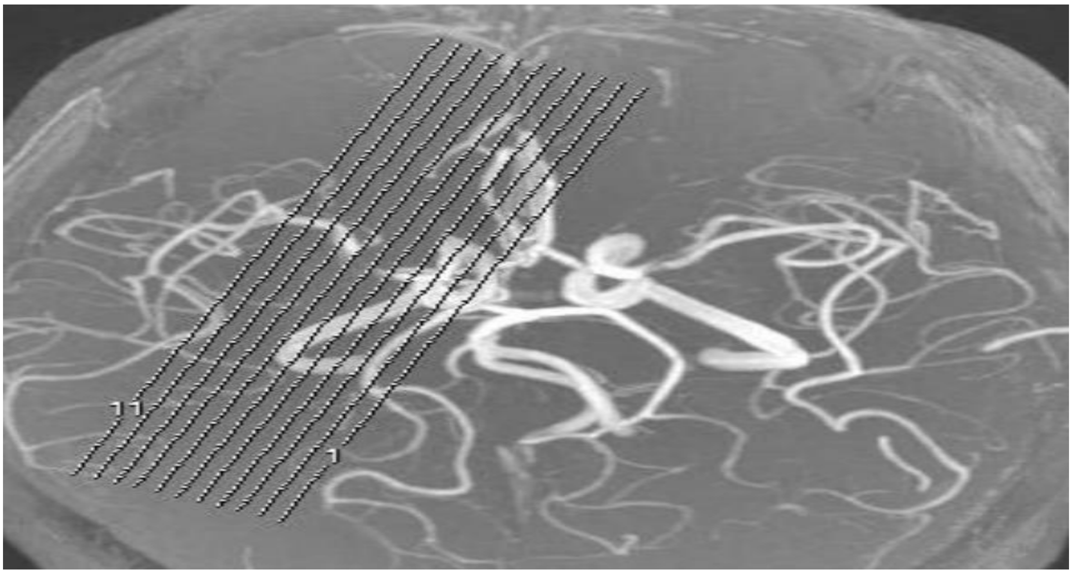

Figure 2. Localization image of middle cerebral artery scan

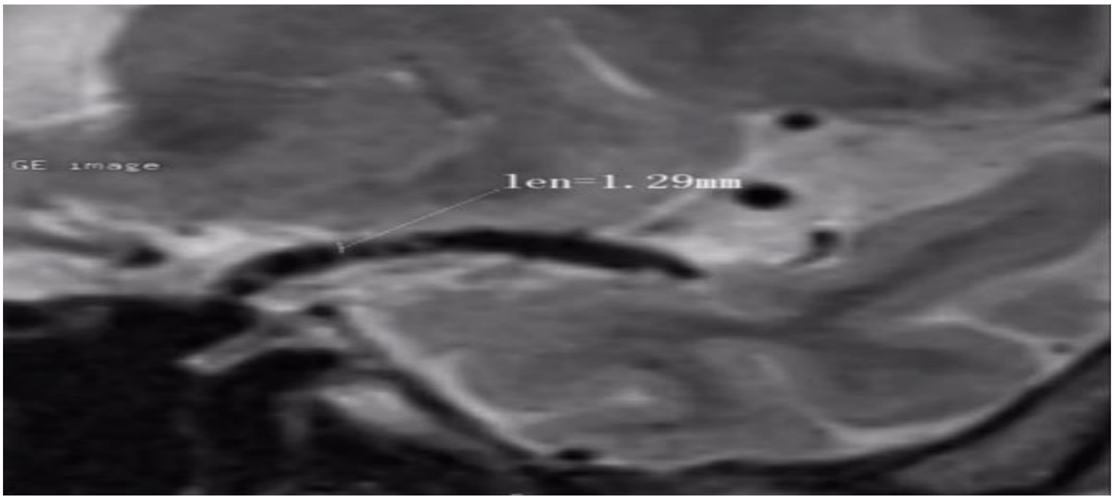

Figure 3. MRI image of the right middle cerebral artery plaque in a patient with non-ischemic stroke

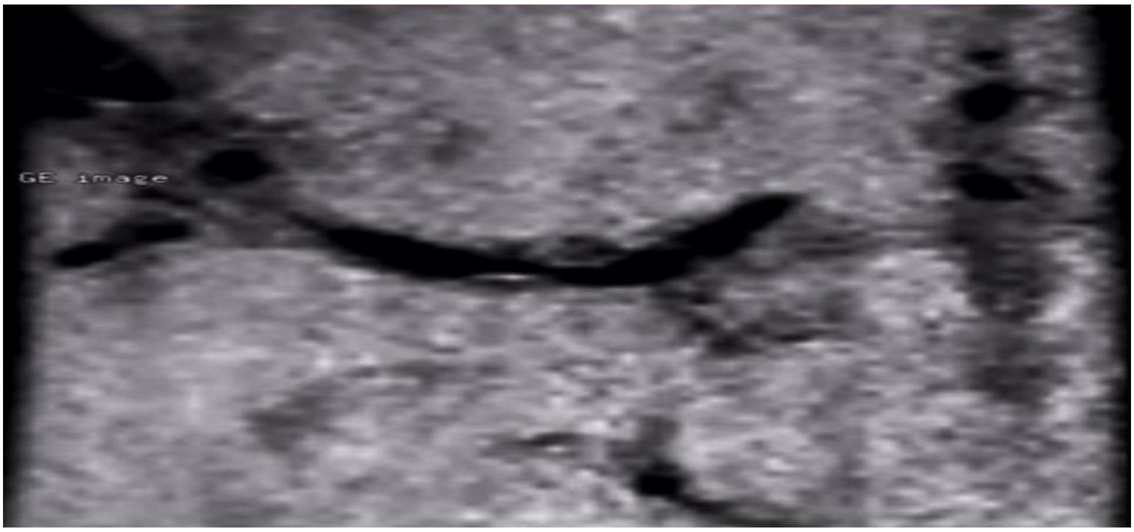

Figure 4. MRI image of the right middle cerebral artery plaque in a patient with ischemic stroke

2.3 Observation indicators

Using DSA diagnostic results as the gold standard, HR-MRI findings in middle cerebral artery stenosis were in comparison with DSA diagnostic results. NWI and responsible plaque height were measured at 6m, 12m, 18m and 24m after discharge to compare NWI and responsible plaque height in patients with non-ischemic stroke or ischemic stroke.

2.4 Statistical analysis

Data were processed by SPSS23.0. The measurement information (matching normal distribution) is presented as ($\bar{x}$ ± s) (t test) and the count information were indicated as % ($\chi 2$ test). $P<0.05$ means the distinction was obvious.

3. RESULTS

3.1 Comparison of diagnostic results of middle cerebral artery stenosis by HR-MRI and DSA

41 athletic patients were found to have stenosis in 49 middle cerebral arteries by DSA, including 33 cases of unilateral stenosis and 8 cases of bilateral stenosis. The accuracy, specificity, and sensitivity of HR-MRI for middle cerebral artery stenosis were 93.90% (77/82), 90.91% (30/33), and 95.92% (47/49). (Table 1)

Table1. Comparison of diagnostic results of middle cerebral artery stenosis by HR-MRI and DSA

DSA	HR-MRI		Total
	Stenosis	Non-stenosis	
Stenosis	47	2	49
Non-stenosis	3	30	33
Total	50	32	82

3.2 Comparison of NWI between patients with ischemic stroke and non-ischemic stroke at different time periods

The distinctions were not obvious (P > 0.05) when comparing NWI at 6m, 12m, 18m and 24m after discharge in patients with ischemic stroke. There was no obvious distinction in NWI at corresponding time points in patients with non-ischemic stroke (P > 0.05). And the NWI was lower in the group of non-ischemic stroke at 6, 12, 18 and 24 months after discharge in comparison with the group of ischemic stroke (P < 0.05) (Table 2, Figure 5).

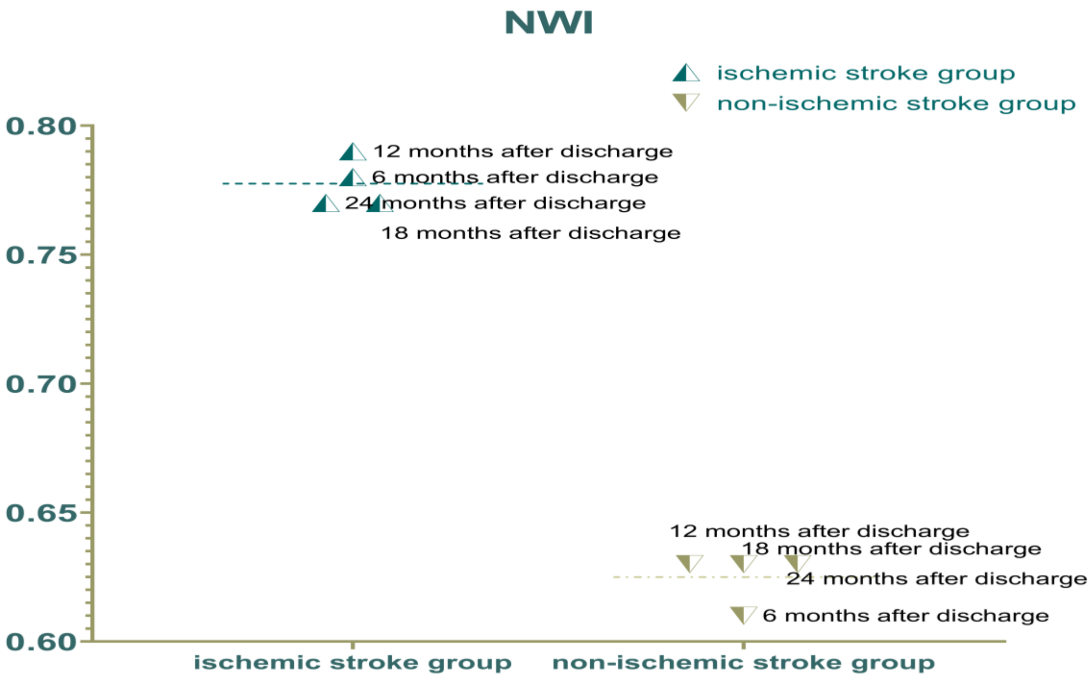

Figure 5. Change in NWI

Table 2 Comparison of NWI between patients with ischemic stroke and non-ischemic stroke at different time periods ($\bar{x}$ ±s)

Time/Group	Ischemic stroke（n=23）	Nonischemic stroke（n=18）	*t*	*P*
6m after discharge	0.78±0.11	0.61±0.22	3.232	0.002
12m after discharge	0.79±0.09	0.63±0.22	3.173	0.002
18m after discharge	0.77±0.10	0.63±0.21	2.821	0.007
24m after discharge	0.77±0.11	0.63±0.21	2.756	0.008
F	0.199	0.039		
P	0.897	0.990		

3.3 Comparison of responsible plaque height between ischemic stroke and non-ischemic stroke athletic patients at different time periods

There was no obvious distinction (P > 0.05) when comparing the responsible plaque heights of ischemic stroke athletic patients at 6, 12, 18 and 24 months after discharge. There was no obvious distinction (P > 0.05) in the responsible plaque heights of non-ischemic stroke athletic patients at 6, 12, 18 and 24 months after discharge. There was no obvious distinction (P > 0.05) in the responsible plaque height at 6, 12, 18 and 24 months after discharge in the group of ischemic stroke in comparison with the group of non-ischemic stroke. (Table 3, Figure 6)

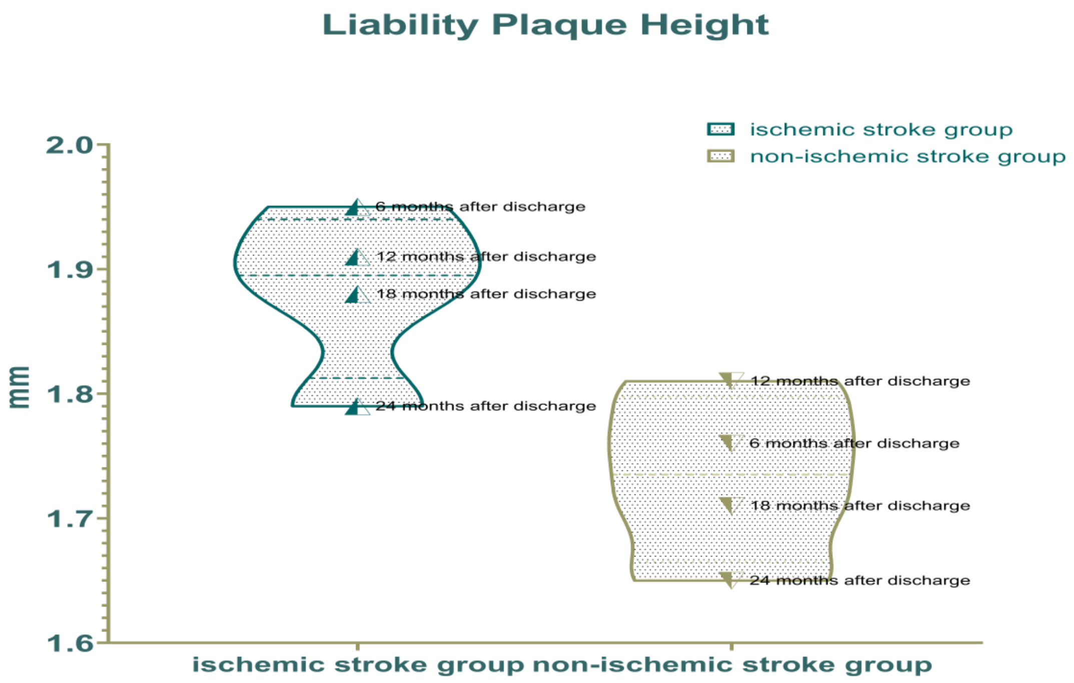

Figure 6. Change in height of responsible plaque

Table 3. Comparison of NWI between athletic patients with ischemic stroke and non-ischemic stroke at different time periods ($\bar{x}$ ±s)

Time/Group	Ischemic stroke（n=23）	Nonischemic stroke（n=18）	*t*	*P*
6m after discharge	1.95±0.49	1.76±0.66	1.058	0.296
12m after discharge	1.91±0.49	1.81±0.62	0.577	0.567
18m after discharge	1.88±0.49	1.71±0.59	1.008	0.319
24m after discharge	1.79±0.54	1.65±0.55	0.817	0.418
F	0.420	0.230		
P	0.739	0.875		

4. DISCUSSION

Intracranial atherosclerosis plays a major role in ischemic stroke and is often relevant to head and neck vasculopathy. Luminal stenosis or occlusion due to wall enlargement of the middle cerebral artery is closely related to vessel wall plate stability (Ha et al., 2021). Currently, there have been numerous clinical studies on the analysis of the nature of the middle cerebral artery plate, but there are few reports on its changes during treatment. For the diagnostic methods of vessel wall thickening, there are some distinctions in the evaluation indexes of different examination methods, but all of them have limitations. Imaging techniques such as CTA and DSA are the main clinical tools used for the diagnosis of intracranial and extracranial vascular stenosis, and their diagnostic results have important implications for treatment planning and prognostic assessment. Nonetheless, DSA is more invasive and not well accepted by patients, while CTA has a certain risk of missed diagnosis and misdiagnosis (Baek et al., 2022). In recent years, it has been found that the risk of stroke cannot be accurately predicted by assessing the luminal stenosis rate alone in light of that the nature and location of the atheromatous plaque in the vessel wall has an essential effect in the development of ischemic stroke in addition to stenosis. (Shen et al., 2018). CTA can be used to detect intracranial and extracranial vascular stenosis with high diagnostic accuracy (Sun et al., 2018). Nevertheless, this technique cannot clearly show the location and morphology of the vascular plaque, and there are false negatives and false positives in the diagnosis of middle cerebral artery stenosis (Zhang et al., 2019). The reason is that the CTA volume reproduction image could be easily affected by the adjustment threshold during the image development process, and when the contrast between the surrounding tissue and the vessel is too high, it can reduce or increase the degree of stenosis (Ouyang et al., 2020). HR-MRI, as the only noninvasive examination technique that can image in vivo intracranial artery wall structure, has a great potential in the diagnosis of middle cerebral artery stenosis and plaque in the vessel wall (Kaczynski et al., 2018).

HR-MRI can not only clearly display the lumen and outer wall boundary of vessels with atherosclerotic disease, but also image the intracranial atherosclerotic vessel wall (Kim, 2021). This enables quantitative analysis of the location and nature of the plaque and provides reliable information for the diagnosis of plaque in the vessel wall (Lee, Lee, Jung, & Jung, 2018). In this study, we found that there was no obvious distinction in NWI and responsible plaque height at 6, 12, 18 and 24 months after discharge in athletic patients with ischemic stroke (Martins et al., 2019). And there was no obvious distinction in NWI and responsible plaque height at 6m, 12m, 18m and 24m after discharge in non-ischemic stroke patients. In comparison with the group of ischemic stroke, the group of non-ischemic stroke had a lower NWI at corresponding time points. The NWI of athletic patients in two groups showed a slight fluctuation within 24 months after discharge, but remained within a limited interval, presumably with stable plaques in the vessel wall during conventional treatment of athletic patients with middle cerebral artery stenosis. The reason for this may be some improvement in vessel wall elasticity in patients with middle cerebral artery stenosis after conventional treatment. NWI can reflect the degree of influence of different individuals or different responsible plaques and vascular plaques on the stenosis (Cai, 2017). Previous studies have found that NWI is higher in symptomatic patients in comparison to asymptomatic athletic patients with middle cerebral artery stenosis, suggesting that for athletic patients with similar vessel size, a larger wall area is associated with a higher risk of cerebrovascular events. However, it has also been found that the larger the vessel wall area in athletic patients with ischemic stroke, the more it suggests that the patient's symptoms are closely related to the morphological characteristics of the vessel wall. Both plaque area and vessel wall index are important indicators used clinically for plaque stability assessment. And luminal stenosis is not only affected by the wall area but also directly related to vasospasm and vasoconstriction. Thus, the diagnosis of atherosclerotic plaque requires a combination of vessel wall index, plaque area, vessel wall area, responsible plaque height and lumen area. Studies have confirmed that an important factor in the recurrence of ischemic stroke is internal carotid atherosclerotic plaque, and quantitative analysis of plaque can accurately assess the risk of stroke occurrence. HR-MRI for the diagnosis of plaque in the vessel wall of patients with middle cerebral artery stenosis can accurately assess plaque vulnerability, including plaque distribution, arterial remodeling, intraplaque hemorrhage and intensification, plaque loading and other characteristics. Additionally, it can clearly show the location of the plaque in the vessel wall, providing a reference basis for plaque stability assessment.

5. CONCLUSION

In summary, HR-MRI examination revealed that patients with middle cerebral artery stenosis had good plaque stability in the vessel wall after conventional treatment, and the application of HR-MRI examination can accurately diagnose middle cerebral artery stenosis and plaque in the vessel wall, providing a reliable basis for clinical diagnosis and treatment.

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