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Original Research Article

Clinical effectiveness of 3.0T high-resolution magnetic resonance imaging in the diagnosis and prognostic assessment of intracranial atherosclerotic disease

Yuqian Wu*, Lulu Gong
Department of Radiological, Chongqing General Hospital, Chongqing 401147, China

For correspondence:* ***Email:* *18502541658@163.com*

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Abstract

Purpose: *To evaluate the usefulness of 3.0T high-resolution magnetic resonance imaging (HR-MRI) in the diagnostic and prognostic assessment of intracranial atherosclerotic diseases.*
Methods: *This retrospective study analyzed the medical data of 100 patients who received intracranial artery 3.0T HR-MRI from November 2020 to November 2021 in Chongqing General Hospital. The patients were divided into 'symptomatic group' (n = 60) and 'asymptomatic group' (n = 40) based on the occurrence of stroke or transient ischemic attack (TIA) within 4 months.*
Results: *Patients with stroke or TIA within 4 months had a higher risk of hyperlipidemia than those without (p < 0.05). The area of the outer edge of the vessel at the stenosis and the North American Standard for Symptomatic Carotid Endarterectomy Test (NASCET) index in the symptomatic group were significantly higher than in the asymptomatic group (p < 0.001). The symptomatic group documented a significantly higher frequency of fibrous cap rupture (56.17 %) versus the asymptomatic group (25.0 %) (p < 0.05).*
Conclusion: *Thus, 3.0T HR-MRI presents significant advantages in evaluating the intracranial arterial wall structure, plaque, and fibrous cap status, and hence can be used in combination with 3D-TOF-MRA in the diagnosis of intracranial atherosclerosis. This combined strategy provides a basis for the assessment of a patient's ischemic stroke condition.*

Keywords: *3.0T HR-MRI, Intracranial atherosclerosis, Ischemic stroke, Intracranial arterial wall structure, Plaque, Fibrous cap status, Hyperlipidemia*

INTRODUCTION

According to the China Stroke Prevention and Control Report, the standardized incidence of first stroke in people aged 40-74 years in China increased by 83.0 % between 2002 and 2013, and the annual incidence of stroke in China exceeded 5 million cases by 2020 [1]. In terms of the pathogenesis of the disease, approximately 80.0 % of strokes are triggered by cerebral ischemia, and 20.0 % - 30.0 % are attributed to arterial plaque rupture and dislodgement [2, 3]. Currently, drugs for the management of stroke include anti-platelet aggregation, statins, antioxidants, and antioxidants. However, long-term medication is associated with various adverse events, which may complicate the clinical care of patients. Endovascular medicine is a new direction in the treatment of intracranial arterial stenosis in recent studies. However, its efficacy and prognostic benefits require further verification.

Therefore, early identification of plaque components and assessment of plaque stability are essential to lower the risk of stroke. Ischemic stroke in Chinese residents is the main culprit in intracranial atherosclerosis, and the middle cerebral artery is most liable to be involved in intracranial vascular plaques. The recurrence and mortality rates of patients with ischemic stroke triggered by middle cerebral artery stenosis are significantly higher than those of hemorrhagic stroke [4, 5], which underlines the importance of the middle cerebral artery examination in the assessment of the risk of stroke in patients. Various imaging techniques, such as transcranial Doppler, magnetic resonance angiography, and digital subtraction angiography used in current practice, only demonstrate the severity of intracranial atherosclerotic stenosis but fail to identify the cause of stenosis [6]. By contrast, high-resolution magnetic resonance imaging (HR-MRI) can measure the plaque load and the thickness of diseased vessels, thereby facilitating clinical assessment of the location and composition of plaque and the wall of diseased vessels. Moreover, research has confirmed the maturity of HR-MRI in the carotid vascular examination, indicating a well-founded theoretical basis for HR-MRI of intracranial arteries [9]. The present study was performed to investigate the benefits of 3.0T HR-MRI in the diagnosis and evaluation of intracranial atherosclerosis.

METHODS

Patients and study design

In this retrospective study, 100 patients who received intracranial artery 3.0T HR-MRI from November 2020 to November 2021 in Chongqing General Hospital were enrolled. The patients were divided into ‘symptomatic group’ (n = 60) and ‘asymptomatic group’ (n = 40) based on the occurrence of stroke or transient ischemic attack (TIA) within 4 months. The study was double-blind, with neither the study participants nor the investigator informed of the trial grouping, and the study designer was in charge of the arrangement and control of the entire trial.

Inclusion criteria

Patients aged ≥18 years, with excellent or good image quality grading (see analysis criteria), with complete clinical data, who received full treatment in Chongqing People's Hospital, without atrial fibrillation, patent foramen ovale, arterial entrapment, arteritis, and other clear causes of acute ischemic stroke, and without vital organ dysfunction or failure were included.

Exclusion criteria

(1) Patients with hearing impairment, speech impairment, unconsciousness, mental illnesses that prevent normal communication, or other serious organic diseases were excluded.

Grouping criteria

The patients were divided into symptomatic group (n=60) and asymptomatic group (n=40) based on to the occurrence of stroke or transient ischemic attack (TIA) within 4 months.

Ethical considerations

This study complied with the principles of the Declaration of Helsinki [10] and was approved by the Ethics Committee of Chongqing General Hospital, prior to the experiment. The subjects signed the informed consent form or their immediate family members signed on their behalf before being included in the clinical trial.

Diagnosis procedures

Examination

A dual gradient 3.0T HR-MRI platform (HD×T platform, TwinSpeed; GE Medical Systems, GE Healthcare, Siemens) with an 8-channel head coil was used to perform a conventional scan and 3D-time-of-flight (TOF) magnetic resonance angiography (MRA) with conventional scan sequences of T1WI, T2WI, and DWI with b values of 0 mm^2/s and 1000 mm^2/s. Firstly, the 3D-TOF-MRA was performed using the "bright-blood" technique to obtain the basic conditions of the patient's intracranial arteries, followed by image reconstruction and data processing. If no stenosis was seen after multidimensional reconstruction by maximum intensity projection (MIP) at the workstation, the vertical middle cerebral artery (MCA) and basilar artery (BA) trunks were further scanned using the "black blood" technique, and the exact location of stenosis was determined based on the patient's infarct area. The scanning sequences contained TSE T2WI, FS-T2WI, TSE T1WI, and FS-T1WI, and the scanning parameters are shown in Table 2. The T1WI+C sequence was performed using gadopentetate glucosamine (Beijing Beilu

Pharmaceutical Co. Ltd, State Drug Administration H20013088) as the contrast agent which was injected at a rate of 2 mL/sec with a high-pressure syringe at a dose of 0.2 mmol/kg.

Image processing

The images were reviewed by 2 clinically experienced imaging physicians on an MRI post-processing workstation.

Reinforcement treatment

Patients in the acute phase were given 300 mg of aspirin daily, which was reduced to 100 mg daily for maintenance therapy after 1 to 3 months of treatment. In addition, 75mg of ozagrel was administered daily for 1 to 3 months. Statins were also orally administered before bedtime daily. Blood pressure, blood lipids, and blood glucose levels were closely monitored.

Analysis criteria

Image quality grading

The image quality was considered excellent if the inner and outer walls of the lumen are clearly displayed. The image quality was considered good if the inner and outer walls of the lumen are clearly displayed at most levels, and the outer walls of the lumen are poorly displayed at some levels. A moderate image quality indicated that the inner and outer walls of the lumen was observed at most levels, with unclear views, while the image quality was considered poor if a large number of artifacts prevented the observation of the inner and outer walls of the lumen.

Stenosis of the middle cerebral artery lumen

The HR-MRI image was first magnified 2.5 times to determine whether the wall of the carrier artery was thickened, followed by a measurement of the vascular area. The T2 images of the middle cerebral artery stenosis were analyzed, and the level with the most severe stenosis was selected to measure the lumen area of the most stenotic vessel. Conventional 3D-TOF-MRA images were reconstructed on 3D processing to produce a cross-sectional image perpendicular to the stenosis, and the most stenotic level was selected to measure the lumen area and the lumen area of the adjacent reference (the widest part of the normal artery proximal to the stenosis). MRA stenosis and 3.0T HR-MRI stenosis were calculated as (1 - area of lumen at stenosis/area of adjacent reference position), expressed as a percentage. Patients were assessed for middle cerebral artery stenosis based on the North American Symptomatic Carotid Endarterectomy Test criteria (NASCET) [11].

Table 1: Comparison of the general profile of patients

Plaque status

Intraplaque hemorrhage is shown as a significantly high signal on T1WI and DWI sequences, high signal or mixed signal in 3D-TOF. Calcified tissues were displayed as an irregular low signal on all sequences of MRI. Lipid or necrotic mass is an equal or slightly high signal on TIWI, DWI, and 3D-TOF-MRA sequences. Thick fibrous cap, thin fibrous cap, and fibrous cap rupture were shown as an equal signal on T1WI sequences of the fibrous cap, unspecific signal on DWI, and banded low signal on 3D-TOF. Tissue fibrosis shadow was an unspecific signal on magnetic resonance.

Parameters assessed

Parameters assessed consist of baseline profiles of the patients, including data: gender, age, body mass, BMI, underlying disease (medical history), lifestyle, education level, monthly income, and place of residence, 3.0T HR-MRI sequence scan parameters, degree of luminal stenosis, conditions of plaques, and fibrous cap rupture status.

Statistical analysis

The SPSS 20.0 was selected as the data processing software, while GraphPad Prism 7 (GraphPad Software, San Diego, USA) was used for graphics. Count data were analyzed using chi-square test while measurement data were analyzed by t-test. $P < 0.05$ was considered statistically significant.

RESULTS

General patient information

The two arms were well-balanced in terms of baseline patient features ($p > 0.05$). Patients with stroke or TIA within 4 months showed a higher incidence of hyperlipidemia than those without these cardiovascular events ($p < 0.05$; Table 1).

3.0T HR-MRI sequence scanning results

The 3.0T HR-MRI sequence scanning parameters are shown in Table 2.

Table 1: Characteristics of patients

Group	Symptomatic group (n=60)	Asymptomatic group (n=40)	X^2/t	*P*-value
Sex			0.000	1.000
Male	42	28		
Female	18	12		
Age (years)				
Range	33-76	32-74		
Mean	56.98 ± 5.65	57.10 ± 5.47	0.105	0.916
Mean weight (kg)	62.12 ± 2.68	62.20 ± 2.40	0.152	0.879
BMI (kg/m^2)	22.98 ± 2.65	22.90 ± 2.68	0.147	0.883
Underlying disease (medical history)				
Hypertension	48	25	3.729	0.053
Diabetes mellitus	30	14	2.192	0.139
Hyperlipidemia	45	20	6.593	0.010
Place of residence			0.029	0.865
Urban	38	26		
Rural	22	14		
Monthly income (yuan)			0.028	0.868
≥4000	35	24		
<4000	25	16		
Living habits				
Smoking	24	15	0.063	0.802
Drinking	28	13	1.991	0.158
Education level			0.000	1.000
High school and below	36	24		
University and above	24	16		

Table 2: 3.0T HR-MRI sequence scanning parameters

Parameter	TR (ms)	TE (ms)	FOV (cm)	Slice thickness (mm)	Slice gap (mm)
3D-TOF-MRA	29	3.4	24×24	1.2	0.6
TSE T_1WI	3000	14.0	13×13	2	2.5
TSE T_2WI	700	50.0	18×18	2	2.5
FS-T_1WI	567	15.8	10×10	2	2.5
FS-T_2WI	2883	49.0	10×10	2	2.5
T_1WI+C	567	15.8	10×10	2	2.5

Table 3: Analysis of intracranial arterial plaque composition in patients [n(%)]

Group	N	Hemorrhage	Calcification	Lipid	Necrotic mass
Asymptomatic group	40	12（30.0）	26（65.0）	25（62.5）	1（2.5）
Symptomatic group	60	30（50.0）	40（66.7）	31（51.7）	3（5.0）
X^2		3.941	0.030	1.143	0.391
***P*-value**		0.047	0.863	0.285	0.532

Degree of middle cerebral artery stenosis

There was no statistical difference in the lumen area of the stenosis at the middle cerebral artery stenosis between the two arms *(p* > 0.05), while the area of the outer edge of the vessel at the stenosis and NASCET were significantly higher in the symptomatic group than in the asymptomatic group *(p* < 0.001)

Intracranial arterial plaque composition

The incidence of plaque bleeding was significantly higher in the symptomatic group than in the asymptomatic group (p < 0.001; Table 3).

Fibrous cap rupture status

The symptomatic group documented a significantly higher frequency of fibrous cap rupture (56.17 %) versus the asymptomatic group (25.0 %) ($\chi^2 = 9.767$, $p = 0.002$).

DISCUSSION

Stroke is classified into ischemic and hemorrhagic stroke, which is caused by sudden rupture or obstruction of blood vessels in the brain [12].

Ischemic stroke is induced by impaired cerebral blood circulation, hypoxia, and ischemia and is characterized by high disability, high mortality, and a low cure rate. It is the primary cause of disability and death in Chinese adults [13]. Currently, with the increasing aging of the Chinese population, the incidence of ischemic stroke has increased yearly [14], for which intracranial atherosclerosis serves as the main cause, and patients with ischemic stroke mostly experience middle cerebral artery involvement. Given the broad range of blood supply to the middle cerebral artery, the resulting atherosclerosis is highly prone to recurrence, and patients with malignant middle cerebral artery occlusion suffer a high mortality rate. Therefore, intensive research on intracranial arteries is of great importance.

It was previously believed that the degree of middle cerebral artery luminal stenosis was the primary criterion for assessing middle cerebral artery atherosclerosis, and a greater degree of luminal stenosis was considered to be associated with a greater tendency to develop ischemic brain symptoms [15]. However, recent studies have shown that, in addition to cerebral ischemia, arterial plaque rupture, and dislodgement also contribute to the onset of stroke, suggesting that the correlation between arterial plaque and cerebral ischemic events is by no means limited to plaque-induced luminal narrowing. The occurrence of cerebrovascular events correlates closely with the stability of the atheromatous plaque, i.e. the element that determines the prognosis of patients with intracranial atherosclerosis is the internal composition of the plaque, the key to which is the property of the plaque. By their properties, plaques are clinically classified as stable or unstable types, with internal lipid nuclei, hemorrhage, and calcification being the determinants for their classification [16]. At this stage of practice, although several imaging methods are available to assess the degree of middle cerebral artery stenosis, most examinations fail to clarify the pathogenesis of stroke, resulting in poor outcomes for some patients and limited applications. With the upgrading of imaging technology, a growing body of evidence suggests that HR-MRI may reflect the properties and characteristics of arterial plaques and thus facilitates the clinical assessment of stroke and TIA [17].

The results of this study revealed that no statistical difference was found in the area of the stenotic lumen at the middle cerebral artery stenosis between the two groups. The area of the outer edge of the vessel at the stenosis, NASCET score, and the incidence of fibrous cap rupture in the symptomatic group were significantly higher than in the asymptomatic group. Thus, compared with traditional imaging techniques, 3.0T HR-MRI can measure lesion vessel thickness, assess the degree of middle cerebral artery stenosis, and provide sufficient spatial resolution conditions. Consequently, it contributes to the determination of plaque location, composition, and diseased vessel wall [18], thereby providing a key basis for the evaluation of clinical manifestations and treatment efficacy. In addition, 3.0T HR-MRI is the only technique that performs non-invasive imaging of the intracranial vessel wall [19], with no side effects for patients. This advantage addresses the reality of the increasing incidence of stroke in China.

CONCLUSION

The 3.0T HR-MRI presents significant benefits in evaluating intracranial arterial wall structure, plaque, and fibrous cap status, and can be used in combination with 3D-TOF-MRA in the diagnosis of intracranial atherosclerosis to provide a basis for the assessment of the patient's ischemic stroke condition.

DECLARATIONS

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Ethical approval

This study was approved by the Ethics Committee of Chongqing General Hospital, China.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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