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Retrospective Cohort Study

Application of MAGnetic resonance imaging compilation in acute ischemic stroke

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Abstract

BACKGROUND

Synthetic magnetic resonance imaging (MRI) MAGnetic resonance imaging compilation (MAGiC) is a new MRI technology. Conventional T1, T2, T2-fluid-attenuated inversion recovery (FLAIR) contrast images, quantitative images of T1 and T2 mapping, and MAGiC phase sensitive inversion recovery (PSIR) Vessel cerebrovascular images can be obtained simultaneously through post-processing at the same time after completing a scan. In recent years, studies have reported that MAGiC can be applied to patients with acute ischemic stroke. We hypothesized that the synthetic MRI vascular screening scheme can evaluate the degree of cerebral artery stenosis in patients with acute ischemic stroke.

AIM

To explore the application value of vascular images obtained by synthetic MRI in diagnosing acute ischemic stroke.

METHODS

A total of 64 patients with acute ischemic stroke were selected and examined by MRI in the current retrospective cohort study. The scanning sequences included traditional T1, T2, and T2-FLAIR, three-dimensional time-of-flight magnetic resonance angiography (3D TOF MRA), diffusion-weighted imaging (DWI), and synthetic MRI. Conventional contrast images (T1, T2, and T2-FLAIR) and intracranial vessel images (MAGiC PSIR Vessel) were automatically reconstructed using synthetic MRI raw data. The contrast-to-noise ratio (CNR) values of traditional T1, T2, and T2-FLAIR images and MAGiC reconstructed T1, T2, and T2-FLAIR images in DWI diffusion restriction areas were measured and compared. MAGiC PSIR Vessel and TOF MRA images were used to measure and calculate the stenosis degree of bilateral middle cerebral artery stenosis areas. The consistency of MAGiC PSIR Vessel and TOF MRA in displaying the degree of vascular stenosis with computed tomography angiography (CTA) was compared.

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RESULTS

Among the 64 patients with acute ischemic stroke, 79 vascular stenosis areas showed that the correlation between MAGiC PSiR Vessel and CTA ($r = 0.90$, $P < 0.01$) was higher than that between TOF MRA and CTA ($r = 0.84$, $P < 0.01$). With a degree of vascular stenosis $> 50\%$ assessed by CTA as a reference, the area under the receiver operating characteristic (ROC) curve of MAGiC PSiR Vessel [area under the curve (AUC) = 0.906, $P < 0.01$] was higher than that of TOF MRA (AUC = 0.790, $P < 0.01$). Among the 64 patients with acute ischemic stroke, 39 were scanned for traditional T1, T2, and T2-FLAIR images and MAGiC images simultaneously, and CNR values in DWI diffusion restriction areas were measured, which were: Traditional T2 = 21.2, traditional T1 = -6.7, and traditional T2-FLAIR = 11.9; and MAGiC T2 = 7.1, MAGiC T1 = -3.9, and MAGiC T2-FLAIR = 4.5.

CONCLUSION

The synthetic MRI vascular screening scheme for patients with acute ischemic stroke can accurately evaluate the degree of bilateral middle cerebral artery stenosis, which is of great significance to early thrombolytic interventional therapy and improving patients' quality of life.

Key Words: Acute ischemic stroke; Magnetic resonance imaging; Magnetic resonance angiography; Computed tomography angiography; Phase sensitive inversion recovery

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Core Tip: This study evaluated the application value of vascular images obtained by synthetic magnetic resonance imaging in diagnosing acute ischemic stroke. Synthetic magnetic resonance imaging can obtain vascular images simultaneously as T2, T1, T2-fluid-attenuated inversion recovery and other contrast images. Compared with the results of computed tomography angiography examination, we found that the vascular images can be used to positively evaluate the degree of intracranial bilateral middle cerebral artery stenosis, which is of great significance to early thrombolytic interventional therapy and improving patients' quality of life.

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INTRODUCTION

Cerebrovascular disease is the second deadliest disease globally, and acute cerebrovascular disease also has a higher disability rate than any other single disease, which brings heavy burdens to society[1-4]. In recent years, imaging has played an increasingly prominent key role in preventing and treating cerebrovascular disease[5]. For example, in treating acute stroke, the treatment time window of some patients with macrovascular diseases can be extended by 6-24 h using image evaluation[6,7]. The long-term survival rate and recurrence rate after acute ischemic stroke also vary significantly with the different causes of the first stroke. The 5-year survival rate of small vessel disease is the highest in both males and females, and the 5-year recurrence rate is the lowest in female patients with small vessel disease and male patients with large vessel diseases[8]. The traditional magnetic resonance imaging (MRI) technology, three-dimensional time-of-flight magnetic resonance angiography (3D TOF MRA), has been widely used in screening cerebrovascular diseases because of its advantages, including non-invasiveness, non-radiation, and no need to inject contrast media[9,10]. However, in the imaging examination of patients with acute stroke, saving time can save the brain, so the shorter the examination process, the better the outcome. Traditional sequences such as T1, T2, T2-fluid-attenuated inversion recovery (FLAIR), TOF MRA, and diffusion-weighted imaging (DWI) require separate scanning, so it

usually takes more than 10 min to complete all the examinations. Furthermore, 3D TOF MRA may overestimate the degree of vascular stenosis due to the hemodynamic changes in stenotic vessels.

MAGnetic resonance imaging compilation (MAGiC) is a newly emerging synthetic MRI technology. While completing one scan, the technician can acquire conventional T1, T2, T2-FLAIR, and other contrast images, quantitative T1 mapping and T2 mapping images, as well as MAGiC phase-sensitive inversion recovery (PSIR) Vessel cerebrovascular images simultaneously through post-processing, which significantly shortens the scanning time required for magnetic resonance examination[11-14]. In recent years, some researchers reported that MAGiC can be used to reconstruct various contrast images that can be applied in patients with acute ischemic stroke, and T2 mapping images acquired by MAGiC can more accurately evaluate stroke onset time[15,16]. However, studies evaluating the clinical application of intracranial vascular images acquired by MAGiC have not been reported.

This study aimed to compare the accuracy of MAGiC PSIR Vessel and TOF MRA in evaluating the stenosis degree of bilateral middle cerebral arteries, and to further explore the application value of MAGiC in acute ischemic stroke.

MATERIALS AND METHODS

General information

A total of 64 patients with acute ischemic stroke diagnosed at the neurology department of our hospital (The Stroke Hospital of Liaoning Province, Liaoning Province, China) from November 2020 to May 2021 were retrospectively analyzed (all conforming to the 2018 edition of Chinese Guidelines for Diagnosis and Treatment of Acute Ischemic Stroke), including 44 males and 20 females, aged from 41 to 78 years (average age: 58 years). Upon admission, all patients underwent multi-sequence brain MRI scanning (including DWI, TOF MRA, and MAGiC), and computed tomography angiography (CTA) scanning was performed within 3 d after MRI examination. The post-processing images of DWI, TOF MRA, synthetic MRI, and CTA were retrospectively analyzed. All patients signed an informed consent form before examinations.

Scanning equipment and parameters

In this study, a SIGNAPioneer 3.0T MR scanner (GE, USA) with a 21-channel head phased-array coil was used. The main scanning sequences are shown in Table 1.

Image post-processing and analysis

MAGiC original image and images (T1, T2, T2-FLAIR, T2 mapping, and MAGiC PSIR Vessel) automatically generated with the post-processing software supplied with the GE host after scanning were analyzed (Figure 1).

The 3D TOF MRA and MAGiC PSIR Vessel images were post-processed with Reformat software of GE ADW4.7 workstation. The consistency of the two examination methods with CTA in evaluating the degrees of intracranial vascular stenosis was investigated.

The degree of vascular stenosis was calculated as (1-diameter of the lumen at stenosis/diameter of the lumen of an adjacent normal blood vessel) × 100%.

With CTA vascular stenosis degree greater than 50% as the classification point, receiver operating characteristic (ROC) curves were plotted for the two examination methods to calculate the area under the curve (AUC).

The method for measuring contrast-to-noise ratio (CNR) values in DWI diffusion restriction areas of traditional T1, T2, and T2-FLAIR images as well as MAGiC T1, T2, and T2-FLAIR images was as follows: $CNR = (\text{mean intensity of stroke lesion} - \text{mean intensity of thalamus}) / \text{standard deviation of the thalamus}$.

Statistical analysis

All quantitative data were analyzed and processed with SPSS25.0 statistical software. With CTA as the control, the consistency and correlation of the two examination methods TOF MRA and MAGiC PSIR Vessel with CTA in evaluating the degree of vascular stenosis were evaluated by Bland-Altman plots and Spearman correlation analysis, respectively. The significant difference was set as $P < 0.05$.

Table 1 3.0T magnetic resonance skull scanning sequences and parameters

	Slice thickness (mm)	Matrix (mm)	TR (ms)	TE (ms)	Acquisition time (min)	FOV (cm)
DWI	5	130 × 160	4221	80.2	0:34	24
TOF MRA	1.4	384 × 224	19	3.4	3:32	24
Synthetic MRI (MAGiC)	1.6	320 × 192	7365	12.9/90.1	4:25	24

MAGiC: MAGnetic resonance imaging compilation; TOF MRA: Time-of-flight magnetic resonance angiography; DWI: Diffusion weighted imaging (b value = 1000); TR: Repetition time; TE: Echo time; FOV: Field of view.

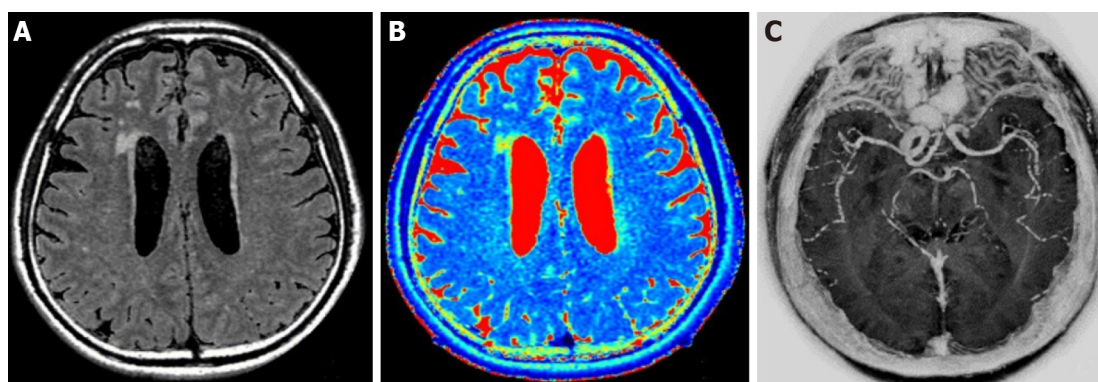


Figure 1 A 61-year-old man with transient ischemic attack. Automatic image reconstruction from MAGnetic resonance imaging compilation (MAGiC) raw data. A: MAGiC T2-fluid-attenuated inversion recovery (left); B: MAGiC T2 mapping (middle); C: MAGiC phase sensitive inversion recovery Vessel (right).

RESULTS

Figure 2 and Figure 3 show the evaluation of intracranial vascular stenosis degree by 3D TOF MRA, MAGiC PSIR Vessel, and CTA. The correlation between MAGiC PSIR Vessel and CTA ($r = 0.90$, $P < 0.01$) was higher than that between TOF MRA and CTA ($r = 0.84$, $P < 0.01$). The area under the ROC curve of MAGiC PSIR Vessel (AUC = 0.906, $P < 0.01$) was higher than that of TOF MRA (AUC = 0.790, $P < 0.01$), as shown in Figure 4.

MAGiC-reconstructed multi-contrast images had reduced CNR values of DWI diffusion restriction areas than the traditional multi-contrast images (traditional T2 = 21.2, traditional T1 = -6.7, and traditional T2-FLAIR = 11.9; MAGiC T2 = 7.1, MAGiC T1 = -3.9, and MAGiC T2-FLAIR = 4.5; Figure 5). In addition, two experienced diagnosticians respectively evaluated whether the images obtained by the two methods could meet the clinical diagnostic requirements of stroke. The results showed that both methods could meet the clinical diagnostic requirements.

DISCUSSION

Synthetic MRI MAGiC is a quantitative MRI technique, which can generate a variety of conventional contrast images (T1, T2, T2-FLAIR, *etc.*), quantitative images (T1 mapping and T2 mapping), and intracranial vessel images (PSIR Vessel) simultaneously in a single scan by acquiring the T1 relaxation rate, T2 relaxation rate, and PD density value of tissues, and has been applied in many sites such as nerves and joints [17-26]. Among them, research has been conducted on the application of T2 mapping in the nervous system, such as the evaluation of edema around tumors and showed epileptic lesions. In recent years, in the imaging diagnosis of stroke, many studies have been conducted to apply synthetic MRI imaging technology. For example, T2 mapping quantitative images acquired by MAGiC could more accurately evaluate stroke onset time [27-29].

MRI can provide important imaging evidence in the prevention, diagnosis, and treatment of cerebrovascular diseases. However, its long scanning time, especially in patients with hyperacute stroke, contradicts the clinical need to carry out treatment as soon as possible. For example, the evaluation of vascular stenosis degree in acute

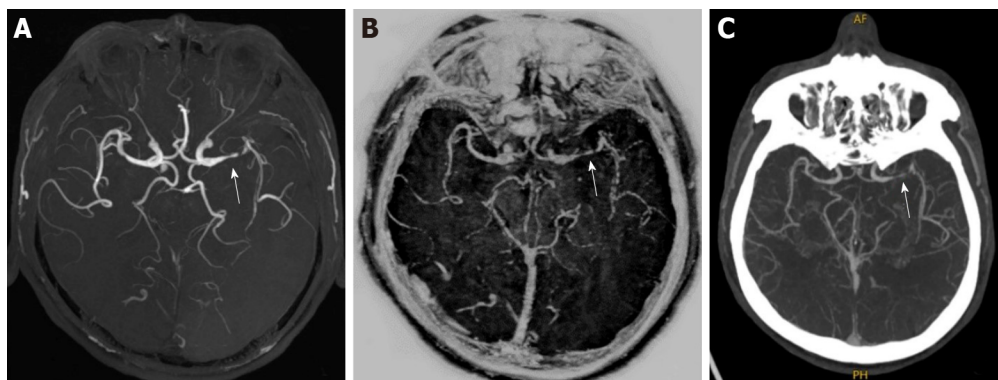


Figure 2 A 49-year-old man with bilateral lacunar cerebral infarction. A: Three-dimensional time-of-flight magnetic resonance angiography (left); B: MAGnetic resonance imaging compilation phase sensitive inversion recovery Vessel (middle); C: Computed tomography angiography (right). All three examination methods showed severe local stenosis of the left middle cerebral artery (arrows).

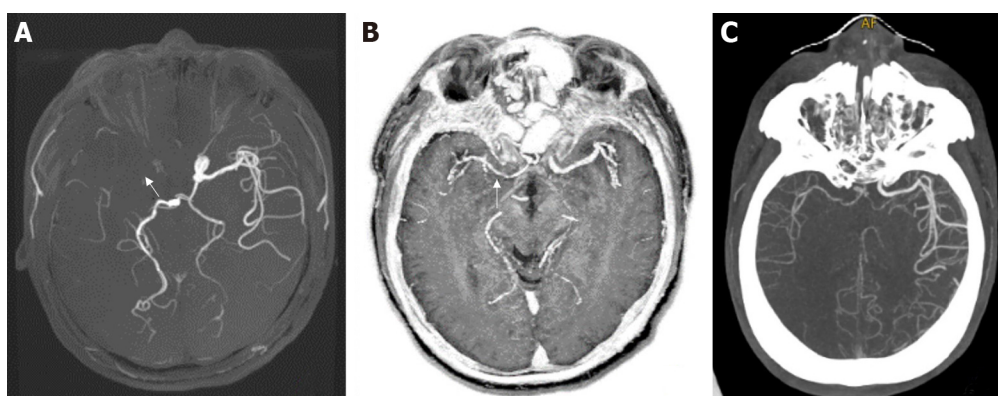


Figure 3 A 53-year-old man with right cerebral infarction. A: The right middle cerebral artery was not shown in three-dimensional time-of-flight magnetic resonance angiography (left); B: MAGnetic resonance imaging compilation phase sensitive inversion recovery Vessel (middle); and C: Computed tomography angiography (right). Both the latter two showed mild and moderate stenosis of the local lumen of the right middle cerebral artery (arrows).

stroke is of great value in defining the etiology and responsible vessels and guiding the selection of subsequent clinical treatment regimens. However, traditional TOF MRA scanning usually takes 3 to 5 min; therefore, a vascular imaging technique with a shorter scanning time is needed in MRI examination. MAGiC PSiR Vessel intracranial blood vessel images are generated simultaneously with conventional T1, T2, and other contrast images, as well as T1 mapping, T2 mapping, and other quantitative images, which can be initially used for screening intracranial blood vessels without occupying additional scanning time. Its imaging principle is based on the use of difference in phase information between flowing blood flow and stationary tissues to image blood vessels, reducing the influence of hemodynamics on blood vessel imaging. In contrast, traditional TOF MRA imaging technology uses the enhancement effect of blood inflow to obtain blood vessel images, which will be affected by changes in hemodynamics. In the area of vascular stenosis, the degree of stenosis may be overestimated due to turbulent or slow blood flow[30-34]. This study revealed that with CTA results as a reference, the area under ROC curve of MAGiC PSiR Vessel examination was higher than that of traditional TOF MRA examinations in patients with vascular stenosis greater than 50%. Some patients with vascular occlusion not displayed by TOF MRA only showed moderate to severe stenosis on MAGiC PSiR Vessel and CTA images. In terms of scanning time, the scanning time of MAGiC was about 4.5 min, and the scanning time of MAGiC combined with DWI was about 5 min, which was significantly less than that of the traditional scanning schemes of TOF MRA and DWI combined with T1, T2, and T2-FLAIR (usually more than 10 min), which is conducive to improving the MRI examination efficiency for patients with acute stroke and treatment window for clinical thrombolytic intervention as soon as possible.

To obtain a clear enough blood vessel display, the slice thickness of the MAGiC image was set at 1.6 mm, which made the CNR values of T1, T2, and T2-FLAIR images generated by MAGiC decrease compared with traditional images due to the influence

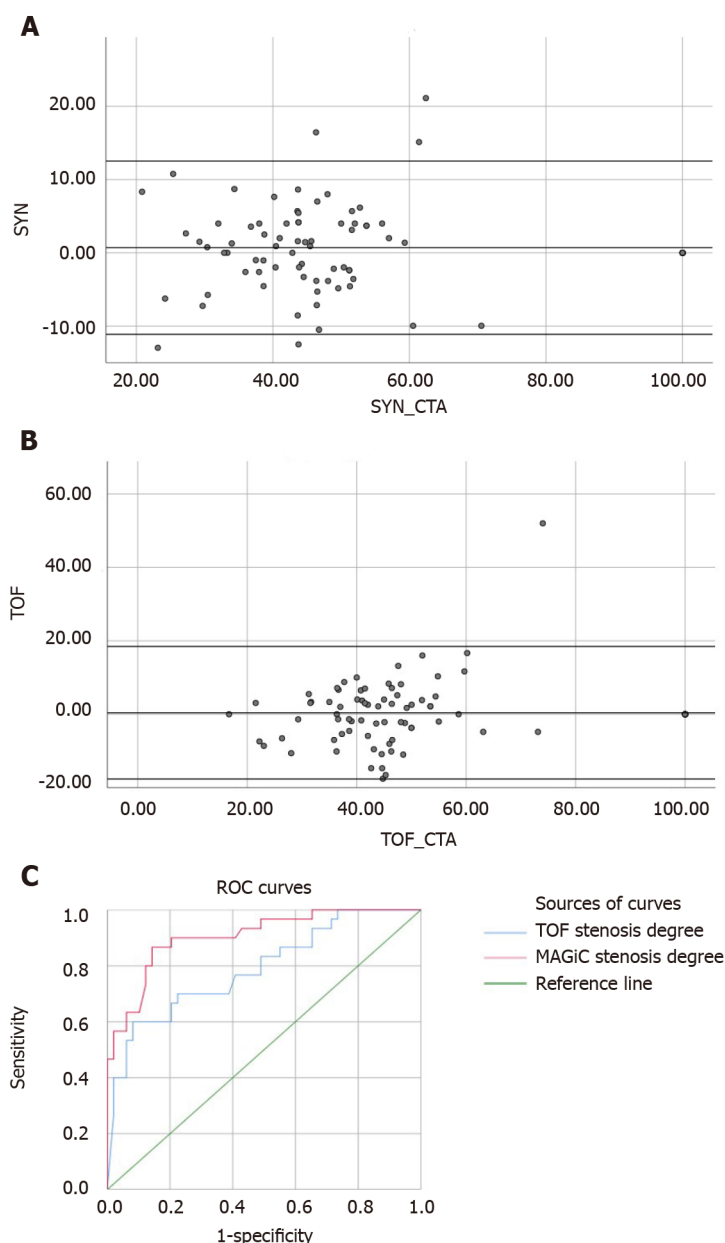


Figure 4 Bland-Altman and receiver operating characteristic curve evaluation of vascular stenosis degrees obtained by MAGnetic resonance imaging compilation phase-sensitive inversion recovery Vessel and time-of-flight magnetic resonance angiography. A: MAGnetic resonance imaging compilation-computed tomography angiography; B: Time-of-flight magnetic resonance angiography; C: Receiver operating characteristic curves. TOF: Time-of-flight; CTA: Computed tomography angiography; ROC: Receiver operating characteristic.

of the decrease in image signal-to-noise ratio. However, the overall display of lesions could meet the diagnostic needs of stroke. In addition, the slices in the MAGiC image were thinner.

There were some limitations to this study. First, this is a retrospective study, and some patients needed to complete CTA and MRI examinations simultaneously, which might result in selection bias. Meanwhile, due to this reason, not all the patients could be scored by the National Institute of Health stroke scale. Second, the number of cases was relatively small, which was mainly because MRI is not widely used in the diagnosis and treatment of acute stroke in clinical departments, as it is considered that the scanning time of this technique is relatively long, which may delay the diagnosis and treatment time of patients. Third, this study did not evaluate the long-term outcomes of patients, *e.g.*, the proportion of recurrent stroke in patients treated with vascular recanalization. The evaluation of long-term outcomes of patients can further clarify the relationships of vascular stenosis degree judgment with cerebrovascular recanalization treatment and stroke recurrence.

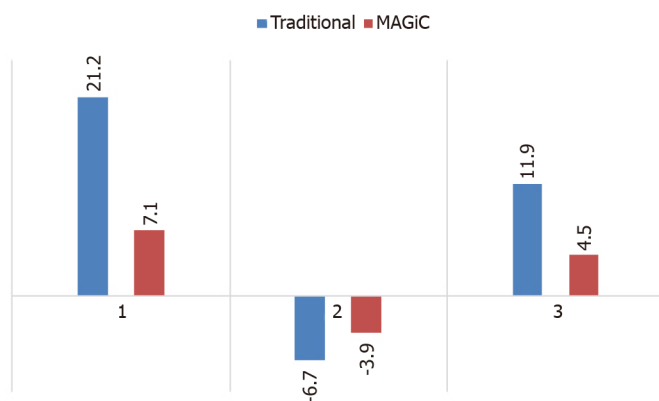


Figure 5 Contrast-to-noise ratio values of diffusion-weighted imaging diffusion restriction areas of MAGnetic resonance tmaging compilation-reconstructed multi-contrast images and traditional multi-contrast images. 1: T2-weighted image; 2: T1-weighted image; 3: T2-fluid-attenuated inversion recovery-weighted image; MAGiC: MAGnetic resonance imaging compilation.

CONCLUSION

In conclusion, MAGiC can simultaneously obtain a variety of conventional contrast images (T1, T2, T2-FLAIR, *etc.*), intracranial vessel images (MAGiC PSIR Vessel), and both T2 and T1 relaxation time quantitative images (T2 mapping and T1 mapping) in one scan, which can accurately determine the onset time of stroke, preliminarily screen intracranial vessels, and further shorten the MRI examination time in patients with acute stroke, thereby guiding clinical thrombolytic intervention as early as possible and improve patients' quality of life.

ARTICLE HIGHLIGHTS

Research background

Synthetic magnetic resonance imaging (MRI) MAGnetic resonance imaging compilation (MAGiC) is a new MRI technology. While completing one scan, the technician can acquire conventional T1, T2, T2-fluid-attenuated inversion recovery (FLAIR), and other contrast images, quantitative T1 mapping and T2 mapping images, as well as MAGiC phase-sensitive inversion recovery (PSIR) Vessel cerebrovascular images simultaneously through post-processing, which significantly shortens the scanning time required for MRI examination.

Research motivation

This study evaluated the application value of vascular images obtained by synthetic MRI in diagnosing acute ischemic stroke.

Research objectives

We hypothesized that the synthetic MRI vascular screening scheme can evaluate the degree of cerebral artery stenosis in patients with acute ischemic stroke.

Research methods

The contrast-to-noise ratio (CNR) values of traditional T1, T2, and T2-FLAIR images and MAGiC reconstructed T1, T2, and T2-FLAIR images in DWI diffusion restriction areas were measured and compared. MAGiC PSIR Vessel and time-of-flight magnetic resonance angiography (TOF MRA) images were used to measure and calculate the stenosis degree of bilateral middle cerebral artery stenosis areas. The consistency of MAGiC PSIR Vessel and TOF MRA in displaying the degree of vascular stenosis with computed tomography angiography was compared.

Research results

Magnetic resonance imaging can provide important imaging evidence in the prevention, diagnosis, and treatment of cerebrovascular diseases. However, its long scanning time, especially in patients with hyperacute stroke, contradicts the clinical need to carry out treatment as soon as possible. MAGiC PSIR Vessel images are

generated simultaneously with conventional T1, T2, and other contrast images, as well as T1 mapping, T2 mapping, and other quantitative images, which can be initially used for screening intracranial blood vessels without occupying additional scanning time.

Research conclusions

MAGiC can simultaneously obtain a variety of conventional contrast images (T1, T2, T2-FLAIR, *etc.*), intracranial vessel images (MAGiC PSIR Vessel), and both T2 and T1 relaxation time quantitative images (T2 mapping, T1 mapping) in one scan, which can accurately determine the onset time of stroke, preliminarily screen intracranial vessels, and further shorten the magnetic resonance imaging examination time in patients with acute stroke.

Research perspectives

The evaluation of long-term outcomes of patients can further clarify the relationships of vascular stenosis degree judgment with cerebrovascular recanalization treatment and stroke recurrence.

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