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High-resolution intracranial vessel wall imaging using 3D CUBE T1 weighted sequence

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ABSTRACT

Purpose: To evaluate the feasibility of high-resolution 3D CUBE T1WI for intracranial vessel wall imaging.
Methods: High-resolution 3D CUBE T1 weighted intracranial vessel wall images (0.4 mm × 0.4 mm × 0.4 mm) of 50 patients were retrospectively evaluated. A 5-point scale (1 poor, 5 excellent) was used to score the imaging quality for displaying the vessel wall of every intracranial artery segments. The inter-observer and intra-observer reproducibility of identifying plaques, intraplaque hemorrhage/luminal thrombosis, and wall enhancement were calculated.
Results: Totally 893 artery segments were evaluated. 3D CUBE T1WI displayed the arteries wall and lumen clearly, with the highest score (4.920 ± 0.837) for the C6–7 segments and the lowest (3.370 ± 1.107) for the C3 segments of the internal carotid artery (ICA). Both intra-observer and inter-observer reproducibility were high for identification of normal walls (κ = 0.928, 95% confidence interval [CI] 0.891–0.954; κ = 0.911, CI 0.868–0.940), plaque (κ = 0.924, CI 0.884–0.954; κ = 0.907, CI 0.866–0.943), luminal thrombosis (κ = 1.000, CI 1.000–1.000; κ = 1.000, CI 1.000–1.000), and wall enhancement (κ = 1.000, CI 1.000–1.000; κ = 0.914, CI 0.863–0.961).
Conclusions: High-resolution 3D CUBE T1WI displayed intracranial wall and lumen clearly, and detected intracranial artery abnormalities with high reproducibility.

1. Introduction

High-resolution MR imaging (HRMRI) has emerged as a useful technique for evaluating intracranial artery diseases, including intracranial atherosclerosis [1–3], vasculitis [4,5], reversible constriction syndrome [6], and moyamoya disease [7]. Currently, the standard protocol of HRMRI includes two sequences: 2D high-resolution cross-sectional T2 weighted imaging (T2WI) and T1 weighted imaging (T1WI) [8]. T2WI has higher signal to noise ratio (SNR) and is more sensitive in displaying the fibrosis cap and lipid core of plaque. T1WI is better in detecting plaque hemorrhage and thrombosis, and is the essential sequence for contrast enhancement studies [9–12,6]. However, such two-sequence HRMRI protocol has limitations. First, 2D images have low spatial resolution in the slice-select direction (2 or 3 mm in general), and are more prone to have obliqueness artifact from partial volume effects due to the tortuosity and variable course of the intracranial arteries [5]. Second, 2D acquisitions is difficult to cover the whole intracranial vessels, which requires relatively long acquisition times [13,14].

Three-dimensional HRMRI has high isotropic resolution. The reconstructed images in multiple planes can be used to 'straighten' tortuous or angled arteries and more accurately represent the lesions [5,12]. Several studies have showed that 3D HRMRI provided SNR-efficient highly reliable measurements of intracranial vessels [13,15], and displayed intracranial atherosclerosis in non-stenotic arteries [16].

However, the three dimensional HRMRI using CUBE technique, which is a variable flip angle 3D fast spin echo sequence, has seldom been reported. In this study, we introduced high-resolution 3D T1WI using CUBE technique (3D CUBE T1WI), and evaluated the

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imaging quality for displaying intracranial wall and the feasibility for detecting artery wall abnormalities.

2. Material and methods

2.1. Patients

This retrospectively study was approved by the Institutional Review Boards of our hospital.

We reviewed the HRMRI database between January 2013 and July 2014, 160 patients who were referred to our department with suspicion for intracranial artery stenosis (by previous imaging studies) or with identified intracranial artery atherosclerosis underwent brain 3D TOF MRA, and intracranial wall imaging using 3D CUBE T1WI. Post-contrast 3D CUBE T1WI were also performed in the patients under 35-year-old (pattern of intracranial wall enhancements may be helpful for identifying the etiologies) [4], and the patients with severe intracranial stenosis (wall enhancement indicates plaque vulnerability) [15]. All informed contents were obtained from the patients or their relatives.

The MRI data were analyzed on a PACS system (GE Healthcare-Centricity RIS CE V3.0). One neurologist with 3 years neuroimaging experience evaluated 3D TOF MRA and 3D CUBE T1WI. Six patients were excluded due to poor imaging quality (2 cases with low signal to noise ratio, 3 with motion or other artifact, 1 with inaccurate positioning). Then, the 3D TOF MRA of the remaining 154 cases were evaluated by the same reader, and the stenosis degree and sites were recorded. The stenosis degree was classified as: non-stenosis, low-grade stenosis (<50%), significant stenosis (≥50%) and occlusion.

On MRA, 26 cases were classified as non-stenosis (group 1), 52 cases classified as low-grade stenosis (group 2), 45 cases classified as significant stenosis (group 3), 31 cases classified as occlusion group (group 4). Ten cases/each group were randomly selected from group 1 and group 4, and 15 cases/each group were randomly selected from group 2 and group 3. Finally 50 cases were recruited for the study.

2.2. MR protocol

All studies were performed on a 3T scanner (GE Discovery MR750) with 8-channel head coil. The protocol included a conventional T2 weighted imaging, diffusion weighted imaging, 3D TOF MRA, high-resolution T2WI of middle cerebral (MCA) or basal artery (BA) and high-resolution 3D CUBE T1WI of intracranial artery. 3D TOF MRA was obtained in an axial plane with the following parameters: repetition time (TR) 27 ms, echo time (TE) 6.9 ms, flip angle 20°, field-of-view (FOV) 24 cm × 16 cm, matrix 320 × 256, slice thickness 1.6 mm, number of excitation(NEX) 1. The parameters of 3D CUBE T1WI were as the following: TR 567 ms, TE 16 ms, FOV 20.4 cm, matrix 320 × 256, slice thickness 0.8 mm, NEX 2, ETL 24. Scan plan: coronal, locs per slab: 64, excitation mode: selective. Phase acceleration 2, zero-filled fourier transform (ZIP 512, ZIP2) was used to reduce pixel size, the finial displaying resolution was about 0.4 mm × 0.4mm × 0.4 mm. One hundred and twenty coronal slices covering anterior and posterior circulation (range 4.8 cm) were acquired with scan time 5 min. Fat suppression technique was used to reduce fat signal from scalp.

Gd-DTPA (0.1 mmol/kg) was administrated intravenously, and 3D CUBE T1WI was repeated 2 min after contrast material administration.

2.3. Imaging analysis

Two readers with 10 years neuroimaging experiences evaluated the 3D CUBE T1WI independently blinded to the other sequences/clinical data. A 5-point scoring system was used to evaluate the image qualities of the intracranial arteries: (1) unclear wall, cannot be assessed; (2) part of the wall clearly shown (≤50%); (3) most of the lumen and wall clearly shown (>50%); (4) either the lumen or outer wall clearly shown; and (5) both the lumen and the outer wall clearly shown. Intracranial artery segments were scored as follows: internal carotid artery (ICA) petrous segment (C2), lacerum segment (C3), cavernous segment (C4), ophthalmic and communicating segment (C6–7), MCA sphenoid segment (M1), insular segment (M2), proximal segment of anterior cerebral artery (A1), basilar artery (BA), proximal segment of posterior cerebral artery (PA), and distal segment of vertebral artery (VA). The abnormalities of the wall were recorded: normal, plaque (localized or diffused eccentric wall thickening), wall enhancement, luminal thrombosis (hyperintensity within lumen, with absence of flow void signal) or intraplaque hemorrhage (high signal within plaque).

One reader assessed twice (2 weeks latter) to calculate intra-observer agreement. The differences between two observers were solved by consensus, and the etiologies of stenosis were determined based on the MRI and clinical data finally.

2.4. Statistical analysis

All raw data were analyzed using a statistical software package of SPSS for Windows version 13.0 (SPSS, Inc., Chicago, IL). Cohen's *k*-statistic was calculated to quantify the inter-observer and intra-observer reproducibility. A value of $k > 0.75$ was used to indicate a high level of reproducibility, and $0.40 \leq k \leq 0.75$ denoted moderate reproducibility.

3. Results

The patients' mean age was 54.9 years (SD, ±15.2), with 32 males and 18 females. Thirty-five patients were diagnosed as atherosclerosis. Seven patients were diagnosed as moyamoya disease and 5 patients were diagnosed as probable vasculitis. Non-other etiologies such as dissection, reversible cerebral vasoconstriction syndrome (RCVS) were diagnosed. Seventeen patients have post-contrast 3D CUBE T1WI. For 950 vessel segments, finally 893 vessel segments were evaluated and 57 segments were excluded for hypogenesis or limitations of scan range. 3D TOF MRA revealed 60 low-grade stenosis, 37 significant stenosis and 49 occluded segments.

3D T1WI displayed the arteries wall clearly. (Fig. 1). The image scores were highest for C6–7, followed by C2, M2, BA, VA, M1, PA, A1, C4 and C3. The image scores were higher for non or low-grade stenosis vessel (4.436 ± 1.073) than that of significant stenosis or occlusion vessel (3.919 ± 1.122). (Table 1).

One hundred and fifty atherosclerotic plaques were found in 35 patients. Of them, 88.57% (31/35) had multiple arteries involvement, most in M1, C6–7, BA, VA and C2 (Fig. 1A,B). None plaque hemorrhage was found. Fifteen thromboses were found in 49 occlusion segments in 21 patients, of those thromboses, high signal that maybe identified as recent hemorrhage were found in 7 segments (Fig. 2). Fifty-five wall enhancements were found in 14/17 patients [3 atherosclerotic and 11 non-atherosclerotic stenosis (6 moyamoya disease and 5 probable vasculitis)]. Atherosclerosis disease showed eccentric and moderate/mild wall enhancement, while non-atherosclerosis showed concentric wall enhancement accompanied vessel shrinkage (Fig. 1C,D). Both intra-observer and inter-observer reproducibility were high for identification of normal wall, plaque, luminal thrombosis, and wall enhancements (Table 2)