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Original Article

Feasibility of improved motion-sensitized driven-equilibrium (iMSDE) prepared 3D T1-weighted imaging in the diagnosis of vertebrobasilar artery dissection☆

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ABSTRACT

Background and purpose. – This study was to evaluate the diagnostic value of improved motion-sensitized driven-equilibrium (iMSDE)-prepared 3D T1-weighted magnetic resonance imaging (MRI) (iMSDE-3DMRI) in intracranial vertebrobasilary dissection (VBD) and to compare iMSDE-3DMRI images with those obtained using 2D high-resolution (HR) MRI with respect to their diagnostic performance in VBD.
Materials and methods. – We retrospectively reviewed 105 lesions from 102 patients who underwent multimodal imaging and contrast-enhanced iMSDE-3DMRI (CE-iMSDE-3DMRI). The 2D-HRMRI protocol comprised four axial HR images. The CE-iMSDE-3DMRI images were reformatted in the axial, coronal, and sagittal planes. The 2D-HRMRI-based diagnosis was compared with the final diagnosis. The 2D-HRMRI and CE-iMSDE-3DMRI images were examined independently for the diagnosis performance of dissection.
Results. – VBD was confirmed in 66 lesions in 63 patients; 17 patients had confirmed atherosclerosis, and 22 had no lesions in the vertebrobasilar artery. Diagnostic performances of 2D-HRMRI (AUC, 0.839 ± 0.04; sensitivity, 94.0; specificity, 79.5; diagnostic accuracy, 88.6) CE-iMSDE-3DMRI (AUC, 0.847 ± 0.04; sensitivity, 84.8; specificity, 84.6; diagnostic accuracy, 84.7) and 2D-HRMRI + CE-iMSDE-3DMRI (AUC, 0.893 ± 0.03; sensitivity, 97.0; specificity, 85.0; diagnostic accuracy, 92.5) were good. Comparisons of the diagnostic performance of 2D-HRMRI andCE-iMSDE-3DMRI showed that combined interpretation of 2D-HRMRI and iMSDE-3DMRI yields a significantly higher diagnostic performance than that of 2D-HRMRI ($P = 0.042$).
Conclusions. – CE-iMSDE-3DMRI showed good diagnostic performance for the diagnosis of intracranial VBD. These results suggest that CE-iMSDE-3DMRI can be used in combination with 2D-HRMRI for the diagnosis of intracranial VBD.

Abbreviations

iMSDE	improved motion-sensitized driven-equilibrium
VBD	intracranial vertebrobasilar artery dissection
2D-HRMRI	two-dimensional high-resolution magnetic resonance imaging
iMSDE-3DMRI	iMSDE-prepared3D T1-weighted MRI
CE	contrast-enhanced
TSE	turbo spin-echo
CTA	computed tomography angiography
TOF-MRA	time-of-flight-MR angiography
DSA	digital subtraction angiography
PDWI	proton density weighted image
T2WI	T2-weighted image
T1WI	T1-weighted image
CE-T1WI	contrast-enhanced T1WI
ROC	receiver operating characteristic
CI	confidence interval

Q1 ☆ The English in this document has been checked by at least two professional editors, both native speakers of English. For a certificate, please see: http://www.textcheck.com/certificate/GJK3pa.

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1. Introduction

Intracranial vertebrobasilar artery dissection (VBD) is an important cause of ischemic stroke and subarachnoid hemorrhage in young and middle-aged adults, especially in Asian populations [1–3]. The development of neuroimaging has increased the detection of VBD and contributed to improving stroke prevention [4,5].

Two-dimensional high-resolution magnetic resonance imaging (2D-HRMRI) of the vessel wall is a well-established method to assess and diagnose VBD [6–8]. However, 2D-MRI is limited by its low spatial resolution in the slice direction and by partial volume artifacts arising from the tortuosity of the intracranial arteries. In addition, 2D acquisition provides only limited anatomical coverage and a limited number of slices, which complicate whole-brain coverage [8–11]. Another consideration is that vessel wall imaging requires the use of a blood-signal suppression technique, such as a pre-regional saturation band or double-inversion. However, these "black blood" techniques are plagued by flow artifacts in the recirculating or stagnant flow.

Three-dimensional HRMRI has sufficient isotropic resolution to allow reconstruction of images in multiple planes. Several studies have shown that 3D-HRMRI has a good signal-to-noise ratio and provides highly reliable measurements in the evaluation of the intracranial vessels [8–10,12–14].

Motion-sensitized driven-equilibrium (MSDE) preparation based black blood imaging uses motion-sensitized gradients to dephase moving blood spins, and it was commonly used in combination with a 3D turbo spin-echo (TSE) readout [15,16]. However, as originally developed, MSDE suffers from signal loss due to inherent insufficient T1 recovery, T2 decay, diffusion effects, and instrumental factors [15]. To overcome these obstacles, an improved MSDE [17] (iMSDE) technique that partially compensates for the instrumental factors was proposed and, in blood-suppressed 3D-HRMRI, was shown to generate higher-quality images. The iMSDE technique can also reduce flow artifacts in the other black blood technique such as pre-regional saturation band [15].

Although DSA is currently the gold standard for the diagnosis and follow-up of VBD, the procedure is invasive and cannot depict direct dissection findings, such as occlusion and mural hematoma. Previous studies have evaluated the use of MRI, including multicontrast HRMRI, in the diagnosis of VBD [6,7,10]. However, because HRMRI, when used for the diagnosis of VBD, requires 3D acquisitions and perfect blood suppression, iMSDE-3DMRI has been suggested as an alternative [15,17,18].

The aim of this study was to evaluate the diagnostic value of iMSDE-3DMRI in intracranial VBD and to compare iMSDE-3DMRI images with those obtained using 2D-HRMRI with respect to their diagnostic performance in VBD.

2. Material and methods

2.1. Patients

This retrospective study was approved by our Institutional Review Board. HRMRI was performed at our institution between February 2015 and September 2016 on 137 patients with clinically suspected VBD. Patients whose HRMRI images did not fully cover the affected segment in the scanning range, were of poor quality, or were obtained with a delay of > 7 days after symptom onset were excluded. Thus, the study population was 102 patients with evaluated using clinical and multimodal imaging [computed tomography angiography (CTA), time-of-flight-MR angiography (TOF-MRA), 2D-HRMRI, and/or conventional angiography] who also underwent contrast-enhanced iMSDE-3DMRI (CE-iMSDE-3DMRI).

Three neuroradiologists (JWC, MH, SYK) and a stroke neurologist (JSL) made the final diagnosis by consensus, after reviewing all clinical and paraclinical data [initial computed tomography (CT), MR, and digital subtraction angiography (DSA) images and the results of etiologic workups] available at hospital discharge and follow-up. The inclusion criteria were as follows [6]:

- clinical history of acute symptoms and/or signs suggesting intracranial VBD;
- suspicious vascular abnormality on CTA, such as stenosis followed by aneurysmal dilatation;
- HRMRI performed within 7 days after the onset of symptoms.

Clinical symptoms or signs of VBD included ischemic symptoms secondary to compromise of the vertebrobasilar artery (such as lateral medullary syndrome), infarction in the territory of the vertebrobasilar arterial system as seen on conventional MRI, sudden onset of posterior headache and/or neck pain, or any combination thereof.

2.2. Image acquisition

The MRI protocol at our institution for the evaluation of intracranial arterial dissection comprises 2D protocols consisted of four axial HR sequences [proton density weighted image (PDWI), T2-weighted (T2WI), T1-weighted (T1WI), and contrast-enhanced T1WI (CE-T1WI)]. In addition, we included CE-iMSDE-3DMRI, and TOF-MRA. All MRIs were performed using a 3T MR system (Intera, Achieva; Philips Healthcare, Best, Netherlands) and a 16-channel neurovascular head coil. The imaging range of the HRMRI was selected by the clinicians, either an experienced stroke neurologist or a senior resident, using the CTA findings as a reference. The parameters for each sequence were as follows:

- PDWI (TR/TE, 2000/31 ms; field of view (FOV), 10 cm; matrix size, 200 × 200; slice thickness, 2 mm; 22 slices; inter-slice gap, 2 mm; number of excitations: 2; acquisition time, 6 min);
- T2WI (2000/100 ms; 10 cm; 200 × 200; 2 mm; 22 slices; 2 mm; 4; 6 min 36 s);
- T1WI (1000/7.9 ms; 10 cm; 200 × 200; 2 mm; 22 slices; 2 mm; 2; 5 min 40 s);
- CE-iMSDE-3DMRI (450/18 ms, ETL = 18, NSA = 1, flow velocity encoding = 2 cm/s for gradient pulses, FOV = 170 × 170 × 44 mm, voxel size = 0.7 × 0.7 × 1.0 mm, slab thickness = 44 mm, slice thickness = 1.0 mm, slice spacing = 0 mm, reformatted images in axial, coronal, and sagittal planes with 1-mm thickness, acquisition time: 4 min 50 s);
- TOF-MRA (25/3.45 ms; flip angle, 20°; 20 × 25 cm; 880 × 267; 1.2 mm; 160 slices; 0.6 mm).

CE-T1WI and CE-iMSDE-3DMRI were obtained using 0.1 mmol/kg gadobutrol (Gadavist; Bayer AG, Berlin, Germany). The black blood technique with pre-regional saturation pulses of 80-mm thickness to saturate incoming arterial flow was used for the 2D-HRMRI examinations.

2.3. Image analysis

Two board certified neuroradiologists (JWC, MH), who had 14 and 8 years of experience of brain image and were blinded to the clinical information and final diagnosis independently, reviewed the 2D-HRMRI and CE-iMSDE-3DMRI images. Two neuroradiologists also checked for direct evidence of arterial dissection (dissection flap, aneurysm, stenosis, mural hematoma) and an overall diagnosis of dissection by sequentially reviewing the 2D-HRMRI first and then CE-iMSDE-3DMRI images with an interval of at least 1

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