Assessment of Carotid Atherosclerotic Disease Using 3D Fast Black Blood MR Imaging: Comparison with DSA

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Introduction: Currently, digital subtraction angiography (DSA) remains the current clinical standard for evaluating carotid atherosclerosis disease. Its known limitations include using ionizing radiation and being unable to visualize the vessel wall. Black-blood (BB) MR imaging techniques have been developed to accurately visualize and quantify both the lumen and the outer wall boundaries of large arteries.1,2 By selectively suppressing the signals coming from the artery lumen, BB-MR imaging can better delineate the structure of the arterial wall. Recent developments in motion-sensitized dephasing preparations3,4 have enabled 3D BB-MR image acquisition in arbitrary planes with robust blood suppression and large longitudinal coverage. Few studies in the literature have compared BB-MR imaging with the gold standard DSA in measuring carotid lumen stenosis.

Purpose: To determine the accuracy of 3D fast BB-MR imaging at quantifying carotid atherosclerosis disease compared to DSA.

Methods: Sixty-five carotid arteries from 52 patients (mean age 64.5 years, 43 males) with at least 50% stenosis identified by duplex ultrasound, underwent 3D BB-MR imaging and DSA within 3 days. Conventional intra-arterial DSA studies were performed using a trans-femoral artery approach and selective common carotid artery catheterization on a digital angiography unit (INNOVA 4100, GE, USA). 3D BB MR images were acquired using a whole body clinical scanner (Philips Achieva TX, Best, the Netherlands), a dedicated phased-array carotid coil and with the improved motion-sensitized driven-equilibrium (iMSDE) prepared rapid gradient echo sequence (3D turbo field echo, TR/TE 9.3/4.4 ms, flip angle 6°, FOV 250[FH] ×160[RL]×64[AP] mm3, acquisition matrix 312×200×80, acquired resolution 0.8×0.8×0.8mm3, Rec resolution 0.4×0.4×0.4mm3, fat suppression selective partial inversion recovery [SPIR], acquisition time 2 minutes 42 seconds). Quantitative measurements including degree of stenosis according to the NASCET criteria, stenotic lesion length and the presence/absence of plaque ulceration were determined and compared between the two imaging techniques.

Results: Very good agreement in measuring luminal stenosis was found between 3D BB-MR imaging and DSA (ICC 0.96; 95% CI: 0.93, 0.97) (Fig.1). The 3D BB-MR stenosis measurements were 1.26% smaller than DSA on average, with limits of agreement of ±7.66% (Fig.2A). 3D BB-MR imaging was also found to have high sensitivity (91.7%), specificity (96.2%) and agreement (Cohen’s κ=0.85; 95% CI: 0.66, 0.99) with DSA for detection of ulcers. Good agreement was found between lesion length measured by 3D BB-MR imaging and DSA (ICC 0.75; 95% CI: 0.51, 0.84). However, stenotic lesion length measurements by 3D BB-MR imaging were on average 4 mm longer than those measured by DSA (P < 0.001) (Fig.2B).

Discussion and conclusions: In the artery-by-artery analysis, compared with DSA, 3D BB-MRI successfully identified almost all carotid lesions in those with > 50% stenosis, with great similarity on morphology of the lesions and severity of stenosis (Fig.3, 4). With 3D BB-MR imaging, both the inner and outer wall of the artery is directly visualized, making it a potentially more accurate approach to visualize the distal extent of the plaque and more reliable measurement of the stenotic lesion length of the plaque compared to DSA. 3D BB-MR imaging was only found to over-identify ulceration on a small group of arteries when compared to DSA, which was presumably caused by the limited spatial resolution. In conclusion, this study shows the usefulness of 3D BB-MR imaging in noninvasive evaluation of the carotid artery stenosis measurements, lesion lengths and ulcer, using DSA as a reference. With fast acquisition and large coverage, 3D BB-MR imaging has the potential to become an alternative imaging approach in evaluating the severity of atherosclerosis.

References:

Fig. 1. Stenosis by 3D BB-MRI versus DSA. The dashed line is the regression line.

Fig. 2. Bland-Altman plots of the difference in stenosis (A) and lesion length (B) measurements between 3D BB-MRI and DSA versus the means.

Fig. 3 Advanced atherosclerotic disease caused severe internal carotid stenosis (arrow), detected on both the DSA (A) and 3D BB-MR imaging (B). The common carotid wall thickening (arrowheads) was visualized on the 3D BB-MR image (B).

Fig. 4 The ulcers (arrow and arrowhead) of the carotid plaque surface at the bifurcation detected on both the DSA (A) and 3D BB-MR imaging (B).

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