Ultrahigh-Resolution 0.11x0.11mm MR Imaging of the Intracranial Atherosclerotic Vessel Wall at 7.0 Tesla

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Introduction

Histopathological studies form the basis of our understanding of pathology and pathogenesis of diseases, for instance atherosclerosis. Magnetic Resonance Imaging (MRI), with its excellent tissue contrasts, could provide at least part of the information normally obtained using macroscopic or microscopic pathology, *in vivo*. Second, some pathology can be better appreciated using MRI compared to histology.[1] Still, these MR techniques need to be validated using histopathologic correlation. So far, validation of MRI has mostly been performed for carotid artery atherosclerosis[2], while intracranial atherosclerosis also plays a role in cerebral ischemic stroke.[3] In this preliminary study, we used ultrahigh-resolution MRI at 7T for detailed imaging of intracranial vessel wall atherosclerosis, and compared findings with histology (gold standard).

Methods

Five anonymous specimens of the Circle of Willis (CoW) were used for this study. The specimens included the major arteries of the CoW. All specimens were cleaned thoroughly and embedded in a petri dish in a 2% agar solution. Care was taken to remove all air from the specimens. During MRI, the specimens were submerged in fomblin (Solvay Solexis, Bollate, Italy) to provide susceptibility matching[4]. Imaging was performed on a 7.0 Tesla whole body system (Philips Healthcare, Cleveland, OH, USA) with two home-made 16-channel dedicated surface coils above and below the specimens, and a volume transmit/receive coil for transmission (Nova Medical, Wilmington, MA, USA). Parameters of the scan protocol can be found in Table 1. First, cactus spines were used as fiducials[5] and placed at 13 locations of histological sampling, to enable spatial correlation with histology (Figure 1B). After a T_1-weighted TFE sequence with full specimen coverage was made, a PD-weighted SE, T_2-weighted TSE and T_2*-weighted TFE sequence were made of each of the 13 marked locations, using the T_1-weighted images for planning (Figure 1). After scanning, the specimens, within the agar, were placed in Ethylenediaminetetraacetic acid (EDTA) for three days to dissolve wall calcifications, to reduce the risk of damaging the specimen during slicing. Subsequently, samples will be taken from the 13 marked locations, and stained with hematoxylin and eosin (HE) and elastic-Van Gieson (EVG) stain. Histological cuts will then be correlated to the MR images (Figure 2; although MRI-histology correlation has not been performed yet with the 0.11x0.11mm scans, previous correlation with the T_1-TFE with 0.18mm isotropic voxels showed promising results).

Table 1 *Scan parameters*

Scan parameter	T_1-TFE	PD-SE	T_2-TSE	T_2*-TFE
FOV (mm)	110x110x34	120x40x1	120x40x1	120x40x1
Acq. resolution (mm)	0.11x0.11x0.11	0.11x0.11x1	0.11x0.11x1	0.11x0.11x1
TR/TI/TE (ms)	55/-/6.0	3500/1100/10	3500/1100/51	24/-/15
Flip angle (degrees)	25	90	90	90
TSE/TFE-factor	1000	-	7	1
NSA	1	2	22	3
Duration (hr:min:sec)	3:39:22	0:42:28	1:05:34	1:03:29

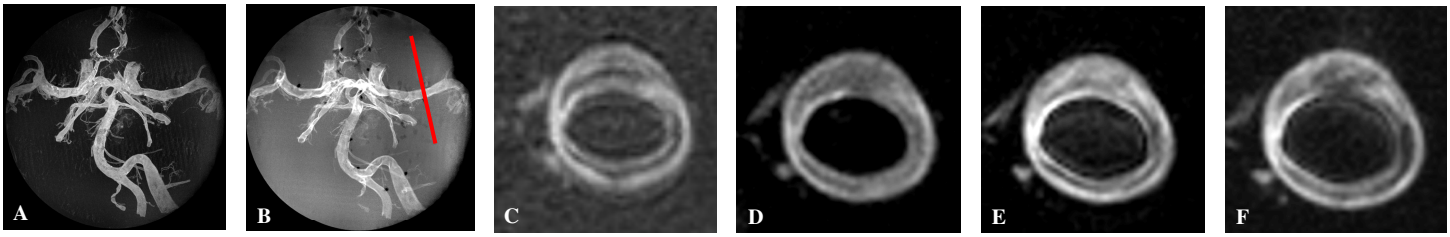

Figure 1 *Scan protocol illustrated.* ***A****, Maximum Intensity Projection (thickness 13mm), providing an overview of the CoW specimen embedded in agar solution.* ***B****, 12mm reconstruction of T_1-TFE with same overview as* ***A****, showing the location of fiducials (black dots).* ***C-F****, cross-section through the left middle cerebral artery (red plane in* ***B****) for T_1-TFE (****C****), PD-SE (****D****), T_2-TSE (****E****) and T_2*-TFE (****F****).*

Results

Heterogeneity of MRI signal intensities could be identified throughout the intracranial atherosclerotic plaques on all ultrahigh-resolution sequences (Figures 1 and 2). Differences in MR signal characteristics are consistent with different layers of atherosclerotic plaque on histology cuts, for instance ossification (Figure 2).

Conclusion

The initial results of this study show that ultrahigh-resolution imaging of ex *vivo* arterial specimens using 7T MRI is feasible. Furthermore, by using this imaging technique, it is possible to discern different tissue layers within the atherosclerotic plaque. Relative to histological studies, post-mortem MRI has the advantage of straightforward assessment of the full length of all intracranial branches (compared to typically only a few histological cuts). These results could in future provide noninvasive information regarding the location, severity and pathogenesis of intracranial atherosclerotic disease burden.

Acknowledgements

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References

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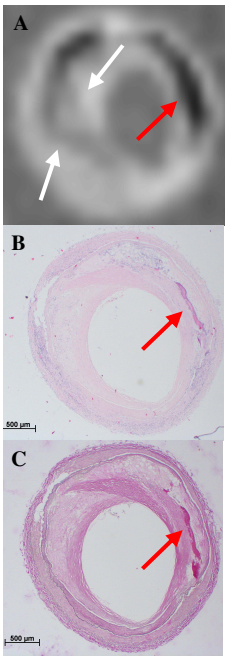

Figure 2 *T_1-weighted (T_1w) 7T MR image (0.18mm isotropic;* ***A****) of the right vertebral artery, showing a hypointense area within the vessel wall (red arrow), corresponding to an area of ossified calcification (red arrows in* ***B*** *and* ***C****) in the histological slices (****B****, H&E staining and* ***C****, EVG staining) of an atherosclerotic plaque located over the internal circumference of the vessel. Furthermore, at least two tissue layers with differing signal intensity can be appreciated on the T_1w sequence (white arrows in* ***A****), showing atherosclerotic plaque heterogeneity.*