HIGH-RESOLUTION 3D DIFFUSION MRI: DETECTION OF LIPID-RICH NECROTIC CORE IN PLAQUES WITHOUT CONTRAST MEDIA

Yibin Xie1,2, Wei Yu1, Zhaoyang Fan1, Christopher Nguyen1,2, Jing An1, Zhaoqi Zhang1, and Debiao Li1,2
1 Cedars-Sinai Medical Center, Los Angeles, California, United States, 2 University of California, Los Angeles, Los Angeles, California, United States, 3 Anzhen Hospital, Beijing, China, 4 Siemens Healthcare, Beijing, China

Target audience: MR scientists interested in diffusion-weighted MRI; physicians interested in atherosclerosis and stroke.

Purpose: Large lipid-rich necrotic core (LRNC) is a well-known feature of rupture-prone atherosclerotic plaque1-2, which is the major cause of both stroke and transient ischemic attack3. Plaque lipid content has also been used clinically to monitor disease progression and the results of therapeutic interventions4. Although contrast-enhanced (CE) MRI was shown possible for LRNC detection4, patients with atherosclerosis often have concomitant renal disease6 which makes CE MRI undesirable. Diffusion MRI (DWI and ADC mapping) showed great promises for discriminating LRNC from fibrous tissue with excellent contrast ex vivo7 and in vivo8. However, conventional 2D EPI-based methods have suboptimal image quality due to susceptibility-induced distortion and blurring. It also has inadequate spatial resolution (in-plane pixel size ≥1.0x1.0 mm²) for imaging plaques, causing partial volume effect and inaccuracies in ADC measurements. The purpose of this work is to develop a novel diffusion MRI method for noncontrast carotid plaque characterization that provides (1) 3D imaging capability, (2) high spatial resolution (0.6x0.6x2 mm³), and (3) reliable image quality.

Methods: Pulse sequence: Diffusion weighting was implemented with a driven equilibrium preparation module, allowing segmented high resolution 3D acquisition. Diffusion preparation was separated from the imaging readout, therefore avoiding instability of phase errors typically plagued multi-shot EPI while maintaining CPMG condition for the readout (Figure 1). Bipolar diffusion sensitizing gradients were used to compensate for 1st-order motion and to reduce eddy currents. Pulse-triggering were utilized for minimizing pulsatile motion. Imaging readout was designed based on 3D TSE for good and consistent image quality at 3T. Reduced field-of-view (rFOV) with inner-volume refocusing pulses was developed to reduce scan time. Arterial blood was suppressed with DIR and FSD for avoiding partial volume effect caused by blood and better vessel wall visualization.

In vivo imaging: Healthy volunteers (n = 12; 3 M, 9 F; aged 23-48 y/o) and patients suspected of carotid atherosclerosis (n = 3; 2M, 1F; aged 58-81 y/o) were scanned on a 3T scanner (Siemens Magnetom Verio) with the following parameters: 3D transverse slab with in-plane resolution = 0.6x0.6x2 mm³; slice thickness = 2 mm; diffusion weightings of b = 30 and 300 s/mm² along the slice direction; total scan time = 5.5±0.6'.

Results:

Figure 2: Panels (A, B) are representative DWI of carotid vessel wall from healthy subjects at b = 300 and 30 s/mm², respectively. Arterial blood suppression was effective throughout the slices with clear visualization of vessel wall at both b-values. No visible susceptibility-induced artifacts were observed. Successful 1st-order motion compensation was achieved as there was no apparent signal loss due to motion. Panel (C) is the ADC map of the corresponding slice. Panel (D) shows the comparison in which the ADC measurements of carotid vessel wall in healthy subjects, averaged at 1.32±0.4×10⁻³ mm²/s, were consistent with previous studies.

Table 1: DWI image quality was quantified with relative SNR and relative CNR by region-of-interest analysis.

Discussion: Diffusion-prepared TSE allows, for the first time, 3D diffusion MRI of the carotid arterial wall in vivo with high spatial resolution and excellent image quality. LRNC findings from the new 3D diffusion MRI and conventional contrast-enhanced MRI demonstrated good agreement. ADC measurements in the healthy carotid wall were consistent with previous studies. ADC measurements in plaques were capable of differentiating LRNC from fibrous plaque tissue and normal wall.

Conclusion: Diffusion-prepared 3D MRI can detect lipid-rich necrotic core in carotid plaque in vivo without the use of gadolinium-based contrast agents, allowing carotid plaque characterization in patients with renal disease.


Table 1. Image quality quantifications.

<table>
<thead>
<tr>
<th>Image Quantification</th>
<th>b = 30</th>
<th>b = 300</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wall rSNR</td>
<td>14.91±2.8</td>
<td>11.61±2.1</td>
</tr>
<tr>
<td>Wall rCNR</td>
<td>13.21±2.6</td>
<td>9.91±1.9</td>
</tr>
</tbody>
</table>

rSNR = Wall/Noise; rCNR = [Wall-Lumen]/Noise