Assessment of calcification size and juxtaluminal status using gray-blood 3D vessel wall MRI

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Introduction: Thromboembolism from carotid atherosclerotic plaque is a major cause of mortality and morbidity from stroke. Carotid plaques that are most likely to cause thromboembolism exhibit high-risk features such as intraplaque hemorrhage (IPH) and juxtaluminal calcification (JCA) [1]. Recently a phase-sensitive inversion-recovery (IR) based sequence (SNAP) [2] was extended [3] to include a PD weighting (SNAP2) that can additionally identify calcification. However its use in identification of calcification size and JCA status has not yet been shown. In this work we extend the SNAP2 reconstruction to provide a gray-blood proton density (PD) weighted image that shows luminal and calcium status on the same image so that JCA status can be assessed and we validate the results in patients with atherosclerosis.

Aims: To validate SNAP2 against traditional 2D black-blood carotid plaque MRI for assessment of 1) calcification size and 2) JCA status.

Materials and Methods: ***Image Acquisition:*** Bilateral arteries (N=14) from 7 patients with 50-79% stenosis by ultrasound were examined with MRI. Traditional 2D multicontrast plaque MRI protocol [1]: TOF, T1w, MP-RAGE, PDw, T2w was acquired using an 8 channel phased array carotid coil. SNAP2 MRI was also acquired with parameters: TR/TE 10/4ms, flip angle 11/5 (corresponding to α and θ in fig 1)., TI 500ms, Resolution 0.8x0.8x0.8mm, FOV (coronal) 16x16x3.2cm, turbo factor 98, scan time 5 min. Thus the first image (I_1) was T1-weighted and the second image (I_2) was PD weighted. ***Image reconstruction***: A polarity function *P(x,y)* which takes values (-1 or +1) depending upon the longitudinal magnetization was calculated using $I_1(x,y)$ and $I_2(x,y)$ as

$$P(x,y) = \frac{I_1(x,y)I_2^*(x,y)}{\|I_1\|\|I_2\|}$$

where * represents complex conjugation. T1-weighted corrected real image was then obtained as $S_1(x,y) = P(x,y)\|I_1(x,y)\|$ and PD-weighted corrected real image was obtained as $S_2(x,y) = P(x,y)\|I_2(x,y)\|$. A sigmoid function was used in reconstructing $S_2(x,y)$ such that gray-blood PD-weighted vessel wall image (fig 2) was available for JCA status review.

Patient image review: Calcification of 2D multicontrast was identified as hypointense area compared to muscle on all contrast weightings. JCA status was identified if there was no intervening tissue between calcification and lumen on black-blood weightings. SNAP2 calcification was identified as hypointense area on $I_2(x,y)$. JCA status was identified on $S_2(x,y)$ if calcification was not separated from the gray-blood lumen by intervening tissue. The coronal SNAP2 images were reformatted to 2mm axial to match the 2D multicontrast images. A trained reviewer drew calcification outlines on 2D multicontrast images and SNAP2 images independent of each other. Status of CA was identified on each slice as no-calcification, JCA or intraplaque CA. Calcification size was compared using intraclass correlation coefficient (ICC) and paired t-test. Cohen's kappa was calculated to assess agreement of CA status.

Results: 210 slices were assessed for calcification. There was good agreement (Kappa = 0.7, p<0.001) between SNAP2 and 2D multicontrast for calcium status on a slice level basis. A representative slice is shown in figure 3. Although calcification size was slightly larger on SNAP2 (2.1±7.5 mm^2 vs 1.8±1.8 mm^2) there was no difference in size of calcification on a slice level by paired t-test (p=0.43). There was significant correlation (0.5, p<0.001) for calcification size by Pearson's test for correlation.

Discussion and Conclusions: Gray-blood SNAP2 provides accurate identification of calcification size and assessment of JCA status comparable to previously validated 2D multicontrast plaque MRI. In addition to calcification identification, the SNAP reconstruction [2] from the same acquisition can simultaneously identify IPH and luminal status (fig 3). SNAP2 thus combines high-risk calcification detection with large coverage in a single scan with high-risk IPH detection of plaque.

References: [1] Saam Radiology 2007; 244(1):64-77, [2] Wang MRM 2013; 69(2):337-45. [3] Balu ISMRM 2014

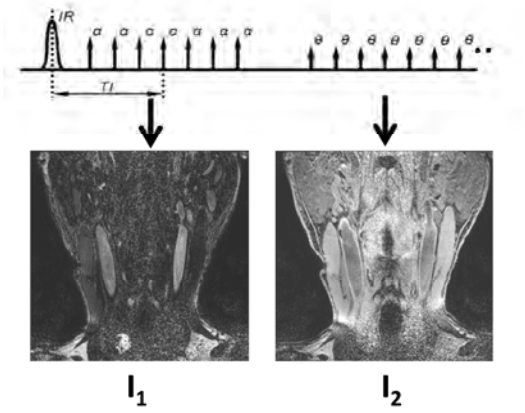

Figure 1: Sequence diagram showing two images acquired in a single acquisition, a highly T1-weighted $I_1(x,y)$ and the PD-weighted $I_2(x,y)$.

Figure 2: Sagittal oblique reformats showing IPH (red arrow) on $S_1(x,y)$ and adjoining CA (yellow arrow) on $I_2(x,y)$.CA can be seen to be intraplaque rather than JCA at this location on gray-blood $S_2(x,y)$.

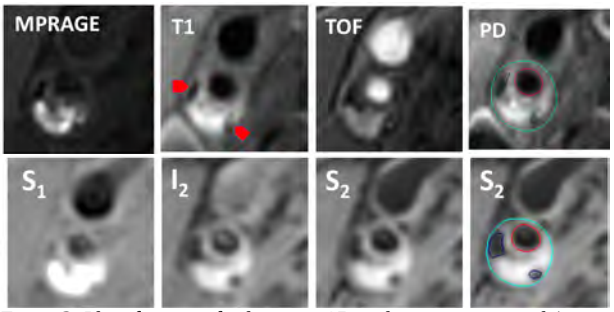

Figure 3: Identification of calcium on 2D multicontrast protocol (top row) and SNAP2 derived weightings (bottom row). Red arrows show calcification. Last column shows respective outlines: red-lumen, light blue-outerwall, darkblue-calcification