High resolution three dimensional imaging of extracranial and intracranial arteries

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INTRODUCTION: Atherosclerosis is a major cause of ischemic stroke. Intracranial arteries (ICA) and extracranial arteries (ECA) are two common places where atherosclerotic plaques are found. Vessel wall imaging can detect atherosclerotic plaques missed by luminal angiography. Imaging both vessels in one scan is highly desirable because of the better coverage and scan time reduction. ICA and ECA have different dimensions. Imaging both arteries in one scanmay implycompromised spatial resolution. Previous attempts to image both ICA and ECA in one slab achieved a spatial resolution of around$(0.8mm)^3$ [5], which is too low for ICA, particularly forthe mid cerebral arteries (MCA) (usually require spatial resolution ~ $(0.5mm)^3$ [1,2]). Technical issues for ICA and ECA imaging are also different. Slow flowing blood at the carotidbifurcation would hamper plaque detection. While blood is usually well suppressed in ICA imaging, the bright CSF signal surrounding MCA makes vessel wall delineationdifficult. Techniques that address either or both issues (e.g., FLAIR pulse) usually imply reduced signal, which translates into reduced spatial resolution. In this study, we propose the use of a 32 channel neurovascular coil combined with acarefully designed and optimized T1 weighted 3D TSE sequence for simultaneous imaging of ECA and ICA at an isotropic spatial resolution of $(0.6mm)^3$. The sequence features robust blood suppression and improved CSF attenuation. The improved T1 contrast also favors the detection of gadolinium based signal enhancement in plaques (an indication for vulnerable plaques [6]). Patient study showed that the technique is useful in identifying plaques in patients with concomitant intracranial and extracranial atherosclerosis plaques.

MATERIALS & METHOD: Neurovascular coil: It was custom designed for neurovascular imaging. The coil has two parts: a 24 channel coil for ICA, and an 8 channel coil for ECA. They are separable and can be used independently. Detail design of the coil was presented elsewhere in this conference (Hu X et al.). The new coil increases SNR needed for high spatial resolution imaging. Pulse sequence: The new sequence was based on T1w-SPACE [4]. To perform high resolution imaging of both ICA and ECA in one scan, several design changes were made. (1) DANTE pulses were applied before T1w-SPACE to suppress flowing blood [7], especially in the carotid bifurcation. (2) Flip-down pulse [4] was used to improve T1 contrast, especially between the MCA vessel wall and CSF (DANTE pulses also reduced CSF, though in a small extent due to its very slow flow). (3) The refocusing pulses' flip angles were increased by using a different signal profile. The echo signal was increased. Note that both (1) and (2) improved T1 image contrast at the expense of image SNR. Meanwhile, the new coil and (3) improved the SNR needed for high resolution imaging. Both the coil and the sequence were designed for, and implemented on a 3T clinical scanner (MAGNETOM TIM TRIO, Siemens).

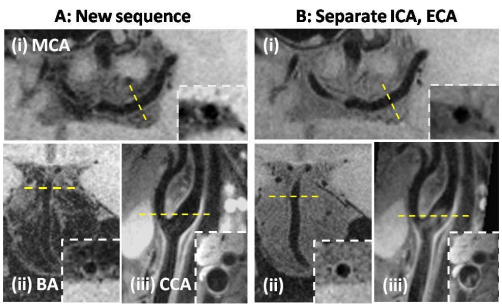

Figure 1. Comparison of images obtained from the 2 methods. MCA = mid cerebral arteries, BA = basilar artery, CCA = common carotid artery

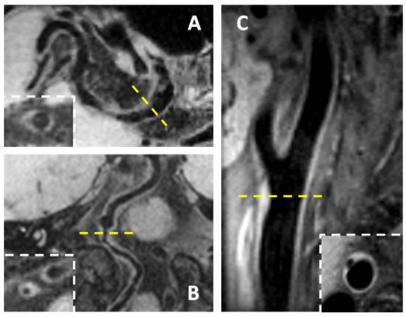

Figure 2. A patient with atherosclerosis in several vessels was scanned using the new sequence. (A) MCA; (B) BA; (C) ECA.

Experiments: The studies were IRB approved, and informed consents were obtained from all subjects. (A) Volunteer study: 3 subjects were scanned. The purpose was to optimize the imaging parameters of the new sequence. Images from it were compared to ICA images obtained separately using conventional T1w-SPACE [2] at $(0.6mm)^3$ isotropic resolution (scan time ~7.5min). Comparison was also made with ECA scanned using a similar T1w-SPACE [8] protocol at $(0.7mm)^3$ isotropic resolution (scan time ~4min). The new sequence achieved a spatial resolution of $(0.6mm)^3$ and took 7.5min. Imaging parameters for the new sequence were: GRAPPA rate 2, ETL=35, TR/TE= 1140ms/23ms, NEX=1.4, base matrix=336, 72slices, FOV= 212mm × 159mm × 40mm. DANTE pulse: 150 blocks, RF pulse interval 1.5ms, flip angle = 12^o. (B) Patient study: 5 male patients (~68.4 years old, 56-76 years old) diagnosed to have either intracranial atherosclerosis or extracranial atherosclerosis were recruited for this study. After spatial localization, the new T1w-SPACE sequence (with modifications mentioned above) was scanned to see the extent of atherosclerosis. Imaging parameters used were same as in the volunteer study. The stenotic segments were identified, and images were visually assessed for image quality, effectiveness of blood suppression and possible presence of artifact.

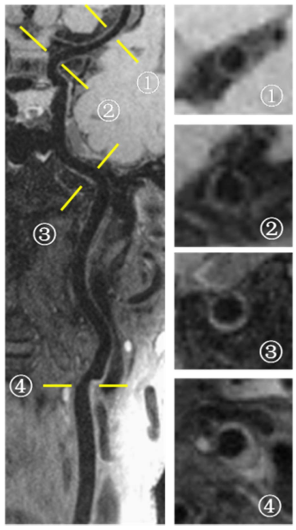

Figure 3.Curved MPR of the vessel wall of another patient. The vessel extends from the common carotid artery up to MCA.

RESULTS: (A) Volunteer study: Figure 1 showed how the optimized new sequence compared with the images obtained from separate scans. CSF was attenuated in the ICA territory, and helps the depiction of vessel wall. The reduced CSF signal around the basilar arteries compared to that around the MCA is the result of flow induced dephasing in that region (CSF flow around MCA is much slower). (B) Patient study in Figure 2 showed one patient with both intracranial and extracranial atherosclerosis plaques. Note again the good contrast between vessel wall and CSF, and the good depiction of vessel wall in fig.2A and 2B. Blood is well suppressed at the carotid bifurcation in fig.2C. Figure 3 showed the extent of atherosclerosis in one patient presented in a curved MPR format. Note the plaque at the carotid bifurcation and the uneven wall thickening at various parts of the vessel.

DISCUSSION: The study showed that by combining several sequence improvements with a well designed neurovascular coil, high resolution imaging of the neurovascular vessel wall is clinically feasible. The images showed an obvious improvement of T1 contrast between CSF and vessel wall.Slow flowing blood was also dephased through the use of DANTE pulses. Compared to previous work, the approach here achieved a voxel volume that is 0.42 times of that reported earlier [5] albeit with a longer scan time. Shorter scan time is available (e.g. 5min) if we increase the spatial resolution (e.g. $0.7mm^3$). The high spatial resolution and the good spatial coverage of the technique would make it a useful tool in the diagnosis of intracranial and extracranial artery diseases simultaneously.

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