High Resolution 3D Intracranial Imaging at 3.0T

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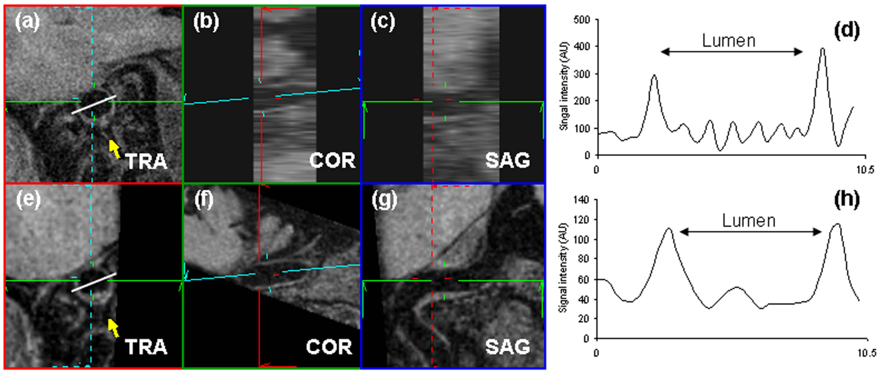
Introduction Vessel wall imaging of intracranial arteries is challenging due to their small sizes and their relatively deep locations inside the brain. 3D Time-of-flight (TOF) and contrast enhanced MRA (ceMRA) are commonly used [1] luminographic techniques. They lack specificity as luminal defects may be caused by various reasons. Dark blood, two dimensional turbo spin echo (2DTSE) has been used to image the vessel walls of intracranials [2] but this 2D approach suffers from low scan efficiency, limited anatomical coverage for the tortuous vessels, partial volume effect and need for careful slice positioning. T1 weighted SPACE (T1w-SPACE) [3] is a TSE variant capable of 3D imaging with high sampling efficiency and good blood suppression, and has previously shown utility for vessel wall imaging of the carotids [4]. We propose here the use of T1w-SPACE for 3D dark blood imaging of the intracranial artery vessel walls at 3.0T with a 32 channel head coil to extend the anatomical coverage and achieve a CT-like spatial resolution of 0.5 mm^3 (isotropic).

Method Imaging: The study was approved by the institutional review board. Six healthy volunteers were recruited. Imaging was done on a 3.0T scanner with 32 receiver channels. A 32 channel head coil was used for signal reception. A FLASH localizer was first run, followed by a high resolution TOF acquisition (0.4x0.4x0.5mm^3) for overview of the intracranial vessels. T1w-SPACE was then run with these parameters: TR/TE=800ms/25ms; echo train length (ETL)=27, NEX=2; fat suppression; bandwidth=475Hz/pixel; true voxel size=0.5mm^3 (isotropic). It was run in two ways: first with iPAT (80 slices for anatomical coverage, 10.6min), and then without iPAT (40 slices for SNR comparison). Lastly, ECG triggered, dark blood multislice 2DTSE [5] of the internal carotid artery (ICA) at the carotid canal was acquired for SNR comparison (imaging parameters: TR/TE = 1RR/9.4ms; ETL=9, NEX=4, bandwidth=302Hz/pixel; fat suppression, dark blood pulse [6] with TI≈450ms). The voxel size was (0.3mm)^2 x 2mm. Interleaved factors of 1 (i.e., no interleaving), 2 or 3 were used, depending on heart rate. 3-4 slices with 2mm gap were acquired. Scan time≈3.3min/interleaved acquisition.
Analysis: For each subject, datasets from 2DTSE and T1w-SPACE with no iPAT were co-registered using commercial fusion software. MPR images of T1w-SPACE at identical positions with 2DTSE were generated. In a total of 18 slices, SNR was measured in the vessel wall and white matter. It was defined as [7]: SNR=average signal in ROI/standard deviation of signal in ROI. SNRv (=SNR/voxel volume) was calculated to account for the differences in voxel size between 2D and 3D acquisitions. A paired t-test was used to compare the SNR and SNRv differences between 2D and 3D acquisitions. Finally, the TOF images were co-registered with T1w-SPACE with iPAT to check if the 40mm slab covered both the ICA and MCA on both sides in each volunteer.

Results Images were successfully acquired in all volunteers. The wall appeared sharper in 2DTSE images compared to T1w-SPACE (Fig.1a versus Fig.1e), likely due to higher inplane resolution in 2DTSE. Meanwhile, the wall was visible in all orientations with T1-SPACE, but not in 2DTSE (Fig.1f & 1g versus Fig.1b & 1c). Blood was dark in all TSE acquisitions. Fig.1d & 1h showed typical signal profiles across the lumen (white lines in Fig.1a & 1e) demonstrating good blood suppression. T1w-SPACE has higher SNR and SNRv than 2DTSE for white matter and vessel wall (Table 1) (*p*<0.0001). T1w-SPACE with iPAT covered both sides of ICA and MCA in all scans. Fig 2 showed a segment of MCA in T1w-SPACE in a volunteer, where the wall was well depicted despite the small vessel size.

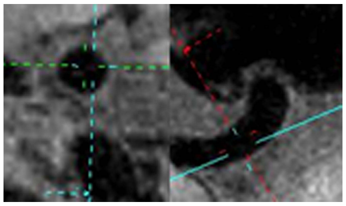
	White matter		Vessel wall	
	2D	3D	2D	3D
SNR	9±2.1	13.2±1.9	2.7±0.4	3.34±0.6
SNRv	50.2±11.5	106±15.5	14.9±2.4	26.7±5

Table 1. SNR and SNRv for 2DTSE and T1w-SPACE (3D) images.



← **Fig 1.** 2DTSE (a-d) versus T1w-SPACE (e-h). T1w-SPACE provides new information about a vessel in other orientations. The visually well suppressed blood corresponds to the signal profiles (d, h) across the lumen.

→ **Fig 2.** One segment of the MCA. Vessel wall could be depicted easily in two different orientations.



Discussion This study showed that 3D dark blood imaging of intracranial arteries can be done in less than 11minutes. Of the two T1w-SPACE protocols, the one without iPAT was used for SNR comparison. In clinical applications, T1w-SPACE with iPAT is more relevant due to its good spatial coverage. The SNR of the two protocols are similar as the iPAT related SNR loss is made up by the iarger imaging volume, less the g-factor of the coil (which may be close to one due to the 32 channels coils and low iPAT factor used).
Compared to 2DTSE, T1w-SPACE covered the major vessels in one scan, with no gap or partial volume effect, and thus would allow the visualization of plaque morphology with CT like spatial resolution. We found both the high field strength and the 32-channel coil are crucial to the high spatial resolution. This technique will be a useful tool for the diagnosis of intracranial vascular diseases.

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