3D Dark Blood TSE for Carotid Vessel Wall Imaging

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Introduction MRI of atherothrombotic lesions is important for in vivo identification of vulnerable plaques [1]. In the carotids, this is typically performed using 2D TSE [2]. 3D TSE is challenging as the scan time is typically very long. For instance, high resolution T1 weighted 3D TSE covering a 24mm slab requires 6 minutes [3]. 3D dark blood TrueFISP is encouraging [4] but acquired-slabs must be limited in thickness and orientation orthogonal to flow to maintain blood suppression. We propose here a new approach to 3D, T2 weighted high-resolution dark blood TSE technique capable of imaging a 180mm slab along the length of the carotids in about 5-6 minutes. We shall show here the technique's potential for vessel wall imaging and dark blood MRA for the carotids. The technique's moderate to heavy T2 weighting may also find application in plaque characterization.

Method Sequence The 3D TSE used differs from conventional approaches in two ways. First, flip angles of refocusing pulses are modulated so that the transverse magnetization changes in a "decay-constant-decay" way with increasing echo number [5-7]. A relatively long echo train length (ETL) for improved imaging efficiency with maintained signal strength is therefore possible. The method also introduces a small T1 dependence in the echoes. Second, refocusing pulses are nonselective to reduce echo spacing and hence echo times. Blood suppression is achieved by natural dephasing of blood through the use of long TE. The technique was implemented on two 1.5T systems (Sonata and Avanto, Siemens, Erlangen, Germany).

Imaging The study, IRB approved, consisted of 6 healthy volunteers and 3 patients with known carotid stenoses (5 stenoses total). Phased array coils (Machnet, Netherlands) were used for signal reception. For volunteers, standard 2D dark blood TSE images (T1W, T2W, PDW), positioned in the transverse plane at the bifurcations, were acquired for reference (using dark blood preparation or saturation bands for blood suppression). 3D dark blood TSE acquisitions were then performed. In patients, 3D dark blood TSE images were acquired first. Contrast enhanced MRA were then performed for comparison. Imaging parameters for T2W 3D TSE were: TR = 1.3 - 1.5s, ETL = 55 or 75 (TE = 109ms or 154ms), bandwidth ~ 600Hz/pixel (echo spacing ~3.72ms), fatsat is used, readout FOV ~ 180mm, ~75% phase FOV, slice thickness = 0.9mm, ~96 slices (subject dependent), phase resolution ~85%, slice resolution ~80% voxel size ~ 0.8 x 0.7 x 0.9mm^3. Scan time is about 5-6 minutes. No triggering/gating is used. For image evaluation, 2D axial images and dark blood MRA images from the 3D TSE data set were reconstructed using the MPR software on the imaging console. In volunteers, the rendered transverse images were compared to the dark blood 2D T2 weighted TSE images. In patients, the dark blood MRA images were compared to the MIP images from contrast MRA.

Results 3D TSE image acquisitions were successful in all subjects. All stenoses in patients were identified on the 3D TSE images. Blood was well suppressed, and no motion artifact was noticed in all cases. Significant image blurring was not observed despite the long ETL used. Image SNR was better with ETL~55 than with ETL~75. Fig.1 shows transverse images from a volunteer. The 2D axial slices from the 3D data set (1a) compared very well with the standard 2D T2W image (1b) with slightly lower inplane resolution. Figures 2 and 3 compared the stenoses from two patients as seen by contrast MRA with those from 3D dark blood MRA acquired using two different ETLs. The rendered 3D TSE images matched contrast MRA images on lesion location and shape very well in both cases.

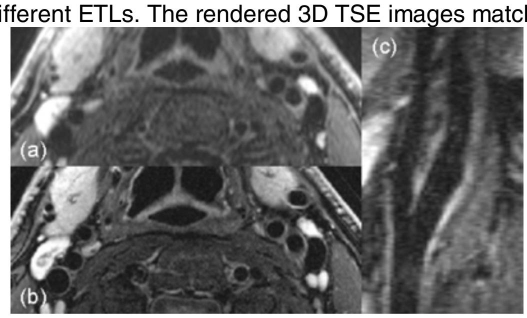

Fig 1. Healthy volunteer: (a) MPR of the same axial slice from 3D dark blood TSE images (0.9mm slice, 0.8x0.6mm^2 pixel). (b) 2D T2W TSE image of the carotid bifurcation (3mm slice, 0.5x0.5mm^2 pixel). (c) MPR of the left carotid bifurcation.

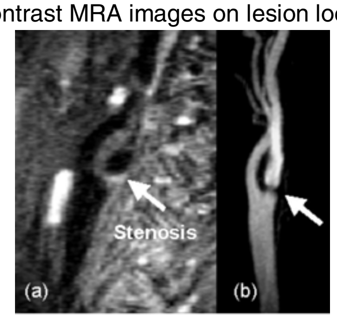

Fig 2. Patient: (a) MPR of 3D dark blood TSE images shows the stenosis (ETL=75, TE=154ms), (b) MIP of the contrast MRA scan shows the stenosis too.

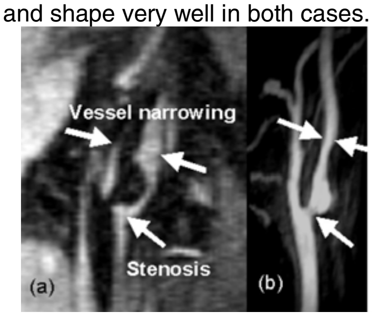

Fig 3. Patient: (a) MPR of 3D dark blood TSE images shows stenosis at the bifurcation and narrowing of the right carotid branch (ETL =55, TE=109ms), (b) MIP of the contrast MRA scan shows the same.

Discussions The results showed that 3D vessel wall imaging of the carotids with the new TSE technique is clinically feasible. In patients, the 3D dark blood images show plaque morphology that is impossible with bright blood MRA. In this study, high-resolution dark blood 3D images were acquired to make vessel wall and plaques more visible. A low-resolution protocol (e.g., 1.2 x 0.9 x 1.4mm^3) would reduce the scan time to 1.5 min which is good for plaque localization. Note that the T2 weighting in this technique would not be reflected by TEs the way it is in standard TSE due to the modulated flip angles of refocusing pulses.

Conclusions This study showed the potential of the new TSE technique. It can be used for 3D dark blood MRA and vessel wall imaging. The technique may also be used for scan plan localization, and potentially plaque characterization.

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