Three dimensional non-contrast MRA of the lower extremities using stepping thin slab acquisition: Initial experience in healthy subjects

T. D. Nguyen[1], M. Cooper[2], P. Spincemaille[1], P. Winchester[1], M. R. Prince[1], and Y. Wang[1]
[1]Radiology, Weill Cornell Medical College, New York, NY, United States, [2]Biomedical Engineering, Cornell University, Ithaca, NY, United States

INTRODUCTION Recent safety concern regarding the risk of gadolinium contrast agents in patients with renal dysfunction has renewed interest in non-contrast (NC) MRA methods (1). Subtraction based techniques such as fresh blood imaging (FBI) rely on differential blood flow between arteries and veins during the cardiac cycle and have been demonstrated for lower extremity imaging (2,3). However, reduced pulsatility in diseased vessels and the need for subtraction may compromise image quality (2). Advanced inflow based techniques such as quiescent interval single shot (QISS) (4) and inflow inversion recovery (IFIR) (5) have been developed to overcome these problems. Inflow techniques utilize a saturation or inversion recovery pulse to suppress the background tissue followed by a time delay to maximize arterial inflow during data acquisition. QISS employs thin slice 2D acquisition and has been demonstrated in the lower extremities. IFIR employs a thick slab 3D acquisition and can provide higher SNR and thinner slices for abdominal imaging, but its utility for MRA of the lower extremities is limited by slower blood flow (6). We propose to develop an IFIR based 3D NC-MRA sequence using a stepping thin slab acquisition (7) which would restore the inflow effect even for slower flow, while at the same time providing the higher SNR and resolution afforded by a 3D acquisition.

METHODS The developed 3D sequence utilizes a slab selective inversion pulse to null signals from veins and other long T1 tissues, and an adiabatic spectrally selective inversion pulse to suppress fat signal (**Fig.1**). Unlike standard 3D IFIR, our sequence excites and acquires a subset of k-space data of a thin 32 mm 3D slab which is continuously advanced upstream similarly to the SLINKY approach (7). The reduced slab thickness improves inflow effect during TI, while the stepping slab acquisition provides large volumetric coverage efficiently and free of Venetian blind artifacts due to the imperfect slab profile. Seven healthy volunteers (35±17 yo) were imaged at 1.5T (GE HDxt) using the developed 3D sequence (TR=4.4 ms, TE=2.2 ms, flip angle=90°, bandwidth=±125 kHz, NEX=1, axial FOV=30-34 cm, matrix=256x256, partial phase FOV=0.625, slice=2 mm, stepping slab thickness=32 mm, total imaging slab thickness=300 mm, partial k_z factor=0.75, TI=1000-1300 ms, inversion slab thickness=100 mm, linear k_z and sliding interleaved k_y view order (7), 8-channel cardiac or body phased-array coil, 2 R-R acquisition, scan time ~ 5 min). Navigator signals were acquired to correct for the k-space phase modulation along the k_y axis (7). Images were reconstructed offline in MATLAB. For comparison, ECG-gated 2D time-of-flight (TOF) MRA was also acquired with matching FOV and matrix (TR=15 ms, TE=3 ms, flip angle=60°, bandwidth=±31.25 kHz, slice=3 mm, slice overlap=1 mm, trigger delay=200 ms, inferior travelling saturation band for venous suppression, 1 R-R acquisition, scan time ~ 12 min). Artery SNR and artery-to-vein CNR were measured for both thighs on a middle slice and results were averaged.

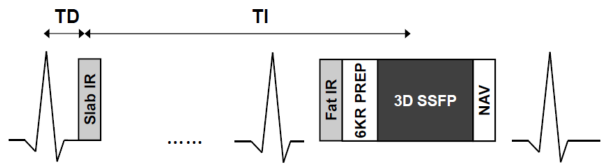

Fig.1. ECG-triggered 3D NC-MRA sequence consisting of a slab inversion pulse (slab IR) played out before systolic peak flow followed by an inversion time (TI) chosen to null the background and enhance the inflow effect prior to 3D SSFP data acquisition. Six Kaiser ramped RF pulses (6KR PREP) prepare magnetization for SSFP readout. A fat inversion (Fat IR) was used to suppress the lipid signal. A navigator signal (NAV) was collected for post-processing data correction.

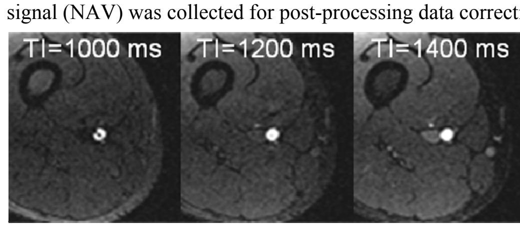

Fig.2. TI effect on background suppression and flow enhancement.

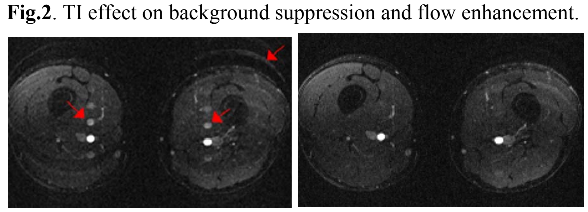

Fig.3. Images obtained before and after navigator phase correction.

RESULTS 3D NC-MRA with stepping thin slab acquisition was obtained successfully in all subjects. Average heart rate was 65±7 bpm. **Fig.2** demonstrates the trade-off between a short TI (better background suppression) and long TI (improved inflow effect). A short TI scout scan was therefore necessary to optimize TI for each subject prior to full volume MRA. **Fig.3** illustrates the benefit of navigator-based phase correction for ghost elimination. **Fig.4** shows an example of concordant MIP images by 2D TOF and 3D stepping slab acquisition. **Fig.5** shows a 48 cm FOV 3D MRA obtained with a body phased-array coil in the thigh and calf stations, demonstrating excellent depiction of the distal superficial femoral artery, the popliteal artery, the popliteal bifurcation, and the tibial and peroneal arteries. Compared to 2D TOF, our sequence provided 21% higher SNR (64±11 vs. 53±6, P=0.004) and similar CNR (49±9 vs. 48±6, P=0.46) and thinner slice (2 mm vs. 3 mm).

DISCUSSION Our preliminary results demonstrated that 3D NC-MRA of the lower extremities using stepping thin slab acquisition is feasible in healthy subjects and warrants evaluation in patients with peripheral arterial occlusive disease. Compared to standard ECG-gated 2D TOF, our sequence provided higher SNR in 60% less scan time. Potential improvements include radial acquisition to further reduce scan time and utilize its self-navigating property for improved phase correction.

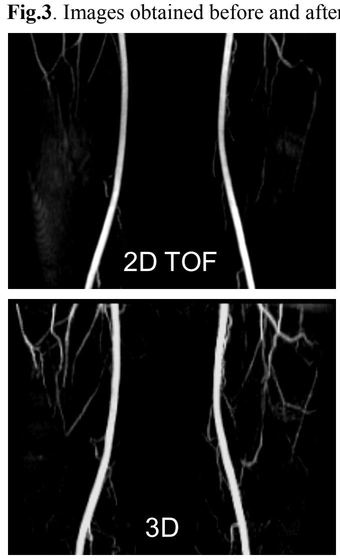

Fig.4. MIP of distal femoral artery.

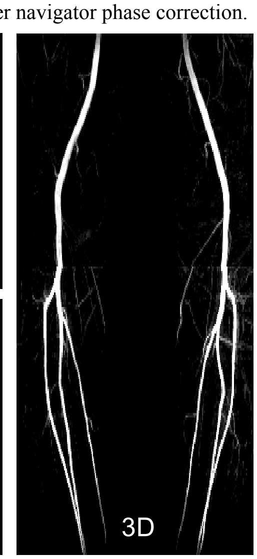

Fig.5. 48-cm FOV 3D MRA.

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