QISS UTE: Quiescent-Inflow Single-Shot MRA of the Peripheral Arteries using an Ultra-Short Echo Time Readout

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Target Audience: Physicians and scientists performing magnetic resonance angiography (MRA) of the peripheral arteries

Purpose: Contrast-enhanced magnetic resonance angiography (CEMRA) is a robust and accurate imaging test for the evaluation of peripheral arterial disease (PAD). Given that impaired renal function is common in patients with PAD, quiescent-interval single-shot (QISS) MRA using a balanced steady-state free precession (bSSFP) readout is increasingly used as a non-contrast alternative to CEMRA and CT angiography (1). However, the use of a bSSFP readout makes the technique sensitive to off-resonance effects, as may occur in the vicinity of orthopedic hardware such as fixation screws or hip prostheses. Moreover, the bSSFP readout is potentially more sensitive than CEMRA (which uses a short TE FLASH readout) to artifacts from flow turbulence caused by a severe stenosis. In order to overcome these limitations, we tested the feasibility of incorporating an ultra-short echo (UTE) readout into QISS.

Methods: The protocol was approved by our institutional review board. Imaging was performed at 1.5 Tesla (MAGNETOM Avanto, Siemens AG, Erlangen, Germany). The prototype QISS UTE sequence had a TE of 0.04ms, compared with 1.44ms for QISS bSSFP. In order to implement the UTE readout, several modifications of the QISS pulse sequence were required. A minimum of two shots was needed to accommodate the two half-sinc RF excitations (2). QISS UTE used a radial k-space trajectory, whereas QISS bSSFP used a Cartesian k-space trajectory. In order to minimize saturation of in-plane spins over the duration of the QISS UTE echo train, a low flip angle (≈10-20 degrees) RF excitation was applied instead of the 90-degree RF excitation used for a QISS bSSFP echo train. Muscle signal was higher with the UTE readout than with the bSSFP readout. Therefore, a magnetization transfer RF pulse was applied once per RR interval. Both QISS UTE and QISS bSSFP used similar readout bandwidths (640 Hz/pixel for QISS UTE vs. 658 Hz/pixel for QISS bSSFP). Images were acquired using 3mm-thick slices, except over the horizontal segment of the anterior tibial artery where 1.7mm slices were acquired.

In order to evaluate the relative sensitivity to off-resonance effects, images were acquired through a standard body phantom after a titanium alloy hip prosthesis had been placed along one edge.

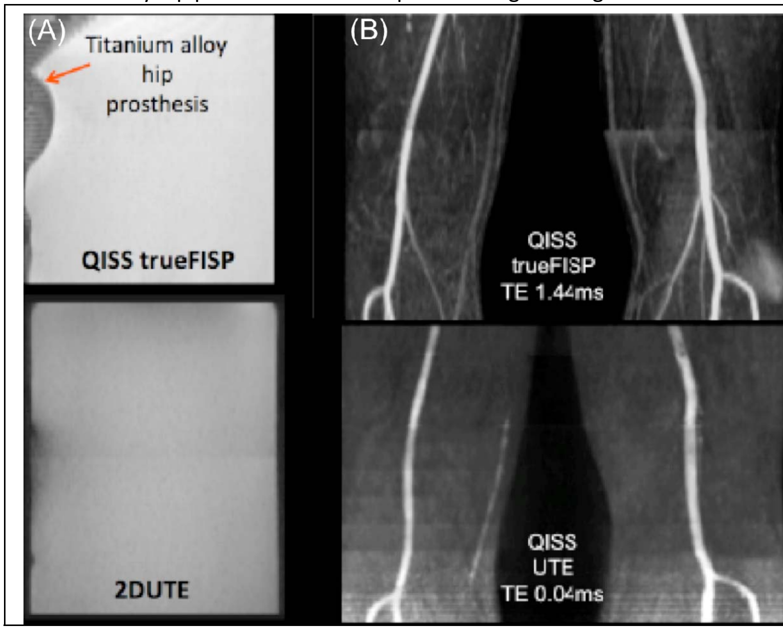

Fig. 1. A. Standard body phantom imaged with a titanium alloy hip prosthesis placed along one side of the phantom (arrow). No fat suppression was applied. Geometric distortion and signal loss are apparent along the right edge of the phantom when imaged with a bSSFP readout (top). The corresponding artifacts are barely visible when imaged with a UTE readout (bottom). **(B) Healthy volunteer.** Top: Antero-posterior maximum intensity projection (MIP) image acquired with QISS bSSFP. Bottom: Antero-posterior MIP acquired with QISS UTE. The major arteries are well shown with both techniques.

Results and Discussion: Images acquired with a UTE readout in a phantom showed a marked reduction in off-resonance artifacts compared with a bSSFP readout **(Fig. 1A)**. In vivo, the arterial supply of the lower thigh and upper calf was well demonstrated using both QISS bSSFP and QISS UTE **(Fig. 1B)**. Small branch vessels were better shown with QISS bSSFP, likely due to a combination of higher SNR and lower muscle signal.

Conclusion: We have demonstrated the feasibility of acquiring non-contrast MRA using the QISS technique in combination with a UTE readout. No flow-related dephasing or ghost artifacts were apparent with the UTE readout, since flow-related phase shifts are negligible at the TE of 0.04ms. The method shows promise for minimizing geometric distortions and signal loss related to metallic orthopedic hardware. Although this work is preliminary, substantial image quality improvements can be expected with additional pulse sequence optimization, e.g. by applying multiple magnetization transfer pulses to further reduce in-plane muscle signal. Alternatively, a high degree of background suppression should be achievable by using a subtractive arterial spin labeled (ASL) approach (i.e. subtracting QISS UTE using a spatially non-selective saturation pulse from QISS UTE using a spatially-selective in-plane saturation pulse). The QISS ASL approach, which has previously been implemented using a bSSFP readout (3), has the additional benefit of eliminating the need for fat suppression, which may be problematic near metallic prostheses.

Referemces: 1. Edelman RR, et al. Magn Reson Med. 2010; 63:951–958. 2. Robson MD, et al. J Comput Assist Tomogr. 2003; 27:825–46. 3. Edelman RR, et al. Proc ISMRM 2014, program #2521.