Ultra-short TE Imaging Protocol for Detection of Aortic Calcification

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INTRODUCTION: Ultra-short TE (UTE) sequences (1-4) have the advantage that they can capture signal from tissue components with T2 in the sub-millisecond range, while preventing signal loss from other sources of artifacts such as off-resonance and susceptibility boundaries. These sequences have been applied to the study of a varied set of tissues including: ligaments, tendons, and ex vivo atherosclerotic calcifications (5). Calcified deposits within atherosclerotic lesions have very short T2 and have been previously quantified simply by the absence of signal on multicontrast images (6,7). In this work, we optimize a protocol for visualization of calcified atherosclerotic lesions in vivo in human aortas. We utilize a previously described UTE sequence (4) to visualize calcium load in patients.

METHODS: Briefly, the previously described UTE sequence utilizes an isotropic 3D radial acquisition scheme in combination with a very short RF pulse and ramp sampling (4). The FID is sampled initially and the TE is defined as the delay between the end of the RF pulse and the beginning of sampling, and is usually due to the time needed to permit switching/tuning of the receive coil. Multiple gradient echoes can also be acquired, typically with fat and water in-phase for better comparison with the FID.

Two healthy subjects were examined on a 1.5T Achieva system (Philips Medical Systems, Best, The Netherlands) using a 5-element cardiac array, according to approved imaging protocols. Optimization included exploring the tradeoff between FOV and percent subsampling of the 3D matrix as well as proper placement and number of surrounding suppression (REST) slabs to minimize streaking artifacts from the radial acquisition.

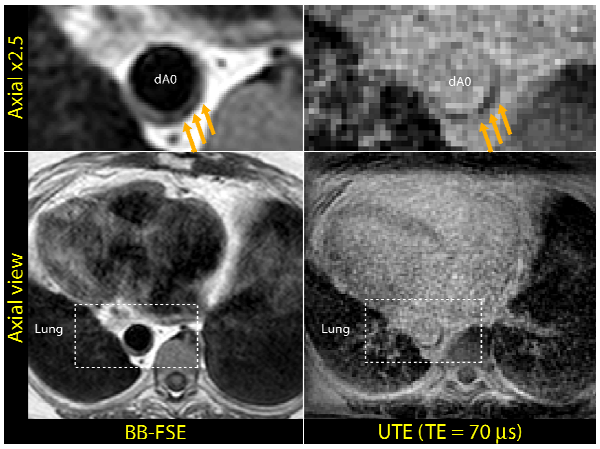

Figure 1: Axial black-blood FSE (left) and UTE (right) images acquired in a patient with known aortic atherosclerosis. Arrows mark the atherosclerotic lesion in the posterior descending aorta (dAo). Signal voids in UTE images correspond closely the location of the plaque in the BB-FSE images.

One male patient (69 yo / 94 kg) was imaged using a 2-echo UTE scan and the following imaging parameters were used: scan time 9:10min, 90% filling of k-space, 160^3 matrix size and $260mm^3$ FOV yielding an isotropic resolution of 1.63x1.63x1.63 mm, TR/TE_1/TE_2=7.29/0.07/4.6ms, (in-phase) and a 10° flip angle. The sequence was cardiac gated to prevent motion of the descending aorta and images were acquired in diastole (600ms post trigger). Cardiac frequency was 64 BPM. Saturation (REST) slabs were used to suppress signals from outside the FOV and to reduce streaking artifacts. For comparison, a VCG-gated black-blood FSE sequence (BB-FSE) was acquired with the following imaging parameters: Scan time 4.6min, 16 echoes per train, 30 5mm 2D slices with no gap, TR/TE = 923/20ms, 3 avgs, FOV = 320x320x150mm, 192x183matrix, 1.67x1.75mm actual resolution reconstructed to 0.626x0.625mm. Imaging took place 300 ms post-trigger.

RESULTS: Scans performed on healthy subjects demonstrated that small FOV acquisitions were superior to large FOV acquisitions, particularly when combined with a "circular" set of REST slabs. Furthermore, acquisition matrices of 128^3 and $1.5mm^3$ were deemed to generate images of sufficient quality. UTE images (not shown) displayed homogenous signal intensities from most tissues, including fat and blood, e.g. the expected contrast of short TR, low flip angle acquisitions. Images acquired on the patient are shown in Figures 1 and 2. Signal voids were also observed in the patient study around the area of an implanted coronary stent and within the pulmonary veins (Fig 2).

DISCUSSION AND CONCLUSIONS: Though the results shown here are very preliminary, they demonstrate the first (to our knowledge) attempt to use UTE sequences for calcium imaging *in vivo* within a cardiovascular arena. Though most components of atherosclerotic lesions are visible within standard MR scanning (e.g. BB-FSE), the presence of calcium is usually determined by the signal void associated with the calcium phosphate deposits. However, within MR there are multiple sources of such voids, and confirmation is difficult unless an accompanying CT is present. With UTE scans, direct calcium visualization is possible for two reasons: 1) there is little contrast in other tissues, highlighting the spatial locations of calcifications, and 2) the extremely short TEs remove most sources of signal voids, supporting the correct identification of calcium. Furthermore, UTE was able to better depict calcium in the luminal side of the aorta, where they could likely be missed by any black-blood-prepared imaging sequence. These preliminary results provide motivation for further study and validation of calcium imaging with UTE sequences.

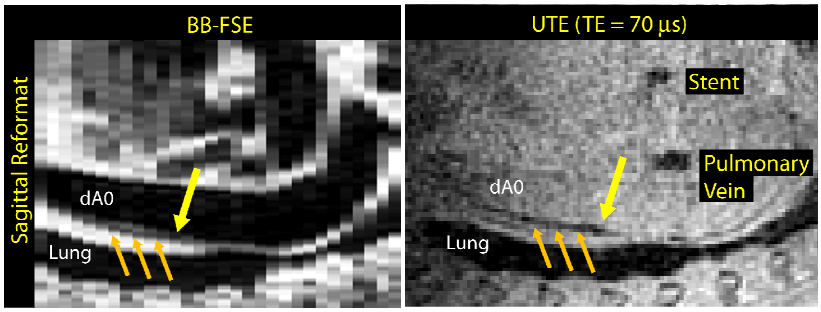

Figure 2: Reformatted sagittal BB-FSE (left) and UTE images (right). The three arrows point to the atherosclerotic lesion. The calcifications visible in the UTE are not directly superimposed, indicating UTE images provide additional information. Also, some of the Ca deposits on the luminal side of the dAo are better depicted by the UTE image, as they are obscured within the blood with BB-FSE (single arrow).

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