Imaging of Metallic Implant Using 3D Ultrashort Echo Time (3D UTE) Pulse Sequence

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INTRODUCTION

Metallic implants are commonly used in orthopedic surgery but produce technical challenges for CT and MR imaging. CT suffers from metal-induced streak artifacts and data loss throughout the field-of-view (FOV) (1). MR imaging near metallic implants suffers from severe artifacts due to large metal-induced field inhomogeneities (2-6). The steep field gradients near metallic implants result in increased intra-voxel dephasing and shortened T2*s. Clinical gradient echo (GE) sequences suffer from large signal loss. In addition, spin echo (SE) type sequences only partly refocus the dephased spins, resulting in spatially dependent signal voids and pile-ups. The in-plane and through plane distortion can be corrected by combining view-angle-tilting (VAT) spin-echo sequence with additional z-phase encoding, as used in slice encoding for metal artifact correction (SEMAC) (5, 6). Another way to suppress metallic artifact is to reduce echo time and voxel size, thus directly minimizing dephasing artifacts. Here we describe the use of a three-dimensional ultrashort TE (3D UTE) sequence employing short hard pulse excitation and 3D radial sampling to provide high resolution isotropic imaging to reduce susceptibility artifacts associated with metal implants (7).

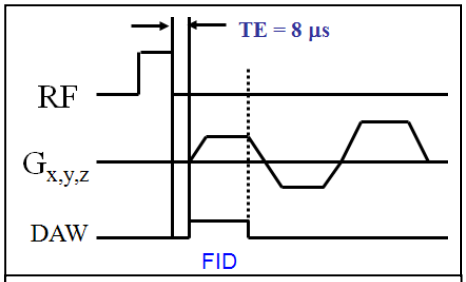

Fig 1 *The 3D UTE sequence employs a short hard pulse for signal excitation followed by 3D radial ramp sampling.*

MATERIALS AND METHODS

The 3D UTE sequence (Figure 1) was implemented on a 3T Signa TwinSpeed scanner (GE Healthcare Technologies, Milwaukee, WI) with a maximum gradient performance of 40 mT/m and 150 mT/m/ms. A short hard pulse (20 μs) was followed by 3D radial ramp sampling for data acquisition. A quadrature knee coil was used for signal excitation and reception. The 3D UTE sequence was first applied to three different types of metal screws or plates (titanium, cobalt-chrome alloy and stainless steel) which were placed in 1% agarose gel and imaged with the following parameters: FOV = 18 cm, TR = 13.6 ms, TE = 8 μs, flip angle = 8°, BW = ±125 kHz, readout = 256 (sampling points = 164), number of projections = 40000, total scan time = 9 minutes. Clinical 2D gradient echo and VAT spin echo sequences with similar imaging bandwidth, FOV and in-plane resolution but thicker slices (2.0 mm) were obtained in both axial and sagittal planes, respectively, for comparison with the single-scan 3D UTE images. A similar 3D UTE protocol (except an increased FOV of 26 cm) was used in a female adult with a complex tibial frature engaged by an intramedullary nail with interlocking screws.

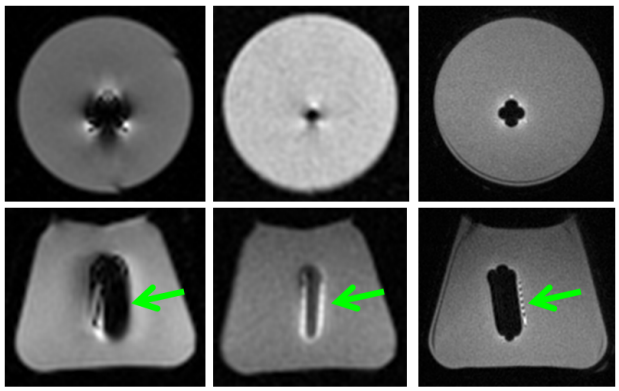

Fig 2 *Imaging of a titanium screw in a 1% agarose Gel phantom using 2D GE (1st column), 2D VAT SE (2nd column) and 3D UTE (3rd column) in the axial (1st row) and sagittal (2nd row) planes (not the same location). Reduced artifact is seen with the 3D UTE sequence.*

RESULTS AND DISCUSSION

Figure 2 shows 3D UTE imaging of a titanium screw as compared with the 2D SE and GE images for all three planes. The 3D UTE images show excellent depiction of the screw with minimal artifact which both the SE and GE images suffer from significant distortion. More obvious artifacts were observed with stainless steel and cobalt alloy metals for all three sequences, but 3D UTE shows markedly reduced artifacts. Figure 3 shows 3D UTE imaging of a female adult post intramedullary nail placement with interlocking screws. There is minimal artifact associated with the metallic implants. Cortical bone was also well depicted due to the short TE of 8 μs.

CONCLUSIONS

The 3D UTE sequence with a TE of 8 μs can provide high isotropic imaging of metallic implants with markedly reduced artifact associated with titanium screws and relatively limited artifact associated with stainless steel and cobalt-chrome alloy.

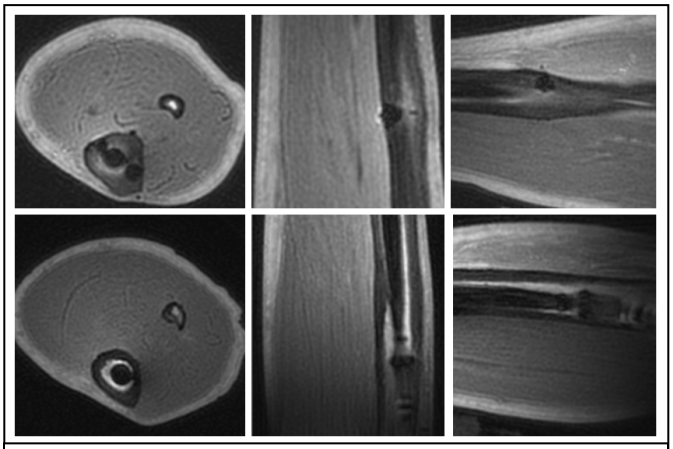

Fig 3 *3D UTE imaging of an adult with intramedullary nail and interlocking screw fixation of a complex tibial fracture (1st and 2nd rows) in the axial (1st column),sagittal (2nd column) and coronal (3rd column) planes. Both metallic implants and cortical bone are well depicted.*

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