$T_{1\rho}$ imaging of articular cartilage after implantation of tibial fracture plate

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Introduction: Tibial plateau fractures are a complex group of injuries resulting in damage to bone, cartilage and ligaments that can be challenging to repair (1). The surgical management is complicated by poor visualization of the often comminuted articular surface, the precarious soft tissue envelope, and the limited surgical exposure available to approach the site of injury. Injuries of articular cartilage alone and osteochondral fractures can be visualized with MRI, which is the only modality for detailed non-invasive assessment of articular cartilage (2). However, with the insertion of metallic fixation plates, the ability to visualize soft tissue within the affected joint is severely diminished. Several MR methods to compensate for B_0 distortions have been discussed (3,4) but are time intensive and require specialized pulse sequences. $T_{1\rho}$ imaging has been shown to have high sensitivity to quantify proteoglycan content within articular cartilage (5). With traumatic tibial plateau fractures, the integrity of the cartilage may become compromised due to several factors such as vascular damage via fractures to the subchondral bone, abnormal loading conditions, and mechanical blunt force trauma to the cartilage matrix. Therefore, the aim of this study is to develop a $T_{1\rho}$ MRI protocol with B_0 distortion compensation to accurately quantify biochemical properties of the articular cartilage post-fixation of the tibia via metallic implant.

Methods: $T_{1\rho}$ imaging was performed on a 1.5 T Siemens clinical scanner (Erlangen, Germany) with vendor supplied knee coil. A $T_{1\rho}$-prepared FSE sequence was used to acquire $T_{1\rho}$-weighted images. The $T_{1\rho}$ cluster was modified to include B_0 and B_1 corrections (6) with the following parameters: TSL = 12, 24, 36, 48 ms, TE = 12 ms, TR =3000 ms, Resolution = 0.78 mm^2 x 5 mm, B_{1amp} = 500 Hz). Localized shimming was performed with the shim voxel containing only the tibial plateau and femoral condyles when applicable. *Phantom Imaging:* Two metallic tibial plates (Synthes, West Chester, PA) were affixed onto a composite tibia (Sawbones, Vashon Island, Washington). One tibial plateau plate was 316L stainless steel with steel screws, while the other was comprised of a titanium plate and titanium alloy screws. *Cadaver Imaging:* Following initial trials from phantom imaging, the titanium plateau plate was secured to the lateral aspect of the tibial plateau approximately five millimeters below the subchondral surface and extending distally. Cadaver was a male (~80 y/o, small build). $T_{1\rho}$ MRI was performed with the same parameters as above. T_2-prepared FSE imaging was performed with the following parameters: prep-TE = 12, 36, 56, 98 ms, readout TE = 12 ms, TR = 3000 ms, resolution = 0.78 mm^2 x 5 mm. B_0 mapping was performed using phase images acquired from low-resolution GRE readouts, parameters: TE = 3.61, 3.75, 3.9, 4.0, 4.1, 4.25 ms, TR = 100 ms.

Results:

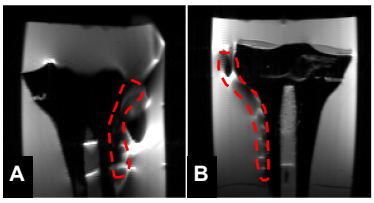
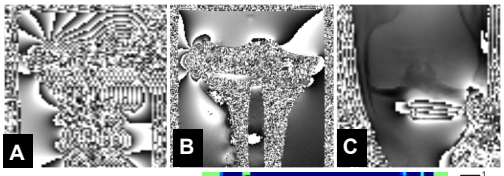


Figure 1: Initial Phantom studies using stainless steel (A) and titanium (B) plates. Red dashes indicate location of plate. Significant distortions in stainless steel pushed for further imaging to use titanium plate.



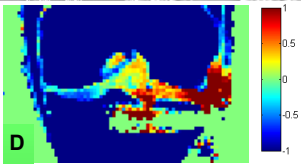


Figure 2: GRE Phase maps of phantom w/ stainless steel (A), titanium (B), and cadaver w/ titanium (C) plates. B_0 map of cadaver knee (D) shows minimal field distortions after voxel shimming, between, -0.5 & 0.9 ppm in cartilage. Color-bar is in ppm.

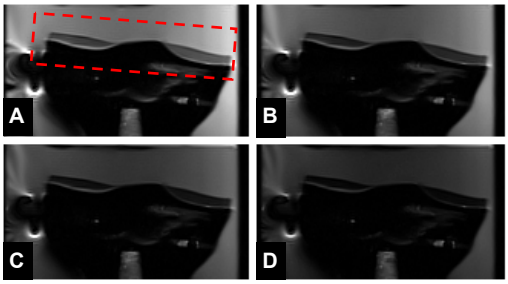


Figure 3: Titanium plate was imaged further with B_1/B_0 compensated $T_{1\rho}$-w images w/ voxel shim (A-D, TSL: 12, 24, 36, 48 ms). Voxel shim located in red dashes. $T_{1\rho}$ images were collected w/o voxel shim had significant artifacts (not shown).

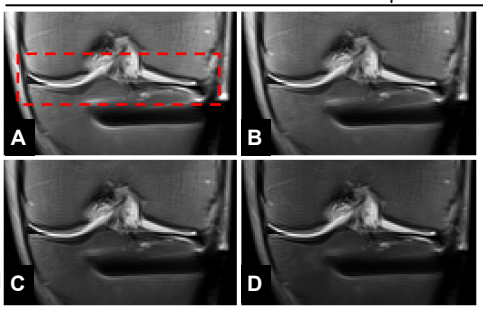


Figure 4: $T_{1\rho}$-weighted images with voxel shim and B_1/B_0 compensation of cadaver knee with titanium plate (A-D) TSL: 12, 24, 36, 48 ms. Distortions around deep tibial screw are significant. The bright signal is due to substantial fluid remained in the joint space.

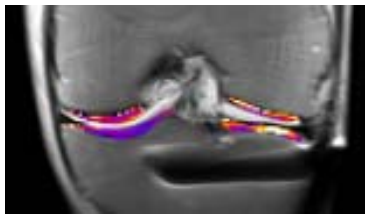


Figure 5: $T_{1\rho}$ map overlaid on a T_2-w image. An R^2 threshold of 0.95 was set to eliminate erroneous pixels. Lateral meniscus and cartilage was surgically altered post-mortem. Color-bar is in ms.

Conclusions: In this study we demonstrated that $T_{1\rho}$ MRI can be performed on individuals who have an implanted titanium proximal tibial plate. Standard B_0 corrections, localized voxel shimming, during scanning were adequate to compensate for field inhomogeneity. However, B_0 mapping has demonstrated that inhomogeneities around deep tibial screw cannot be mitigated and may impact calculated $T_{1\rho}$ values in lateral compartments. Inherent B_1 and B_0 compensation features of the $T_{1\rho}$ sequence allow for further improvements, which will provide a more robust and accurate method to quantify cartilage over T_2 weighted imaging. Future work will focus on $T_{1\rho}$ imaging of patients after fracture fixation with proximal tibial plates to follow cartilage health and integrity. Inversion recovery -prepped $T_{1\rho}$ MRI will be implemented to eliminate fluid buildup, if any, in the synovial cavity.

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