Magnetic Resonance Imaging of Periprosthetic Tissues in the Presence of Joint Arthroplasty

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Introduction. Magnetic resonance imaging (MRI) has been shown to be an effective and accurate means by which to assess bone loss and synovitis surrounding arthroplasty (*1*). MRI in the presence of orthopedic devices is challenging because the implants create susceptibility artifact which produces in-plane and through-plane image distortions. The effect of image distortion and "pixel-pileup" limit the visualization of periprosthetic tissues and bone metal interface.

Investigators have also developed novel techniques to minimize susceptibility artifact using a pre-polarized MRI system (*2*) or view-angle tilt (VAT) (*3*). These techniques have not been adopted for widespread clinical use due to the need for specialized scanning hardware (pre-polarized MRI) or a lack of mitigating slice-selective distortions (VAT). A promising variation of VAT utilizing alternative slice-encoding strategies has recently been demonstrated (*4*).

Another approach, the multi-acquisition variable-resonance image combination (MAVRIC) technique has recently been shown to minimize image distortions by combining image datasets acquired at numerous frequency bands offset from the dominant proton frequency (*5*). The goal of this study was to scan individuals with total joint replacements, and evaluate the image quality of 3D MAVRIC scans with standard-of-care 2D fast-spin echo (FSE) scans.

Methods. All methods were approved by the local Institutional Review Board with informed consent of subjects before enrollment in the study. *Image Acquisition*: All scanning was performed using clinical 1.5 Tesla clinical scanners (GE Healthcare, Waukesha, WI) and a quadrature or an 8 channel phased array knee coil (Invivo, Orlando, FL), or a 3 element shoulder coil (MedRad, Indianola, PA). Standard of care 2D FSE imaging was performed along three orthogonal planes with the parameters: TE: 26-34 ms, TR: 4200-4500 ms, BW: ±100 kHz, FOV: 18-22 cm, NEX: 4-5, acquisition matrix: 256-352 x 512, slice thickness: 3-4 mm (*6*). Scan time was 6-11 minutes for each imaging plane. Next, 3D FSE based MAVRIC scans were acquired using the parameters: TE: 21-43.4 ms, TR: 2400-4000 ms, BW: ±125 kHz, FOV: 22-27 cm, NEX: 0.5-1, acquisition matrix: 256-320 (Freq) x 128-256 (Phase), slice thickness: 3-5 mm. Scan time for MAVRIC was 11-18 min. *Image Analysis*: The MAVRIC and corresponding FSE images were compared for depiction of osteolysis, synovitis, joint specific tendon insertions and overall image appearance.

Results. Fifty-three subjects have been scanned to date, comprised of 26 total knee arthroplasties (TKAs), 15 total hip arthroplasties (THAs), 8 total shoulder arthroplasties (TSAs), 2 hip resurfacings and 2 volunteers with orthopedic hardware near the proximal femur. MAVRIC scans were effective in reducing metal susceptibility artifact as compared to standard-of-care FSE images (Fig. 1). For TKA imaging, MAVRIC was more successful at highlighting the extent of osteolysis (5/26, 19%), displaying the outline of tibial polyethylene components (11/26, 42%) and displaying the posterior portions of the femoral cobalt chromium components (7/26, 27%) than corresponding FSE images. The limited resolution of the MAVRIC images prevented detection of fibrous membranes seen in FSE images (4/26, 15%). The FSE images also provided better overall visualization in volunteers with oxidized zirconium (3/26) compared to cobalt chromium (23/26) implant components. For THA imaging, MAVRIC images was superior to FSE images for displaying the anterior column of the acetabulum (10/15, 67%), however, the higher resolution FSE images were better for evaluating the insertion of the abductor tendons. For TSA imaging, MAVRIC images resulted in better visualization of soft tissues than FSE images (5/8, 63%), specifically the anterior margin of the supraspinatus tendon which was typically obscured in FSE image. The MAVRIC images of both hip resurfacing implants displayed the entire acetabular zone, which was not seen in the FSE images. MAVRIC images also minimized artifact seen in FSE images in a subject which may have indicated fracture through the stem of the implant adjacent to periosteal bone formation. The scan time of initial MAVRIC series was minimized by limiting the TR to 2400 ms, producing T1-weighted images, but longer TE values were used to highlight fluid around the arthroplasties. Newer versions of MAVRIC set TR to 4000 ms, allowing for clinical feasible scan times and reducing T1 weighting effects. All MAVRIC scans were well tolerated by the subjects.

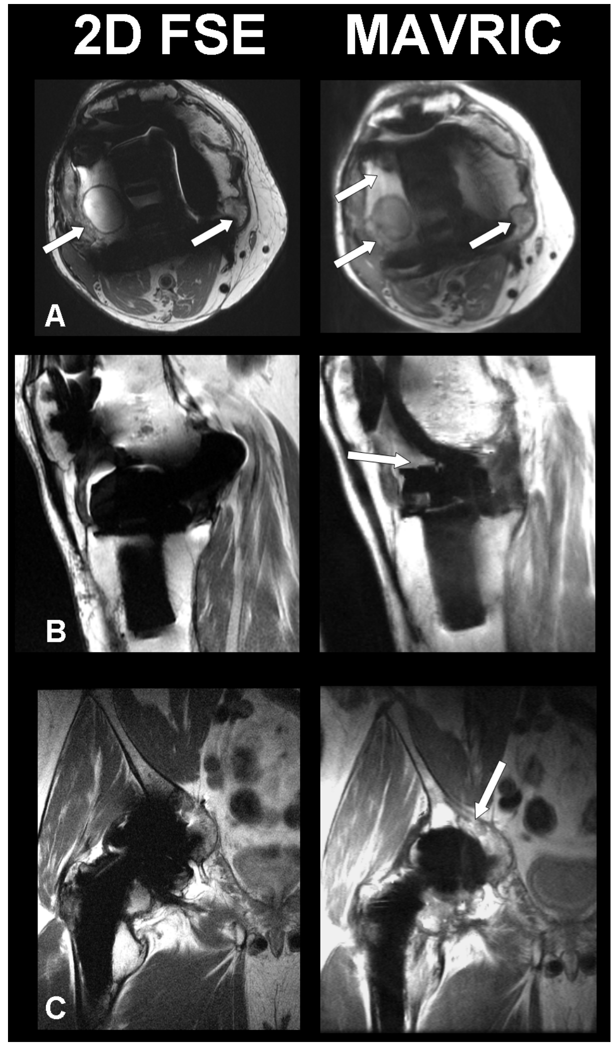

Figure 1. (A) Axial FSE image (Left) and corresponding MAVRIC image (Right) from TKA subject. The 2D FSE image demonstrates osteolysis (arrow) in the central and posterior condyle due to image distortion; the MAVRIC scan also displays osteolysis anteriorly (arrows). (B) Sagittal 2D FSE image (Left) and MAVRIC image (Right) from TKA subject. Significant susceptibility in the 2D FSE image obscures surface fracture of the polyethylene tibial component evident in the MAVRIC scan (arrow). (C) Coronal 2D FSE image (Left) and corresponding MAVRIC image (Right) following THA. The 2D FSE image obscures the focal acetabular osteolysis, the full extent of which is displayed in the MAVRIC image (arrow).

Discussion. The 3D MAVRIC scanning technique successfully minimized in-plane and through plane image distortions, as compared 2D FSE scanning. MAVRIC was effective for visualizing soft tissues around TSAs, polyethylene inserts and osteolysis around TKAs, and the anterior acetabulum in THA. The higher resolution FSE images were effective for diagnosing formation of fibrous membrane on all implants, adjacent tendons for THAs, and imaging of oxidized zirconium TKAs. Newer versions of MAVRIC used during the study allowed for increased in-plane resolution (16/53, 32%). The results of this study indicate for continued MAVRIC development to increase in-plane resolution to match FSE imaging for evaluation of painful arthroplasty. Future studies will use MAVRIC to investigate the relationship between appearance of periprosthetic synovium and clinical symptoms.

References.1. T. A. Walde *et al.*, *Clin Orthop Relat Res*, 138 (2005), 2. R. D. Venook *et al.*, *Magn Reson Med* **56**, 177 (2006), 3. Z. H. Cho *et al.*, *Med Phys* **15**, 7 (1988), 4. W. Lu *et al.*, *Magn Reson Med* **62**, 66 (2009), 5. K. M. Koch *et al.*, *Magn Reson Med* **61**, 381 (2009), 6. H. G. Potter *et al.*, *J Bone Joint Surg Am* **86-A**, 1947 (2004)