Magnetic Resonance Imaging of Arthroplasty: Comparison of MAVRIC and conventional Fast Spin Echo Techniques

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Introduction. Assessment of bone loss and synovitis following arthroplasty 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 peri-prosthetic tissues and the bone-metal interface. 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 (*2, 3*). The goal of this study was to scan individuals with total joint replacements, and evaluate the image quality of 3D MAVRIC scans compared to 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 3 element shoulder coil (MedRad, Indianola, PA) or 8 channel cardiac coil (GE Healthcare, Waukesha, WI). 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 (*4*). 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: 3-5mm. Scan time for MAVRIC was 11-18 min. *Image Analysis*: The MAVRIC and FSE images in the corresponding plane were graded in consensus by two experienced musculoskeletal radiologists for the following factors: visualization of the synovium, surrounding bone and hip abductors or supraspinatus tendon; presence of synovitis, presence and location of osteolysis, presence of supraspinatus tendon tear. Visualization was evaluated using a three grading point scale: 1, poor; 2, fair; 3, good. The MAVRIC images were evaluated separately from the corresponding FSE images for each subject. A Wilcoxon signed rank test was performed to detect a difference of MAVRIC and FSE grading scale for each joint. Statistical significance was set at $p < 0.05$.

Results. 80 subjects in total were scanned, including 55 hip arthroplasties (HAs) and 25 shoulder arthroplasties (SAs). All MAVRIC scans were well tolerated by the subjects. For HA imaging, visualization of the synovium was significantly better on MAVRIC compared to FSE images (mean difference 0.67, $p < 0.0001$). Synovitis was seen on both MAVRIC and FSE scans in 47 patients (85%). Synovitis was seen only on the MAVRIC scans in 6 patients (11%) and was seen only on the FSE scans in 1 patient (2%). MAVRIC was significantly better at visualizing the acetabulum (mean difference 0.76, $p < 0.0001$) and the femur (mean difference 0.58, $p < 0.001$). Osteolysis was seen on both MAVRIC and FSE scans in 25 patients (45%). Osteolysis was seen only on the MAVRIC scans in 9 patients (16%). Of these, 5 patients had peri-acetabular osteolysis, 3 patients had femoral osteolysis and 1 patient had both peri-acetabular and femoral osteolysis. Osteolysis was seen only on the FSE scans in 1 patient (2%). The hip abductors were better visualized on the FSE scans (mean difference -0.96, $p < 0.0001$). For SA imaging, visualization of the synovium was significantly better on MAVRIC compared to FSE images (mean difference 0.6, $p < 0.01$). Synovitis was seen on both MAVRIC and FSE scans in 18 patients (72%). Synovitis was seen only on the MAVRIC scans in 4 patients (16%). MAVRIC was significantly better at visualizing the humerus and glenoid (mean difference 1.04, $p < 0.0001$). Osteolysis was seen on both MAVRIC and FSE scans in 6 patients (24%). Osteolysis was seen only on the MAVRIC scans in 6 patients (24%), which was present around the glenoid in 4 patients and around the glenoid and humerus in 2 patients. Visualization of the supraspinatus tendon was significantly better on MAVRIC images compared to FSE images (mean difference 0.84, $p < 0.0001$). Supraspinatus tendon tears were seen in 4 patients (16%) on both MAVRIC and FSE images and were seen only on the MAVRIC scans in 12 patients (48%). In no case was synovitis, osteolysis or supraspinatus tendon tear seen only on the FSE images.

Discussion. In the assessment of HA's, MAVRIC scanning significantly improved visualization of the synovium and the bony acetabulum and femur. MAVRIC improved the detection of synovitis and osteolysis, especially the presence of peri-acetabular osteolysis. The hip abductors were better assessed on conventional FSE images due to higher spatial resolution. In the assessment of SA's, MAVRIC scanning significantly improved visualization of the synovium, the glenoid and humerus and the supraspinatus tendon. MAVRIC greatly improved the detection of supraspinatus tendon tears, compared to conventional FSE scans. The results of this study support the use of MAVRIC as an additional sequence to complement the information obtained by optimized FSE images in the evaluation of the painful arthroplasty, particularly when there is concern regarding osteolysis or in a patient with a SA, the presence of a supraspinatus tendon tear. Future studies will use MAVRIC to assess the relationship between the appearance of the peri-prosthetic synovium and clinical symptoms.

References. 1. T. A. Walde *et al.*, *Clin Orthop Relat Res* **437**, 138 (2005), 2. K. M. Koch *et al.*, *Magn Reson Med* **61**, 381 (2009), 3. K.M. Koch et al, *Magn Reson Med*, E-Pub, DOI: 10.1002/mrm.22523, 4. H. G. Potter *et al.*, *J Bone Joint Surg Am* **86-A**, 1947 (2004)
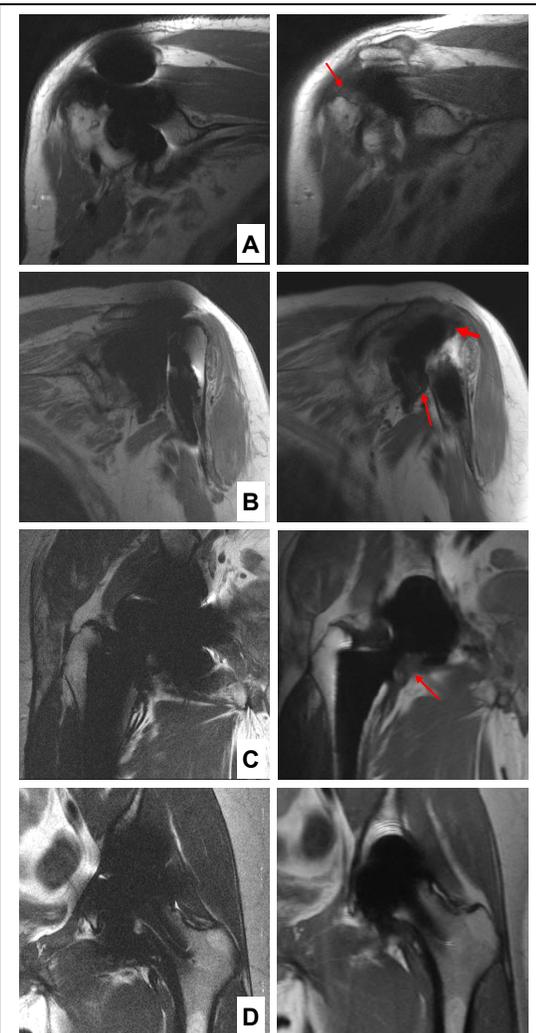
Fig 1. Corresponding FSE (left) and MAVRIC (right) images demonstrate: (A) improved visualization of the supraspinatus tendon (arrow); (B) improved visualization of synovitis (thin arrow) and peri-humeral osteolysis (thick arrow); (C) improved visualization of synovitis (arrow); (D) improved visualization of the acetabulum and femur on MAVRIC scans.