Assessment Of Osteonecrosis Following Instrumentation For Femoral Neck Fracture Using Contrast Enhanced Mavric-sequence

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Disclosures:

Introduction: Femoral neck fractures (FNF) frequently occur in elderly patients with osteoporosis (1). Complications of FNF are osteonecrosis (ON) of the femoral head and non-union, particularly in displaced FNF. Although patients with ON after FNF fixation may be asymptomatic, undiagnosed ON could be a potential cause of unexplained pain after surgical fixation of the fracture. The risk of collapse and development of hip osteoarthritis indicates the need for early detection and close follow up with advanced imaging.

Most fracture complications are assessed by radiographs, a two-dimensional (2D) imaging technique with poor soft-tissue contrast. Magnetic resonance imaging (MRI), an imaging modality with high soft-tissue contrast is more sensitive for early detection of ON, than radiography (2). A limitation of MRI following surgical fixation of FNF is metal susceptibility artifact, causing misregistration of signal encoding in the slice and frequency encoding directions. The artifact obscures visualization of tissues and osseous detail adjacent to metal instrumentation. Newer, multi-spectral imaging techniques, such as the multi-acquisition variable-resonance image combination (MAVRIC) sequence, sufficiently mitigate in-plane and through-plane the susceptibility artifacts to allow detection of structural defects around metallic implants (3). The prevalence of ON in MR images following metallic fixation of displaced FNF remains unclear using sequences with metal artifact reduction protocols. The goals of this study were: 1) To compare the ability of 2D fast spin-echo (FSE) and MAVRIC sequences to visualize ON around stainless steel fixation screws in patients with FNF, and 2) To determine the feasibility of estimated semi-quantitative perfusion measurements with the MAVRIC sequence.

Methods: Following IRB approval with informed consent, MR images of 17 patients (4/13 M/F, 62 ±11 y.o.) were acquired immediately following FNF, at 3 and 12 months after FNF repair. All repairs were performed with stainless steel pin fixation and fibular cortical bone allograft placement. Most (94%) patients had displaced FNF. Imaging Protocol: Imaging was performed on a clinical 1.5T MR scanner (GE Healthcare, Waukesha, WI) with an 8 channel cardiac coil. Three plane 2D-FSE proton density (PD) images were acquired: repetition time (TR): 4000ms; echo time (TE): 25ms; receiver band width (RBW): ±125kHz; slice thickness (ST): 2.5-4mm; slice spacing (SS): 0mm; acquisition matrix (AM): 512 x(256-384); number of excitations (NEX): 3-5; echo train length (ETL): 14-24; field-of-view (FOV): 24-28 cm. Pre- and post- contrast coronal T1w MAVRIC images at 3 and 12 months post-op were obtained: TR: 1000ms; TE: 10ms; RBW: ±125kHz; ST: 3.5mm; SS: 0mm; AM: 512x256; NEX: 0.5; ETL: 8; FOV: 38-44 cm. Radiographs were acquired at all time points. ON Quantification: ON was recorded on radiographs by radiologists blinded to the MRI results. The presence, location and volume of ON were recorded from FSE and MAVRIC images at 3 and 12 months after surgery. Signal Intensity (SI) Enhancement: SI was measured in pre- and post- contrast MAVRIC images with regions of interest (ROIs) placed in the ON, in the rim of the ON, in the marrow of the ilium and femoral diaphysis (FD), and in the femoral cortical bone. The percent (%) SI enhancement was normalized to cortical bone (negligible uptake) to correct for any differences of pre-scan excitation parameters between MAVRIC acquisitions. Statistics: A chi square test was used to detect differences of ON detection between MAVRIC and FSE images. Differences of ON volume and change of ON volume over time between FSE and MAVRIC, and % SI enhancement (MAVRIC only) were evaluated with paired t-tests. P<0.05 was considered as statistically significant. Statistical analyses were performed using PRISM software (La Jolla, CA).

Results: 17 patients were enrolled, and four patients did not have a 12 month follow up MRI. ON Quantification: At 3 months post-operatively, ON was detected in 77% of patients with MAVRIC, 65% with FSE, and 0% with radiographs (Fig. 1). At 12 months post-operatively, ON was detected in 77% of patients using MAVRIC, 77% with FSE, and 15% with radiographs. ON was detected in 23 of 30 cases (3 and 12 months combined). The detection rate of an ON (3 and 12 months combined) was similar between MAVRIC and FSE images, p=0.56; however, a difference of ON volume was detected at 3 months post-op between the MAVRIC images (5.5 ± 4.3 cm³) and the FSE images (1.9 ±2.4 cm³), p=0.0002. A difference was also found at 12 months post-op (4.8 ± 3.8 cm³ vs. 2.0 ± 1.7 cm³), p=0.0099. No change in the volume of ON was detected over time, using FSE or MAVRIC, p=0.24 and p=0.90, respectively.

SI Enhancement: A significant increase of % SI enhancement was found in the rim of the ON (34 ± 19 %) as compared to the ilium (-16 ± 15 %) and FD (-9 ± 22 %) after 3 months, p<0.0001, and 12 months, p<0.006. The contrast enhancement difference between the center of the ON and the ilium or the femoral diaphysis was similar at 3 and 12 months. No change in SI
enhancement at 3 months vs. 12 months was found for the rim and the center of the ON.

**Discussion:** This study used FSE and MAVRIC imaging to assess the detection rate and volume of ON around metallic implants, and to estimate post-contrast SI measurements using MAVRIC. The results indicate that radiographs underestimate the prevalence of ON after FNF fixation as compared to MRI, and FSE images underestimate the volume of the ON as compared to MAVRIC images. In addition, estimated semi-quantitative perfusion using MAVRIC found a significant increase in SI enhancement in the rim of ON.

The higher detection of ON with MRI may be due to the superior soft tissue contrast of MRI and the lack of an extended time frame necessary for radiographic detection of ON (5).

The similar detection rate of ON between FSE and MAVRIC but the larger ON volume in MAVRIC images is due to metal susceptibility artifact in the FSE images. MAVRIC images permitted greater visualization of the extent of ON.

Quantitative perfusion was performed using MAVRIC since the gradient echo sequences typically used in perfusion measurements create poor quality images near metallic hardware. The increase of uptake at the interface of the ON and at the surrounding normal bone marrow at both 3 and 12 months may be attributable to vascular regeneration and reparative tissue in the transitional zone.

A limitation of the study may be detecting ON volume using FSE images and unenhanced MAVRIC images but since the detection rates were similar between the two series, it may be feasible to compare the two sequences. Additionally, the current patients may not be representative of all patients presenting with FNF.

This study shows the strength of MRI over standard radiography, MAVRIC over 2D-FSE imaging for quantifying ON near metallic hardware, and feasibility of quantitative perfusion using MAVRIC. Future studies with may provide important prediction modeling for the risk of collapse and the development of osteoarthritis.

**Significance:** Assessment for ON following FNF using radiographs alone will underestimate prevalence. MRI following FNF fixation is feasible using the MAVRIC technique and will permit semiquantitative assessment of bone perfusion.

**Acknowledgments:** HSS institutional research agreement with General Electric Healthcare

**References:**

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**Figure 1.** Example of the detection of ON (arrow) comparing (a) coronal 2D-FSE and (b) coronal MAVRIC-sequences. The ON on the 2D-FSE image (a) is only partially detected, and its extent is underestimated as compared to the MAVRIC image (b).