Perfusion of the Femoral Head following Fracture Using Dynamic Contrast Enhanced MRI

J. P. Dyke[1], C. Hettrich[2], K. Hentel[1], S. Boraiah[3], and D. Lorich[4]
[1]Radiology, Weill Cornell Medical College, New York, NY, United States, [2]Orthopedics, Vanderbilt University Medical Center, Nashville, TN, United States, [3]Orthopedics, Westchester Medical Center, Hawthorne, NY, United States, [4]Orthopedic Trauma, Hospital for Special Surgery, New York, NY, United States

Introduction: Assessment of femoral head vascularity immediately following fracture of the femoral neck is valuable in predicting the development of avascular necrosis and the functional outcome thereafter. Fat suppressed dynamic contrast enhanced (DCE) MRI provides a technique to estimate bone perfusion in-vivo by imaging uptake of Gd-DTPA in the femoral head over time.[1-3] Accurate quantitation of bone perfusion may aid the clinician in determining whether to preserve the joint or proceed to hip arthroplasty depending on conservation of the surrounding vasculature.[4]

Methods: Ten adult subjects [56.1±5.8 yrs, 4M/6F] presented with minimally displaced subcapital fractures of the femoral neck as assessed in the emergency room. Both injured and contralateral hips were imaged simultaneously using a 1.5 Tesla General Electric MRI system with an 8-channel phased-array resonator. Injection of gadopentetate dimeglumine (Gd-DTPA; Schering Plough, Wayne, NJ) was administered at a standard concentration of 0.1 mM/kg. The DCE-MRI sequence used a coronal fat suppressed 3D spoiled gradient echo pulse sequence (LAVA). A temporal resolution of 7 sec/image over 45 time points was used for a scan time of 6 minutes. Additional parameters were a 40 cm field of view, a 256 x 128 matrix, 26 slices of 4 mm thick, a repetition time of 3.6 ms, an echo time of 1.7 ms and a flip angle of 12 degrees.

The Brix 2-compartment pharmacokinetic model was used to analyze the DCE-MRI uptake curves in the normal and injured femoral head.[5] The model contains the parameters: A(signal amplitude), k_{ep}(exchange rate between plasma and extravascular extracellular space (EES) in min^{-1}), and k_{el}(elimination rate in min^{-1}). The amplitude (A) is proportional to the fractional volume of EES (v_e) while k_{ep} represents a ratio between the permeability surface area product (K_{trans}) and v_e assuming constant T_1 and relaxivity values at short times following injection of contrast. Multiple regions of interest (ROI) were taken over the entire femoral head to produce a single time intensity curve using the control side as a reference in each subject. Analysis software was written in-house using IDL 6.4 (ITT Visual, Boulder,CO) to fit the time intensity curves.

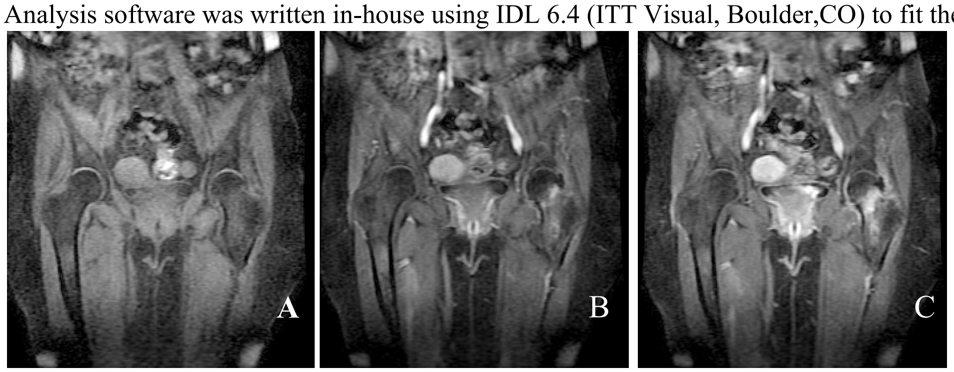

Figure 1: A) Fat suppressed T_1-weighted images of the control and injured side prior to bolus injection of Gd-DTPA,
B) At several frames following administration and
C) At 6 minutes post-injection showing more complete filling at the fracture site.

Results: There was a significant (p=0.016) decrease in the initial rate of contrast uptake within the injured femoral head [Ak_{ep} = 0.28 ± 0.09 min^{-1}] compared to the control side [Ak_{ep} = 1.09 ± 0.28 min^{-1}]. A trend existed (p=0.07) showing a lower maximum % enhancement in the injured side [32%±10%] compared to the control side [51%±5%]. Figure 1 displays time points from the DCE-MRI scan showing enhancement at time points prior to and following contrast injection. Changes in the time intensity curves between the control and injured side can be seen in a representative subject shown in Figure 2.

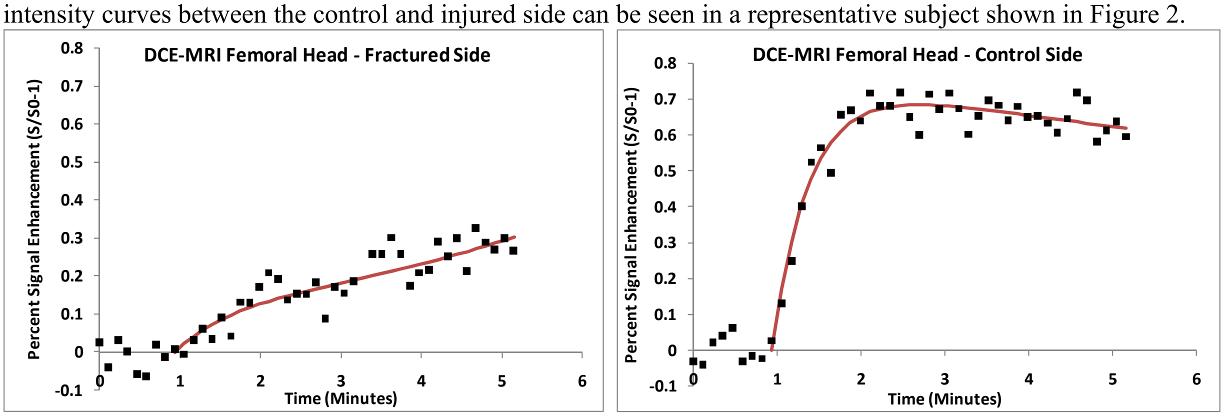

Figure 2: Time intensity curves display percent enhancement in the femoral head following administration of contrast.

Discussion: Knowledge of bone perfusion at the time of injury is essential in assessing whether adequate vascularity exists to predicate reliable healing. Further validation of this method to predict the occurrence of avascular necrosis following surgery will be essential in establishing the use of this technique in the clinic.

1)Dyke JP, Aaron RK. Ann N Y Acad Sci. 2010;1192:95-102. 2) Kamano M, Narita S, Honda Y, et.al. Clin Ortho Rel Res 1998;350:179-186. 3) Lang P, Mauz M, Schorner W, et.al. AJR 1993;160:335-341. 4) Boraiah S, Dyke J, Hettrich C, et.al. J Bone Joint Surg Br. 2009;91:131-137. 5) Tofts PS, Brix G, Buckley DL, et.al. Journal Mag Reson Imag 1999;10:223–232.