Assessment of Bone Circulation in the Hip Following Fracture of the Femoral Neck Using MRI

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Disclosures:

Introduction: An estimated 352,000 hip fractures occur each year in the USA of which 90% are the result of a fall. The reported incidence of the two primary hip fracture types include intertrochanteric fractures at a rate of 54% and femoral neck fractures at a rate of 46%. Surgical fixation of a femoral neck fracture is often associated with a high complication rate (non-union, avascular necrosis (AVN) of the femoral head and late segmental collapse) and an increased secondary reoperation rate. Traumatic injury and associated compromise of the tenuous blood supply to the femoral head is of major concern during this injury and is presumed to be one of the primary etiologic factors for these devastating complications. Following a femoral neck fracture, the presumed viability of the femoral head and healing potential dictates surgical treatment to either operative fixation or arthroplasty.

Quantitative assessment of femoral head vascularity 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) We hypothesized that quantitative modeling of DCE-MRI quadrant analysis of the femoral head may better typify perfusion characteristics in subjects with displaced fractures of the femoral neck that could potentially be averaged out by analysis of the entire femoral head. 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: A total of twenty seven subjects (9M/18F) with an average age of 60.0 years (± 13.2) were enrolled (range of 28 to 85 years). All fractures were classified as Garden Stage III-IV in this study. Injured and contralateral hips were imaged simultaneously using a 1.5 Tesla General Electric MRI system with an 8-channel phased-array torso coil. Injection of Gd-DTPA (Schering Plough, Wayne, NJ) was administered at 0.1 mM/kg using a power injector. The DCE-MRI sequence used a coronal fat suppressed 3D spoiled gradient echo pulse sequence with a temporal resolution of 7 sec/image over 45 time points for a scan time of 6 minutes. The Brix 2-compartment 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), kep (exchange rate between plasma and extravascular extracellular space (EES) in 1/min), and kel (elimination rate in 1/min). The initial area under the curve (IAUC 90s) and peak enhancement were also calculated. Regions of interest (ROI) were taken over the entire femoral head and further subdivided into quadrants to produce time intensity curve using the control side as a reference in each subject. Analysis software was written in-house using IDL 8.1 to fit the time intensity curves.

Results: Significant decreases were found in both arterial and venous supply to the femoral head in various quadrants between injured and control sides (Table 1). The fractional IAUC for the total femoral head on the fracture versus control side was 39%. The fractional perfusion (IAUC) in the superolateral quadrant was 50% while the inferolateral quadrant was 55%. The fractional perfusion (IAUC) in the superomedial quadrant was 44% and in the inferomedial quadrant 46%. Perfusion (Ak, IAUC, Peak) was higher in the lateral compared to the medial side of the head which affirmed results from previous cadaveric studies. (4) The IAUC of the superomedial quadrant was lowest for both control and fracture sides and was significantly decreased (p<0.01) from the superolateral and inferolateral on both.

Discussion: Two principal perfusion deficits were seen within the femoral head of the fractured hip compared to that of the contralateral hip. Decreased arterial inflow to the region was seen via a reduction in the parameters A and Akep. These represent the initial amplitude and slope of the wash-in phase of contrast in the femoral head. This deficit in inflow supply may be related to fracture induced tamponade of the capsule secondary to hemarthrosis. However, pressure induced tamponade of the foveal blood supply is not expected to occur given the vessels are not disrupted by the fracture. Likewise, a decrease in elimination or wash-out of the contrast from the region was seen as a more negative value in the parameter kel implying venous outflow obstruction or stasis as compared to that of the control side. This was visually apparent as an increasing time intensity curve at the end of the scan. In total, the IAUC and peak enhancement were both significantly reduced on the fracture side.
indicating decreased perfusion. The effect may be due to pressure secondary to the hematoma tamponade effect at the venous structure of the retinacular system. The peak enhancement on both control and injured sides was seen in the superolateral and inferolateral quadrants. This is a comparable finding to our previously published cadaveric study that reported that the superior and inferior retinacular arteries are the main blood supply to the femoral head. To our knowledge, this is the first study to quantify the pharmacokinetic uptake characteristics of each quadrant of the femoral head in control and fracture sides.

**Significance:** Knowledge of quadrant specific arterial and venous perfusion deficits in the clinic may provide a more accurate prognostic indicator of femoral head viability that will aid in prospectively choosing patient specific treatment options.

**Acknowledgments:**

**References:**

<table>
<thead>
<tr>
<th>Control vs. Fracture</th>
<th>kep(1/min)</th>
<th>Akep(1/min)</th>
<th>kel(1/min)</th>
<th>IAUC(90s)</th>
<th>Peak Enh.</th>
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<tbody>
<tr>
<td>Whole Head</td>
<td>0.53 vs. 0.29</td>
<td>1.76 vs. 1.19</td>
<td>0.91 vs. 0.28</td>
<td>0.07 vs. 0.04</td>
<td>0.43 vs. 0.17</td>
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<tr>
<td>Superolateral</td>
<td>0.58 vs. 0.31</td>
<td>2.12 vs. 1.72</td>
<td>1.20 vs. 0.49</td>
<td>0.06 vs. -0.05</td>
<td>0.52 vs. 0.26</td>
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<tr>
<td>Inferolateral</td>
<td>0.58 vs. 0.34</td>
<td>2.15 vs. 1.78</td>
<td>1.23 vs. 0.57</td>
<td>0.06 vs. -0.03</td>
<td>0.53 vs. 0.29</td>
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<tr>
<td>Superomedial</td>
<td>0.47 vs. 0.19</td>
<td>1.81 vs. 1.80</td>
<td>0.66 vs. 0.23</td>
<td>0.04 vs. 0.02</td>
<td>0.32 vs. 0.14</td>
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<tr>
<td>Inferomedial</td>
<td>0.45 vs. 0.23</td>
<td>2.06 vs. 1.78</td>
<td>0.87 vs. 0.34</td>
<td>0.05 vs. -0.03</td>
<td>0.39 vs. 0.18</td>
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