A LONGITUDINAL QUANTITATIVE EVALUATION OF LESION SIZE CHANGE IN OSTEONECROSIS OF THE FEMORAL HEAD USING 3D-MR VOLUME REGISTRATION

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Introduction: There is a considerable controversy regarding the repair process of osteonecrosis of the femoral head (ONFH). Several investigators have reported that the bone reparative process around the necrotic lesion is extremely slow, and that the lesion size is unlikely to change during the natural course of the disease. Others have suggested that complete healing may occur in early stage if the necrotic lesion is small and not adjacent to the articular surface.

This lack of agreement across studies may reflect differences in methodology. Ideally, a longitudinal study to detect lesion changes should utilize full three-dimensional (3D) high resolution imaging, such as 3D MRI and control for effects of differences in subject position between scans.

It is possible to obtain much more accurate positional matching of serially acquired magnetic resonance images of the hip using a subvoxel image registration (Fig. 1). The accuracy of the alignment of images has been already shown to be to a fraction of a voxel (0.42 mm). In this study, we have examined patients with ONFH at two time points during the natural course of the disease, namely at presentation, and on minimum one year later, in order to test the hypothesis that small osteonecrosis can be repaired partly or completely during the early stages.

Materials and Methods: Eighteen hips in 15 patients with ONFH without arthrological evidence of collapse were included in this study. The presence of a necrotic lesion was confirmed in all cases by the observation of a low intensity band distinct from the normal fat intensity or slightly decreased signal area with band pattern on MR images. Of the 18 hips, 15 hips were in stage 1 and 3 hips were in stage 2 at the initial radiographs, according to the Association Research Circulation Osseous (ARCO) international staging system. There were 8 males and 7 females with a mean age of 43.8 years (range, 18-64 years). Osteonecrosis was related to steroid use in 15 hips, and related to alcohol abuse in 3 hips.

All patients were subjected to MR imaging using a 1.0-Teslar MRI system (Signa MRI; General Electric, Milwaukee, WI, USA). A three-dimensional spoiled gradient-echo sequence (SPGR) was used in coronal direction with a repetition time (TR) of 7.9ms, echo time (TE) of 3.1ms, and flip angle of 30 degree. The field of view was 320 mm, the matrix size was 256x256, and the slice thickness was 1mm.

Prior to registration the follow-up scans were segmented in order to eliminate the femoral head and surrounding soft tissues which were potentially deformable. The follow-up scans were then accurately registered to the baseline scans using the volume registration algorithm, and the images corresponding to the same coronal slice as baseline scan were obtained.

Outlines of the necrotic lesion surrounded by low intensity regions were traced on base-line scan and accurately registered follow-up scan, and increasing, decreasing and unchanged areas of lesions were classified using image-editing software (Adobe Photoshop; Adobe Systems, San Jose, CA, USA). The area of the outlined structure on each particular slice was measured using Scion Image software (Scion Corporation, Frederick, Maryland, USA). The measured areas are multiplied by the sum of the slice to determine the actual volume of the outlined structure.

For each subject, the measured volume was normalized to the total femoral head volume, which was determined by segmenting the femoral head proximal to head-neck junction, to give a measure of the volume-to-femoral head ratio (VFR).

Intraobserver error was calculated from 10 measurements of the same slice by the same observer. It was 2.4%.

Results: Three of 18 hips showed spontaneous reduction in the size of the lesions. There was a trend for mean necrotic lesion volume and its VFR at baseline to be smaller in patients who showed decreases in lesion size. (Table 1)

Patients were divided into two groups based on interval between diagnosis and baseline MR. One group was classified when the intervals were less than 6 months and the others were classified when the intervals were more than 6 months. The prevalence of lesions showing a reduction in size was significantly higher when the intervals were less than 6 months. (p<0.02, Fisher’s exact probability test) (Table 1).

Table 1 Baseline lesion volumes and intervals between diagnosis and baseline scan in decreasing lesions and unchanged lesions

<table>
<thead>
<tr>
<th>Lesion size change</th>
<th>Decrease</th>
<th>No change</th>
</tr>
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<tbody>
<tr>
<td>(n=3)</td>
<td></td>
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<tr>
<td>(VFR (%))</td>
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<tr>
<td>4.6 ± 2.5</td>
<td>7.5 ± 5.5</td>
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<tr>
<td>(9.1 ± 3.9)</td>
<td>(16.7 ± 12.4)</td>
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</tbody>
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Interval between diagnosis and baseline MR scan

| Less than 6 months | 3 |
| More than 6 months | 12 |
a. Values are mean ± S.D.
b. P<0.05 (Fisher’s exact probability test).

Discussion: A few studies have shown spontaneous regression of the necrotic lesion. Sakamoto et al. reported that in 14 (45%) of 31 hips with the band-like zones in patients who have received high dose of corticosteroids, necrotic lesions showed incomplete regressive changes about one year after treatment had started [1]. Kubo et al. reported that in 4 (17.3%) of 23 hips with ONFH who have had renal transplantation, lesions tended to become smaller in size in average follow up period of 4.3 years after renal transplantation [2]. However, nobody has investigated the details of ONFH which showed a reduction in lesion size over time.

It would be reasonable to predict that smaller lesions may be repaired rapidly. Kopecky et al. reported that smaller asymptomatic lesions tended to become smaller or disappear [3]. In this study, lesion volumes at baseline were also smaller in patients group showing decreases in lesion size. Sakamoto et al. reported that in 14 necrotic lesions, which showed decreases in size about one year after initial corticosteroid treatment, there was no further change in size with a longer follow-up [1]. In current study, necrotic lesions within 6 months after diagnosis tended to show a reduction in size.

In conclusion, there were some lesions demarcated by bands on MRI scan which decreased in size in relatively early stages and smaller lesions had a tendency to decrease in lesion size over time.

References:

Fig.1 Serial 3D-MR images of bilateral hip joint of 18-year-old woman with systemic lupus erythematosus. (A) At baseline, MR image showed a necrotic lesion surrounded by a band like zones of decrease signal intensity in the weight-bearing area of left femoral head. (B) At one year after baseline scan, follow-up MR images showed a reduction in size of the lesion. (C) Accurately registered follow-up MR images showed no improvement of lesion size.