The pattern of bone marrow oedema on MRI in osteonecrosis of the femoral head

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It has been suggested that transient osteoporosis or the bone marrow oedema syndrome (BMOS) may be the initial phase of osteonecrosis of the femoral head (ONFH) and that there may be a common pathophysiology. In this study, we have assessed the MR images of 200 consecutive patients with ONFH in respect of the BMO pattern in order to test this hypothesis.

This pattern was not observed in the early stage of ONFH. The initial abnormal finding detected on the MR images was an abnormal band of intensity at the junction between the necrotic area and the normal bone. Structural damage of the head seems to result in the appearance of the BMO pattern and the development of pain in ONFH. There was no finding to support the existence of a continuum between BMOS and ONFH.

Patients and Methods

We reviewed the MR images of 200 consecutive patients with non-traumatic ONFH. The scans were taken between October 1993 and July 1998. There were 177 men and 23 women with a mean age of 42 years (19 to 78). The diagnosis of ONFH was based on the typical findings on MRI and/or plain radiographs. In all patients, at least one hip was treated surgically, and the diagnosis was confirmed by histological examination. Risk factors identified included alcoholism in 68 patients and corticosteroid therapy in 32, but in 100 patients, none was apparent. Seven of the 150 patients with bilateral disease had a total arthroplasty of one hip before MRI. A total of 343 hips with ONFH and 50 with no evidence of ONFH were included in the study.

In most cases, MRI was carried out using one of three units: a 1.5T Horizon (GE, Milwaukee, Wisconsin), a 1.5T Magnetom SP (Siemens, Erlangen, Germany) or a 1.0T Magnetom Expert (Siemens). T1-weighted images were obtained in the coronal, sagittal and axial planes, with repetition times (TR) of 440 to 750 ms and echo times (TE) of 10 to 20 ms (TR/TE = 440 to 750/10 to 20). T2-weighted images were obtained in the coronal planes, with repetition times (TR) of 1800 to 2500 ms and echo times (TE) of 70 to 105 ms (TR/TE = 1800 to 2500/70 to 105). In all planes, the section thickness was 5 or 6 mm, and there was no gap. The field of view was 25 to 40 cm and the matrix was (179 to 360) × (192 to 512). In 35 patients, MRI was carried out at another hospital using a similar technique with 1.0T or 1.5T machines. Two of the authors (YMK, HJK) reviewed all the MR images and plain radiographs together, without any clinical information. BMO was characterised by diffuse abnormalities of low signal intensity on a T1-weighted image which converted to iso- or high signal intensity on a T2-weighted image.
All femoral heads were classified according to the system proposed by Steinberg, Hayken and Steinberg. Subchondral fractures are frequently undetected on plain radiographs but these were seen on MRI. We reviewed the MR images of those cases with definite crescent signs on the radiographs. On the T1-weighted image, subchondral fractures are seen as bands of low signal intensity running parallel to the subchondral bone plate. On the T2-weighted image, they appear as either bands of low signal intensity or as bands of low signal intensity with an inner band of high intensity like a double-line sign (Fig. 1). After MRI, many cases classified on plain films as stage II, and some as stage I, were reclassified as stage III (Table I).

Results

Table I gives details of the results. There were 50 hips at stage 0, 62 at stage I, 52 at stage II, 60 at stage III, 119 at stage IV, 28 at stage V and 22 at stage VI.

The BMO pattern was not identified in any of the stage-0 or stage-I hips. It was observed in only two patients (3.8%) of the 52 at stage II and in 53 (88.3%) at stage III. After stage III, as the cases advanced, the frequency of the BMO pattern decreased.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Total</th>
<th>Bone marrow oedema (%)</th>
<th>Painful hip (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>50</td>
<td>0 (0.0)</td>
<td>0 (0.0)</td>
</tr>
<tr>
<td>I</td>
<td>62 (64*)</td>
<td>0 (0.0)</td>
<td>1 (1.6)</td>
</tr>
<tr>
<td>II</td>
<td>52 (79*)</td>
<td>2 (3.8)</td>
<td>4 (7.7)</td>
</tr>
<tr>
<td>III</td>
<td>60 (31*)</td>
<td>53 (88.3)</td>
<td>59 (98.8)</td>
</tr>
<tr>
<td>IV</td>
<td>119</td>
<td>63 (52.9)</td>
<td>119 (100.0)</td>
</tr>
<tr>
<td>V</td>
<td>28</td>
<td>11 (39.3)</td>
<td>28 (100.0)</td>
</tr>
<tr>
<td>VI</td>
<td>22</td>
<td>9 (40.9)</td>
<td>22 (100.0)</td>
</tr>
</tbody>
</table>

Table I. Bone marrow oedema and hip pain in osteonecrosis of the femoral head

* number of hips at each stage based on radiological crescent sign only

All the patients with definite collapse of the head (stages IV, V and VI) had pain and all hips, except one at stage III, were painful. No hips at stage 0, one (1.6%) at stage I and four (7.7%) at stage II were painful.

Subchondral fracture, BMO and pain were highly correlated with each other in the hips at stages 0, I, II and III (chi-squared test, p = 0.001).
Discussion

There have been a number of descriptions of MRI of subchondral fractures.\textsuperscript{6,9,10} Mitchell et al\textsuperscript{10} reported that a fracture within the necrotic lesions was best seen on T2-weighted images as a subchondral band of high signal intensity. They called it the ‘MR crescent sign’\textsuperscript{.11-13} Jergensen et al\textsuperscript{9} observed that a subchondral fracture appeared as a low signal band on the T1-weighted image and this remained low on the intermediate T2-weighted image. According to the observations of Vande Berg et al\textsuperscript{6} subchondral fractures appear as bands of low signal intensity running parallel to the subchondral bone plate and of high signal intensity within the intermediate or low-signal-intensity necrotic marrow on the T2-weighted images. Our observations were similar to those of Vande Berg et al.\textsuperscript{6} We observed a subchondral fracture as an irregular band of low signal intensity running parallel to the subchondral bone plate on the T1-weighted image. On the T2-weighted image, the band remained as low signal intensity or became a band of low signal intensity with an inner band of high signal. At times, both patterns appeared in different images of the same head on the T2-weighted image (Fig. 1). The reason for these varying observations is not clear, but we think that it may be due to the differences in the stages of the lesions and the technique used to obtain the images. Detection of subchondral fractures is very important in the early stages of ONFH. Because the necrotic area appears as
isosignal intensity on MR images in the early stages of the disease, an irregular subchondral band of abnormal signal intensity would be easily detected. MRI is much more sensitive than plain radiography in detecting subchondral fractures. In some hips, we were able to confirm a very tiny subchondral fracture which was not detected on radiography, but was seen on MR images with the BMO pattern (Fig. 2).

The BMO pattern is an important and frequently observed MRI finding in ONFH but it was not observed in the early stages of the disease. It was seen most often in heads at stage III when a subchondral fracture had developed. The first abnormal finding on the MR image was an abnormal signal band representing the reparative fibrovascular tissue and formation of reactive new bone at the outer margin of the necrotic area. Sakamoto et al.4 and Kubo et al.7 carried out prospective follow-up studies using MRI on patients at high risk for ONFH. Nakamura et al.15 evaluated the early MR images and histological findings of ONFH in a canine model. They all reported that the first abnormal finding, detectable on the MR images, was this band of abnormal signal intensity. In these reports, the BMO pattern was either not mentioned or was observed in late stages. In our study, the band was of low signal intensity on the T1-weighted image in all cases at stages I and II. On the T2-weighted image, it appeared as a double-line sign in all but three cases in which it was of low-signal intensity.

The BMO pattern is diffuse. It often extends beyond the head into the neck and intertrochanteric area and has also been reported involving the acetabulum. By contrast, subchondral fractures occur in a localised area. Therefore, it is very possible that the BMO pattern is only detectable on MRI when the subchondral fracture is just beginning. This suggests that the two cases at stage II with the BMO pattern were actually at stage III, but the subchondral fracture was not detectable. We believe that the BMO pattern appears as a secondary reaction to the subchondral fracture. Kubo et al.7 in a prospective follow-up of recipients of a renal allograft, also reported that the pattern appeared on MR images and was associated with radiological collapse and clinical symptoms. Glimcher and Kenzora16-18 emphasised that the subchondral fracture was a critical event involved in the functional failure of a femoral head with osteonecrosis. Our results have shown that hips at stage I or II are rarely painful. All patients at stage III had pain except one. This suggests that in ONFH, pain develops because of the structural breakdown of the involved head. The close relationship between subchondral fracture, pain and the BMO pattern was confirmed statistically.

According to the Ficat system, stage-I hips are symptomatic and about half are painful.19 Plain radiographs are usually normal or, at most, show only minor changes such as subtle loss of clarity with poor definition or blurring of the trabecular pattern. These are quite different from our observations. We think that many cases of Ficat stage I are not actually ONFH, but transient osteoporosis. Whether to include or exclude Ficat stage-I cases seems to be a very important factor affecting the overall results of operations for ONFH. This may be one of the reasons for the variable results of core decompression from different authors.20 ONFH and BMOS have several distinguishing clinical and radiological features.21 Well-recognised aetiopathological factors for ONFH such as steroids, alcohol, connective-tissue disease, etc do not predispose to transient osteoporosis. The BMO associated with transient osteoporosis of the hip is, as its name suggests, accompanied by osteoporosis on plain radiography which is not a feature of ONFH. In our study, we did not observe any MR images of ONFH which support the existence of a continuum between it and transient osteoporosis. We do not believe that we have sufficient evidence to support a close relationship between the two diseases. We agree with Guerra and Steinberg21 that they are separate clinical entities.

In conclusion, in ONFH the initial abnormal finding detected on MR images was a band of abnormal intensity at the junction between the necrotic and the normal area. The BMO pattern was not observed in early stages of the disease. In ONFH, the structural damage seems to bring about the marrow oedema pattern and pain.

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References


