The relationship between osteonecrosis of the proximal femur identified by MRI and lesions proven by histological examination

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Total hip replacement in patients with advanced osteonecrosis of the femoral head is often complicated by early loosening of the femoral component. Recent evidence has suggested that abnormal bone extending into the proximal femur may be responsible for the early failure of the femoral component. We aimed to identify which patients were at high risk of early failure by evaluating gadolinium-enhanced MR images of histologically-confirmed osteonecrotic lesions beyond the femoral head.

Although the MR signal intensity has been shown to correlate well with osteonecrosis in the femoral head, it was found to be relatively insensitive at identifying lesions below the head, with a sensitivity of only 51% and a predictive value of a negative result of only 48%. However, the specificity was 90%, with the predictive value of a positive MRI finding being 86%. Only those patients with osteonecrosis of the femoral head secondary to sickle-cell disease, who are known to be at high risk of early loosening, had changes in the MR signal in the greater trochanter and the femoral shaft. This observation suggests that changes in the MR signal beyond the femoral head may represent osteonecrotic lesions in areas essential for the fixation of the femoral component. Pre-operative identification of such lesions in the neck of the femur may be important when considering hip resurfacing for osteonecrosis of the femoral head, following which early loosening of the femoral component and fracture of the neck are possible complications.

Magnetic resonance imaging is well established as the method of choice for investigating the early stages of osteonecrosis of the femoral head and asymptomatic contralateral disease.¹⁻⁵ This is a painful and progressive condition which often affects younger patients.^{6,7} Multiple aetiologies have been described which predispose to its development, and up to half of such patients may have asymptomatic disease in the opposite hip.⁸ Early detection of osteonecrosis may lead to surgical intervention and prevention of the complications which follow collapse of the femoral head. The use of gadolinium-enhanced MRI has recently been shown to improve the diagnosis of the early stages of the condition.^{9,10}

Progression of the disease often leads to collapse of articular cartilage and the development of disabling secondary osteoarthritis (OA). In the United States it has been reported that up to 12% of all patients undergoing total hip replacement (THR) have OA secondary to osteonecrosis of the femoral head.¹¹ However, one review of the literature has suggested that such treatment has a high rate of early failure because of loosening of the femoral compo-

nent.¹² Recent studies have also indicated that isolated resurfacing of the femoral head for osteonecrosis has a higher risk of failure of the femoral component than was originally thought.^{13,14} Relief from pain and the Harris hip score¹⁵ are poorer in hip resurfacing for osteonecrosis than those for THR and some authors have reported that more than half of their patients require revision for pain within two years.^{16,17} At present, it is impossible to predict pre-operatively which patients are at risk of early failure of the femoral component.

Recently, the presence of histologically-abnormal bone in regions of the femur crucial for the fixation of the resurfacing implant has been demonstrated, and this may be a contributing factor in premature loosening.¹⁸ It has been suggested that osteonecrosis is a factor in the mechanism of failure of the femoral component and of fracture of the femoral neck in patients undergoing hip resurfacing procedures.^{19,20} The positive correlation between the histological findings of osteonecrosis and the intensity of the MR signal in the femoral head before operation is well documented.²¹⁻²³ However, there are no reports on the changes

in the intensity of the signal extending beyond the femoral head into those regions of the proximal femur required for fixation of the component.

Our aim was to correlate the MR signal changes with the histology of bone samples from four regions beyond the femoral head in patients undergoing THR for osteonecrosis of the femoral head. It was postulated that detection of abnormal bone in the proximal femur by changes in the MR signal in the femoral neck could be used to predict which patients would be at risk of early failure of the femoral component in particular and which patients therefore would be unsuitable for hip resurfacing.

Patients and Methods

After obtaining the approval of the ethical committee, 15 symptomatic patients with advanced osteonecrosis of the femoral head on plain radiography (ARCO stage III or stage IV according to the criteria of Ficat and Arlet²⁴) had MRI of their proximal femora.²⁵ The osteonecrosis of the femoral head was secondary to the administration of steroids in six patients, sickle-cell disease in four, alcohol abuse in two and was idiopathic in three (Table I). All the patients underwent THR within four months of having MRI.

Magnetic resonance imaging was performed using a 1.5 T Elscint Gyrex scanner (Gyrex; Elscint Ltd, Haifa, Israel). Coronal and sagittal sections of 5 mm thickness were taken at intervals of 2.5 mm of both proximal femora. Relative T1-weighted spin-echo (SE) images (repetition time (TR) 600 ms, echo time (TE) 20 ms) and T2-weighted SE images (TR 2600 ms, TE 90 ms) were taken for all patients. In addition, inversion recovery fat-suppressed images (STIR-TR 2600 ms, TE 25 ms, T1 110) were obtained.

After these sequences had been taken, 0.2 ml/kg of Magnevist contrast (Bayer Schering Pharma AG, Berlin, Germany) was administered intravenously (1 ml Magnevist = 469 mg of dimeglumine gadopentetate). Coronal contrast-enhanced T1-weighted SE images were obtained 30 minutes after injection.

All the images were reviewed in conjunction with pre-operative anteroposterior plain radiographs of the pelvis. Osteonecrosis of the femoral head was classified according to the ARCO classification. The radiologist (ALH) was unaware of the underlying cause of the osteonecrosis.²⁵ Images of the contralateral femoral head were also examined and graded as part of the clinical screening process for asymptomatic disease. The presence of an abnormal change in the signal consistent with osteonecrosis was recorded for each of the four areas of the proximal femur beyond the femoral head (Fig. 1).

During THR, the head was harvested for histological confirmation of osteonecrosis and graded according to the classification of Arlet and Durroux.²⁶ Biopsy samples of cancellous bone were also taken from the four regions of the proximal femur, examined for evidence of osteonecrosis

Fig. 1

Diagram showing the five regions of the proximal femur in which abnormalities in the MR signal were recorded.

and graded according to the method described by Humphreys et al.²⁵ The histological presence or absence of osteonecrosis was recorded for each of the four areas and compared with the MRI findings. The pathologist (PAR) was unaware of these and the underlying cause of the osteonecrosis.

Statistical analysis. The agreement between an abnormal signal intensity on an MR image and abnormal histology was assessed by the use of a kappa statistic. The presence or absence of osteonecrosis in each sample was considered to be the most statistically reliable method of assessment. The closer the kappa value was to 1.0 in each region, the stronger the agreement. Therefore, the strength of the agreement was deemed to be poor at a kappa value ≤ 0.20 , fair at 0.21 to 0.40, moderate at 0.41 to 0.60, good at 0.61 to 0.80 and very good at 0.81 to 1.0.

Results

All 15 patients had evidence of advanced osteonecrosis of the femoral head on plain radiography and MRI. The diagnosis was confirmed by histological examination of the femoral head.

Magnetic femoral imaging of the proximal femur. Abnormal signal intensity was present beyond the head in 10 of the 15 patients, but only five of these had changes extending beyond the neck (Table I, Figs 2 and 3). Histologically-abnormal regions which were normal on standard SE T1- and T2-weighted or STIR images did not show enhancement on post-contrast T1-weighted sequences.

Table I. Details of MRI and histological findings in the 15 patients

Case	Diagnosis	Femoral head		Femoral neck*		Greater trochanter		Lesser trochanter		Femoral shaft	
		ARCO classification ²⁴	Histological grading ²⁷	MRI	Histological grading	MRI	Histological grading	MRI	Histological grading	MRI	Histological grading
1	Idiopathic	III	III	-	-	-	+	-	+	-	+
2	Steroids	III	III	-	+	-	+	-	-	-	+
3	Idiopathic	III	III	+	-	-	-	-	+	-	+
4	Steroids	IV	IV	-	-	-	-	-	+	-	+
5	Steroids	III	III	+	-	-	+	-	-	-	-
6	Sickle-cell disease	IV	IV	+	+	+	+	+	+	+	+
7	Sickle-cell disease	IV	III	+	+	+	+	+	+	-	+
8	Steroids	IV	III	+	+	-	-	-	-	-	+
9	Alcohol abuse	III	IV	+	+	-	+	-	-	-	-
10	Steroids	IV	IV	-	-	-	-	-	-	-	+
11	Sickle-cell disease	III	IV	+	+	-	+	+	+	+	+
12	Steroids	IV	IV	+	+	-	-	+	+	-	-
13	Idiopathic	III	III	-	+	-	-	-	+	-	+
14	Sickle-cell disease	IV	IV	+	+	-	+	+	+	+	+
15	Alcohol abuse	III	IV	+	+	-	+	-	-	-	+

* +, abnormal signal; -, normal signal

Fig. 2a

Fig. 2b

Fig. 2c

MR images of both hips and proximal femora showing abnormal signal changes beyond the femoral heads in areas of histologically confirmed osteonecrosis in a) T1, b) T2- and c) gadolinium-enhanced sequence.

In total, 40 of the 60 regions of the proximal femur had abnormal histology, but only 20 had abnormal changes in the MR signal. However, eight of the ten patients with histological abnormalities in the femoral neck had abnormal MR changes. Beyond the femoral neck MR changes were present in only 10 of 30 regions with abnormal histology. Statistical analysis demonstrated a poor agreement between MR changes and histological findings for the greater trochanter and femoral shaft with fair agreement in the femoral neck and moderate agreement in the lesser trochanter (Table II).

Overall, MRI was relatively insensitive in detecting osteonecrosis beyond the femoral head, with a sensitivity of 51% and a predictive value of a negative result of 48%. However, the specificity was 90% with the predictive value of a positive MR finding of 86%.

Discussion

The positive correlation between MRI and the histological findings of osteonecrosis in the femoral head has been noted previously.²¹⁻²³ We found that osteonecrosis may occur beyond the femoral head and that these areas may be demonstrated by MRI. Hip resurfacing has been advocated as a method of treatment for advanced osteonecrosis of the femoral head since such patients are often young and active.²⁸ However, recent clinical reports on the results of isolated resurfacing for osteonecrosis have been less promising with regard to relief from pain and the clinical outcome.^{16,17} Early failure of the femoral component and fracture of the femoral neck have been described after hemi- and full resurfacing.^{14,20,29} It has been suggested that osteonecrosis in the femoral neck may play an important role in this failure.³⁰ A compromised oxygen concentration

Fig. 3a

Fig. 3b

Fig. 3c

MR images of a patient with steroid-induced osteonecrosis of the femoral head showing normal signal intensity in the neck, greater trochanter and shaft on a) T1, b) T2 and c) gadolinium-enhanced sequences despite histological evidence of osteonecrosis in these areas.

and even complete disruption of the blood supply to the femoral head of patients undergoing hip resurfacing have also been documented.¹⁹

Identification by MRI of histologically-confirmed osteonecrotic lesions beyond the femoral head has not been previously reported. We believe that our study provides further concern regarding adequate support of the femoral component and fixation in hip resurfacing for osteonecrosis of the femoral head. Extension of the osteonecrotic process beyond the head may have a role in the early failure of such components.

Nelson et al¹⁴ noted that the rate of failure of hemiresurfacing was higher in those patients with sickle-cell disease than in those with other underlying aetiologies. In our study, those patients with sickle-cell disease also had an abnormal MR signal in all regions of the femur and abnormal histology in all biopsy specimens.³¹⁻³³

Table II. Comparison of MRI and histological findings and regional kappa values

Region of femur	MRI	Histology		Kappa value	Result
		Normal	Abnormal		
Femoral neck	Normal	3	2	0.40	Fair
	Abnormal	2	8		
Greater trochanter	Normal	6	7	0.19	Poor
	Abnormal	0	2		
Lesser trochanter	Normal	6	4	0.50	Moderate
	Abnormal	0	5		
Femoral shaft	Normal	3	9	0.12	Poor
	Abnormal	0	3		

Our study has demonstrated MR signal changes beyond the femoral head in regions of the femur with histologically-confirmed osteonecrotic lesions. However, MRI was relatively insensitive in identifying these changes, but in those patients in whom they occurred in the femoral neck on the pre-operative MR image, there may be an increased risk of developing early prosthetic failure or fracture of the femoral head.

In order to determine the clinical relevance of abnormal MR signal changes extending into the proximal femur, a larger longitudinal study is required with follow-up of patients until failure of the femoral component has occurred.

No benefits in any form have been received or will be received related directly or indirectly to the subject of this article.

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