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ORIGINAL ARTICLE

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Correlation of magnetic resonance imaging and intraoperative punctate bleeding to assess the vascularity of scaphoid nonunion

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Abstract Thirty-two patients with radiographic evidence of scaphoid nonunion were preoperatively evaluated by magnetic resonance imaging (MRI), then observed intraoperatively for punctate bleeding of the fragments. Although MRI and intraoperative findings matched in 19 patients, there was no correlation in 13 patients. While 7 of these latter patients showed normal MRI but no punctate bleeding during the operation, the remaining 6 had preoperative MRI of avascularity but punctate bleeding during the operation. After internal fixation and bone grafting, all but 1 of these 13 patients achieved union. We conclude that the diagnosis of avascular necrosis should only be made when both MRI and intraoperative findings indicate avascularity.

Introduction

Scaphoid nonunions are generally treated by either vascularized [20] or nonvascularized [8, 9] bone grafting. On the other hand, when one or more fragments are avascular and no longer salvageable [7, 8] other treatment modalities including partial or complete excision [5, 19], prosthetic replacement [11], total or limited arthrodesis [18], proximal row carpectomy [5], or total excision combined with radial advancement osteotomy [7] are utilized.

To select the appropriate procedure among these alternatives, the surgeon should have preoperative knowledge of the vascularity to be able to predict the healing capacity of the fracture [13]. Vascularity of the scaphoid may be assessed by plain radiographs, scintigraphy [10], magnetic resonance imaging (MRI) [13, 14, 16], or direct inspection of punctate bleeding [6, 9], but these methods have some limitations. Sclerosis on plain radiographs reflects, in fact, either new bone formation as a reaction of living tissue to ischemia [4], dystrophic calcification, or bone compaction [1], or relative osteopenia of other bones due to immobilization [9]; scintigraphy is not also specific for bone necrosis [4, 14], and false-positive results may be obtained, particularly due to synovitis [3]. For these reasons, some authors assess vascularity by direct observation during the operation [6, 9], while others decide on preoperative MRI [13, 16]. By taking into account the false-positive and false-negative results of either technique [6, 12], we report our experience of combining MRI with direct observation of punctate bleeding.

Patients and methods

The study consisted of 32 scaphoid nonunions; 11 patients had been treated by casting before, and the remainder were neglected cases. MRI scans were obtained of all patients, sequential 4- or 5-mm-thick images with a 1.5-T MRI scanner and a 3-inch circular surface coil. T_1- and T_2-weighted images were obtained from all patients, and they were specifically evaluated for evidence of avascularity of the scaphoid fragments. All examinations were interpreted by staff radiologists who were blinded to the study and by the surgeon himself.

During the operation, the tourniquet was deflated, and the fragments were inspected for punctate bleeding; in some instances, especially when there was doubt regarding bleeding, the fragments were drilled by a Kirschner wire. Then, the operation continued as follows: bone grafting and internal fixation by either a Herbert

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screw or two Kirschner wires, depending on the surgeon's choice, when the preoperative MRI revealed normal intensity whether punctate bleeding was present or not; or when punctate bleeding was observed during the operation without taking into account the preoperative MRI scans. Total excision of the scaphoid with radial advancement osteotomy [7] was performed in the case of avascularity, revealed both by MRI and by the absence of punctate bleeding.

Results

By taking into account the MRI results and observation findings during the operation, the patients fell into four groups (Table 1). In group 1 (5 patients), MRI revealed normal intensity, and punctate bleeding was observed; in group 2 (7 patients), normal MRI without punctate bleeding; in group 3 (6 patients), hypointense signals on T_1-weighted and hyperintense signals on T_2-weighted MRI (Fig. 1) with punctate bleeding during the operation. Fourteen patients showed avascularity on MRI and no punctate bleeding (group 4). When internal fixation with bone grafting was utilized for the patients in the first three groups, all cases achieved union except for one in group 3.

Histologic examination of group 4 was not possible, because the excised scaphoid was used as a bone graft to fill the defect in the radius created by the advancement of the fragment.

Table 1 Data of the patients (*N* normal intensity, *AVN* avascular necrosis)

Group	Number of patients	MRI findings	Punctate bleeding	Union achieved
1	5	N	+	All
2	7	N	–	All
3	6	AVN	+	All but one
4	14	AVN	–	Excision

Fig. 1 A patient from group 3. Although magnetic resonance imaging showed AVN of the scaphoid, union was achieved after internal fixation combined with bone grafting

Discussion

In current clinical practice, the term "avascular necrosis" (AVN) is used to label a wide spectrum of conditions of assumed circulatory comprise [3]. Herbert [8] proposed a classification distinguishing bone ischemia from true AVN. This point is especially important, for the evolutionary process of ischemia may be reversible at any stage [4], but in the case of true AVN, there is no healing capacity, and salvage procedures should be utilized [8, 9].

Some authors clinically assess the vascularity of the scaphoid by MRI [13, 14, 16], while others use direct observation during the operation [6, 9]. The results of the present study do not always correlate well with earlier findings. In groups 1 and 4 patients, the MRI and operative findings matched and thus presented no difficulty. In the patients of group 2, (normal MRI and no bleeding), the scaphoids should have been excised if only intraoperative findings had been taken into account, or in patients of group 3 (abnormal MRI but bleeding), if the operation had been planned by MRI findings alone.

In the pathogenesis of AVN, bone anoxia initially leads to necrosis of the fat and other elements of the bone marrow, while the lacunal osteocysts and the osteoblasts in the trabecular seams may survive [2, 3]. At this stage, MRI may show a normal appearance due to the proportion of necrotic or normal bone marrow components, but intraoperative inspection may not reveal punctate bleeding due to anoxia, as in our group 2 patients.

Then the inflammatory reaction is established, and repair starts from the adjacent viable bone. These reparative processes occur by revascularisation [3, 4, 12]. At this stage, MRI shows images suggesting AVN as the normal marrow of bone has not been established yet, but bleeding is observed during the operation due to revascularisation. This stage correlates well with our group 3 patients.

The rate of development of the reaction of the tissue to the ischemic process that leads to AVN after insult and the stage of the repair process at the time of MRI may alter the properties of tissues and how they appear on MRI [4, 15]. Also, the associated synovitis and increased synovial fluid may contribute to signal intensity changes on MRI [16]. Therefore, we believe that the diagnosis of AVN should not based solely on MRI.

In the present study, we did not perform histologic analysis for two reasons: first, it was not possible in group 4 because the excised scaphoid was used as a bone graft to fill the defect in the radius created by the advancement of the fragment. Second, avascular changes are often present in an irregular patchy configuration and are thus variable within a single specimen. Therefore, random biopsy does not accurately predict the status of the entire specimen [17].

On the other hand, there may be some difficulty in detecting punctate bleeding [16], and drilling of the suspected fragments should be utilized.

In conclusion, the results of our study indicate that the viability of scaphoid fragments should be assessed by

combining MRI findings with intraoperative observation of bleeding, and the diagnosis of AVN can only be made when both of the parameters indicate avascularity.

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