Diagnosis of scaphoid fracture and dedicated extremity MRI

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We evaluated the value of dedicated extremity magnetic resonance imaging (E-MRI) in patients with clinical suspicion of a scaphoid fracture and normal initial radiographs. 52 patients underwent E-MRI within a mean of 4 (2–10) days after trauma. Follow-up radiographs were performed at average 11 (8–14) weeks after trauma, and these images were used as the "gold standard". A T1-weighted turbo gradient echo 3D and a tau short inversion recovery STIR were performed, both in coronal planes. The imaging time was less than 10 min. The images were evaluated independently by two radiologists. E-MRI detected occult fractures of the scaphoid in 9 patients, and of the distal radius in a further 6 patients. All these fractures were confirmed at follow-up radiographs. Furthermore, E-MRI revealed a fracture of the capitate bone in 1 patient, and of the triquetrum in 2 patients, and in 8 patients, bone bruise in 1 or more of the carpal bones. However, these fractures and bone lesions could not be confirmed by the follow-up radiographs. The agreement between the two examiners was high (kappa = 0.8) for E-MRI detection of fractures. E-MRI seems to be better than radiographs in the early diagnosis of occult fractures of the scaphoid bone and the wrist.

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Almost one fifth of scaphoid fractures are not visible on the initial plain radiographs and the frequency of false positive clinical diagnosis ranges from 25–100% (Hunter et al. 1997). A clinical suspicion of a scaphoid fracture, but with normal radiographs, often leads to cast immobilization, and new clinical and radiological check-ups after 10–14 days (Abdel-Salam et al. 1992). However, it may sometimes take up to 6 weeks for an occult scaphoid fracture to become visible on a plain radiograph (Waizenegger et al. 1994).

To prevent unnecessary immobilization, diagnostic modalities other than radiography have been evaluated, including bone scintigraphy (Matin 1979, Stordahl et al. 1984, Brown 1995), thermography (Hosie et al. 1987), CT (Jonsson et al. 1992), and ultrasound (Christiansen et al. 1991).

Whole-body MRI of the wrist (Imaeda et al. 1992) has been reported to be better than other modalities for diagnosing fractures of the carpal bones (Lepistö et al. 1995, Gaebler et al. 1996, Breitenseher et al. 1997).

We examined the value of dedicated extremity MRI (E-MRI) in patients with clinical suspicion of scaphoid fracture and normal initial radiographs, using late radiographs as the "gold standard" for fracture.

Patients and methods

In a prospective study, we enrolled 52 consecutive patients (27 men, mean age 44 (15-87) years) with clinical suspicion of scaphoid bone fracture after trauma, from November 1997 to November 1998. Pain and tenderness in the anatomical snuffbox were present in all patients, and all had normal radiographs of the wrist and carpal bones, including 4 oblique-view scaphoid radiographs.

The radiographs were reported by both the doctor on duty in the emergency room as well as an orthopedic surgeon and a radiologist on the next day. If radiographs of the scaphoid bone were normal, the patient was referred for E-MRI of the

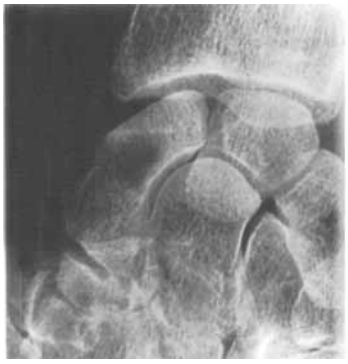

Figure 1. A. Patient with a trauma of the wrist. No sign of fracture on the initial radiographs. B. A recent transverse fracture in the scaphoid (the sclerotic line) on follow-up radiographs (same patient as A).

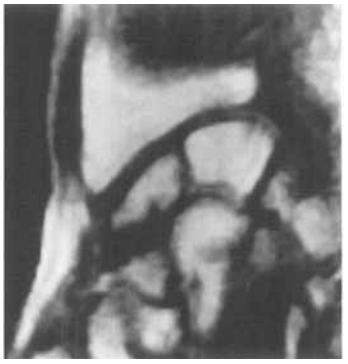

Figure 2. A fracture of the scaphoid on the initial E-MRI showing a definite fracture line on the T1-weighted sequences with a signal intensity that differed from the adjacent osseous structures (same patient as Figure 1).

wrist as soon as possible.

5 of the 52 patients were excluded due to technical problems with the E-MRI.

All patients underwent the routine treatment of the orthopedic department, i.e., a low dorsal plaster splint applied from the elbow to the interphalangeal joint of the thumb for 11 (8–14) days. Thereafter the following routines were used.

If there were no clinical or radiographic signs of a scaphoid fracture and E-MRI had also failed to demonstrate a fracture, the plaster was removed, and the patient was discharged.

If the patient still had clinical but no radiological or E-MRI signs of a fracture, cast immobilization with a low dorsal splint was continued and clinical and radiological examinations including E-MRI, were performed again after 2 weeks.

If the patient had clinical and/or radiological (including E-MRI) signs of a scaphoid fracture, the patient was treated with a circular-cast immobilization for at least 8 weeks.

Follow-up E-MRI and radiographs of the carpal bones were performed within a mean of 11 (8–14) weeks after the trauma in patients who had a fracture or bone bruise on the first E-MRI (Figure 5).

E-MRI of the wrist was performed using a dedicated extremity scanner (ARTOSCAN 0.1 T Esaote, Genoa, Italy) with a linear coil and an 11 cm field of view in all sequences. The patients sat in a chair next to the scanner with only the affected forearm in the gantry of the scanner. The imaging time was less than 10 minutes.

In all patients, 2 sequences were performed: a T1-weighted Turbo Gradient Echo 3D, repetition time 30; echo time 12 (30/12), flip angle 90 degrees, reconstructed in a coronal plane with a section thickness of 3.0 mm and no intersection gap, and a fast short inversion recovery STIR 1000/(90)/30, 2 acquisitions, flip angle 90 degrees in a coronal plane with a section thickness of 3.0 mm and an intersection gap of 0.4 mm.

The initial E-MRI was performed within a mean of 4 (2–10) days after trauma with the forearm and hand supported in a plaster splint. The second E-MRI was performed without the cast, at the time of the clinical and radiographic examinations 11 (10–14) days after the trauma.

Late follow-up radiographs and E-MRI were taken an average of 11 (8–14) weeks after the trauma.

On E-MRI T1-weighted sequences, a diagnosis of carpal bone fracture was made if there was evidence of a fracture line with a signal intensity different from the adjacent osseous structures and/or a definite cortical fracture line in combination with a bone marrow abnormality in a diffuse area of a carpal bone (Yao and Lee 1988) (Figure 1).

A diffuse area within the bone showing increased signal intensity on the STIR-sequences and a reduced signal intensity on the T1-weighted sequences, but no visible fracture line, was considered a bone bruise (Figure 4).

The main location (i.e., proximal, middle or distal third) and orientation (i.e., transverse, through

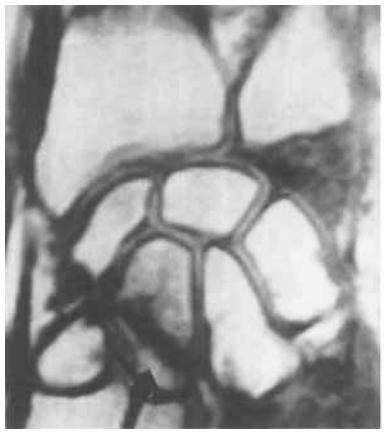

Figure 3. A fracture of the capitate showing a definite fracture line on the T1-weighted sequences, as in Figure 1A.

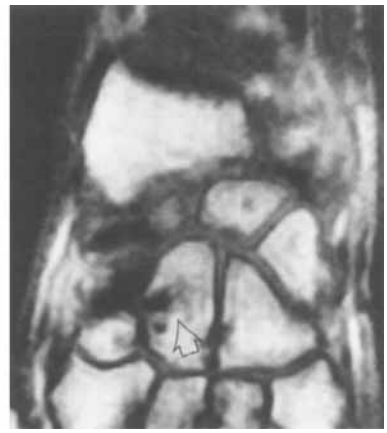

Figure 4. Bone bruise of the capitate, demonstrating the difference in the MRI findings between a fracture (Figure 3) and bone bruise.

the waist of the scaphoid or vertical, parallel to the axis of radius) of the fracture line were noted.

A fracture was diagnosed on the radiographs , if a sclerotic line and/or resorption around the fracture line was seen on the follow-up radiographs (Figures 2 and 3). These radiographs were evaluated blinded by two radiologists in random order and without clinical or demographic data of the patient. All the E-MRI and radiographs were analyzed independently and blinded, by the same two radiologists, without knowledge of the plain radiographs.

The late follow-up radiographs, taken 11 (8–14) weeks after the trauma, were used as the gold standard.

The interobserver agreement was expressed in terms of kappa statistics, as a 2-level kappa result, with E-MRI interpreted as positive or negative for fractures and consequently for bone bruise.

Results

The initial E-MRI performed mean 4 (2–10) days after the trauma revealed some lesion in 31 of 47 patients (Figure 5).

In 7/47 patients with normal radiographs, a scaphoid fracture was diagnosed on the initial E-MRI by both radiologists. 4 of the 7 fractures were located in the middle third of the scaphoid bone,

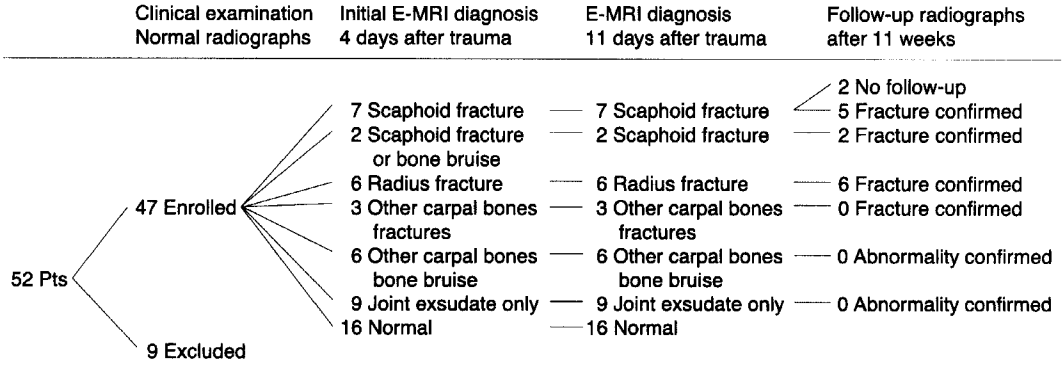

Figure 5. Examinations and results of findings in 52 patients clinically suspected of scaphoid bone fracture after trauma (2 patients had more than one diagnosis).

and 3 were located in the distal third. All the fractures were transverse. In a further 2/47 patients, 1 radiologist described the initial E-MRI of the 2 patients as doubtful scaphoid fractures, while the senior radiologist described the initial images as definite scaphoid fractures. In 2 patients with a scaphoid fracture, bone bruise was also present in the capitatum.

On the second examination, approximately 2 weeks after trauma, no other fractures or lesions were diagnosed on E-MRI or radiographs.

On the follow-up examination 11 (8–14) weeks after the trauma, 2 of the 7 patients who had a scaphoid fracture on the previous E-MRI refused to participate. In the remaining 5, a scaphoid fracture was confirmed at E-MRI and on the radiographs. All 7 patients were treated with a circular-cast immobilization for 6–8 weeks. In the 2 patients with questionable signs of a scaphoid fracture, a sclerotic line was detected on the follow-up radiographs, confirming the suspicion of a fracture in the scaphoid bone at the initial E-MRI. These 2 patients were also treated with a circular-cast immobilization for 6–8 weeks.

In 6 patients in whom E-MRI had detected a fracture in the distal radius, the fracture was confirmed on follow-up radiographs. All 6 patients were treated with a low dorsal splint for 4 weeks.

2 patients in whom the initial E-MRI had detected fractures of the triquetrum, an avulsion of the triquetrum was found on the follow-up radiographs in 1 of the patients. However, the fracture seen on E-MRI could not be confirmed on the radiographs.

In the patient who had a capitatum fracture on E-MRI, follow-up radiographs revealed no sign of fracture (Figure 5). In all cases where the initial E-MRI had detected bone bruise only in the carpal bones, it was not possible to find any signs of fracture on the follow-up radiographs.

In 23/47 patients, joint exudates were detected by E-MRI. 14 of these patients had other lesions, but in the remaining 9, joint exudate was the only abnormality detected by the E-MRI. On the second E-MRI, joint exudates were still present in all but 1.

In 16 patients, the E-MRI was described as completely normal by both radiologists, and follow-up radiographs revealed no fracture.

With E-MRI interpreted as positive or negative, the interobserver agreement was almost perfect: kappa = 0.8 (95% confidence limits of kappa = 0.6 and 1.0) for detection of fractures with E-MRI. The interobserver agreement for E-MR imaging bone bruise was moderate, kappa = 0.5 (95% confidence limits of kappa = 0.07 and 0.9).

Discussion

Previous studies have indicated that MRI is of value in diagnosing occult fractures (Deutsch et al. 1989), and by using E-MRI, imaging of the wrist has become very easy. The examination can be done in less than 10 minutes, and it is not necessary to remove the plaster splint.

Our findings indicate that a dedicated extremity MRI scanner is useful in patients with clinically suspected scaphoid fracture when radiographs are normal. On all patients who had a scaphoid fracture on late follow-up radiographs, the fracture was detected early on E-MRI. Moreover, we found no new lesions on the second E-MRI, performed 10–14 days after the trauma, vs. the initial E-MRI.

The interobserver agreement in detecting fractures of the carpal bones was high, although one of the radiologists had limited experience in evaluating MR images. By using E-MRI, we found 18 more occult fractures in 47 patients. This is in agreement with other studies, which reported occult fractures of the carpal bones detection of in up to half of the patients, using whole-body MR scanners (Gaebler et al. 1996, Breitenseher et al. 1997, Hunter et al. 1997).

In the 3 patients with fractures of the capitatum and triquetrum detected by E-MRI, an avulsion of the triquetrum was found in 1 patient, but no other fractures were visible on the follow-up radiographs. Fractures of these bones are rarely diagnosed on radiographs, probably because undisplaced fractures are difficult to detect and because the fractures tend to heal quickly without complications. Our 3 patients became pain free within 2 weeks and the treatment was stopped on the second clinical examination.

Likewise, bone bruise lesions detected with MRI, could not be recognized on any of the fol-

low-up radiographs. It has been suggested that bone bruises represent a spectrum of radiographically occult bone injuries, ranging from bleeding, infarction and edema to microscopic compression fractures of cancellous bone (Kier et al. 1991, Zeiss et al. 1995). In a recent study, histology of bones with bone bruise revealed microfractures of cancellous bone, fragments of hyaline cartilage and edema as well as bleeding in the fatty marrow, between intact lamellar bone trabecules (Rangger et al. 1998). However, the clinical importance of bone bruise is not clear.

In addition to the lesions described above, E-MRI revealed joint exudates in 23 patients, 14 of whom had a fracture or bone bruise, but in 9 patients, joint exudate was the only abnormality detected. These changes could be due to lesions of the soft tissue of the wrist and, on the second examination 11 days after the trauma, E-MRI showed no differences in the amount of joint exudate. Therefore, joint exudate on the initial E-MRI may indicate that other lesions of the wrist are present.

In our opinion, patients with a clinical suspicion of wrist fracture and a normal radiograph should be examined immediately with E-MRI to detect any occult fractures, and thus prevent patients with simple sprains but no fractures from being immobilized for weeks.

Abdel-Salam A, Eyres K S, Cleary J. Detecting fractures of the scaphoid: The value of comparative x-rays of the uninjured wrist. J Hand Surg (Br) 1992; 17: 28-32.

Breitenseher M J, Metz V M, Gilula L A, Gaebler C, Kukla C, Fleischmann D, Imhof H, Trattnig S. Radiographically occult scaphoid fractures: Value of MR imaging in detection. Radiology 1997; 203: 245-50.

Brown J N. The suspected scaphoid fracture and isotope bone imaging. Injury 1995; 26, 7: 479-82.

Christiansen T G, Rude C, Lauridsen K K, Christensen O M. Diagnostic value of ultrasound in scaphoid fractures. Injury 1991; 22, 5: 397-9.

Deutsch A L, Mink JH, Waxman A D. Occult fractures of the proximal femur: MR imaging. Radiology 1989; 170: 113-6.

Gaebler C, Kukla C, Breitenseher M, Trattnig S, Mittlboeck M, Vecsei V. Magnetic resonance imaging of occult scaphoid fractures. J Trauma 1996; 41 (1): 73-6.

Hosie K B, Wardrope J, Crosby A C, Ferguson D G. Liquid crystal thermography in the diagnosis of scaphoid fractures. Arch Emerg Med 1987; 4: 117-20.

Hunter J C, Escobedo E M, Wilson A J, Hanel D P, Zink-Brody G C, Mann F A. MR imaging of clinically suspected scaphoid fractures. AJR 1997; 168 (5): 1287-93.

Imaeda T, Nakamura R, Miura T, Makino N. Magnetic resonance imaging in scaphoid fractures. J Hand Surg 1992; 17B,1: 20-7.

Jonsson K, Jónsson Å, Sloth M, Kopylov P, Wingstrand H. CT of the wrist in suspected scaphoid fracture. Acta Radiol 1992; 33: 500-1.

Kier R, McCarthy S, Dietz M J, Rudicel S. MR appearance of painful conditions of the ankle. Radiographics 1991; 11: 401-14.

Lepistö J, Mattila K, Nieminen S, Sattler B, Kormano M. Low-field MRI and scaphoid fracture. J Hand Surg 1995; 20B (4): 539-42.

Matin P. The appearance of bone scans following fractures, including immediate and long-term studies. J Nucl Med 1979; 20: 1227-31.

Rangger C, Kathrein A, Freund M C, Klestil T, Kreczy A. Bone bruise of the knee. Histology and cryosections in 5 cases. Acta Orthop Scand 1998; 69 (3): 291-4.

Stordahl A, Schjørh A, Woxholt G et al. Bone scanning of fractures of the scaphoid. J Hand Surg 1984; 9B: 189-90.

Waizenegger M, Wastie M L, Barton N J et al. Scintigraphy in the evaluation of the "clinical" scaphoid fracture. J Hand Surg (Br) 1994; 19: 750-3.

Yao L, Lee J K. Occult intraosseous fracture: detection with MR imaging. Radiology 1988; 167: 749-51.

Zeiss J, Paley K, Murray K, Saddemi S R. Comparison of bone contusion seen by MRI in partial and complete tears of anterior cruciate ligament. J Comput Assist Tomogr 1995; 19: 773-6.