Eur Radiol (2003) 13:612–617
DOI 10.1007/s00330-002-1600-2

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Clinical impact of MRI in acute wrist fractures

Received: 15 March 2002
Revised: 10 June 2002
Accepted: 17 June 2002
Published online: 11 September 2002

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Abstract The purpose of this study was to evaluate the clinical impact of MRI in the early diagnosis of wrist trauma. High-resolution MR imaging was performed on a 1.5-T unit (Symphony Quantum, Siemens, Erlangen, Germany) using coronal and axial T1- and T2-weighted fat-saturated turbo-spin-echo sequence via a dedicated wrist coil within a mean of 6.6 days after initial radiographs in 54 patients (56 wrists) with clinical suspicion of wrist fractures and normal plain or indistinct radiographs. Initial radiographs were evaluated independently by two senior radiologists and the hand surgeon without knowledge of the MRI findings. The initial treatment protocol was based on evaluation of plain films and clinical findings by the hand surgeon. Treatment protocol was changed after MRI examination if necessary. In 31 of 56 wrists MRI findings resulted in a change of diagnosis. There were false-positive diagnoses on plain radiographs in nearly one half (*n*=25) of the patients. False-negative diagnoses on plain radiographs resulted in 6 cases. Magnetic resonance imaging detected additional injuries of soft tissue in more than one third (*n*=20). In 22 of 56 wrists the period of immobilization could be shortened or ended, in 12 of 56 it was prolonged, and in 3 of 56 a surgical intervention was necessary. In 19 wrists MRI had no therapeutic consequences. Our data demonstrate the high clinical impact of MRI in the detection of acute wrist fractures. We recommend MRI of the wrist immediately on the day of trauma if there is clinical suspicion and normal plain radiographs. Accurate diagnosis by MRI examination within the first days following trauma may reduce economic costs due to shortened immobilization time in cases with a suspected fracture but plain radiographs.

Keywords High-resolution MRI · Wrist · Carpal bones · Scaphoid fracture

Introduction

Since the first reports of MRI studies of the wrist by Hinshaw et al. in 1977, MRI has gained more importance in the diagnosis of musculoskeletal lesions of the carpal bones and distal forearm [1]. Modern operative techniques of trauma surgeons require optimal imaging. An early and adequate treatment turned out to be most important to prevent the wrist of avascular necrosis and pseudoarthrosis. In cases of chronic wrist pain MR imaging is rated as high. Its diagnostic importance in the acute wrist trauma is still discussed, although previous reports indicated the high sensitivity and specificity of MRI in detecting occult wrist fractures [2, 3, 4, 5, 6]. Moreover, this non-invasive method allows the diagnosis of additional soft tissue lesions [7, 8, 9]. High costs make it impossible to use MRI in acute wrist lesions as a standard.

The purpose of this study was to indicate those patients for whom early MRI examination might have a clinical impact. This study was designed to evaluate a cost- and time-effective study protocol for the examination of the distal forearm and carpal bones.

Patients and methods

Wrists of 54 consecutive patients, i.e. 56 wrists with clinical suspicion of a fracture of the carpal bones and/or the distal forearm, were studied (33 males, 17 females; mean age 36.1 years, age range 12–83 years) between January 2000 and June 2001. In all cases conventional radiographs and special scaphoid radiographs failed to demonstrate a definite lesion. Twenty-six right- and 30 left hand wrists were studied. The injury was acute in all cases: first examination and performance of initial radiographs were done at average 1.6 days after trauma (range 0–31 days). Seventy percent of the patients were working, 26% went to school or university, 2% were at home, and 2% were retired.

In more than two-thirds of the cases the traumatic injury was caused by a fall on the dorsal extended hand (n=37). Nearly 50% of the injuries happened as an industrial accident (n=21), and more than one-third as a sports accident (n=16). In 8 cases trauma was caused by a traffic accident.

Magnetic resonance imaging studies followed on average 6.6 days after initial radiographs (range 0–28 days). The indications for further MRI examination were either:

1. Pain on palpation of the fovea radialis or at the dorsal hand or forearm
2. Constant pain with or without stress
3. Limited movement out of pronation or in dorsal flexion-/extension movement
4. Swelling
5. Combination of the above-mentioned criteria

In all patients MRI indications were proved by the same senior hand surgeon.

Conventional radiographs

Conventional radiographs were taken in the posterior–anterior (PA) and lateral views. In 18 cases additional scaphoid bone series were performed. A sclerotic or radiolucent fracture line within the intraosseous trabecular pattern, a break in the continuity of the corticalis, and a sharp step-off of the cortex of the carpal bone indicated a fracture. All images were interpreted by two musculoskeletal senior radiologists and one senior hand surgeon. Plain films were evaluated separately.

MRI

All MRI examinations were performed on a 1.5-T magnet (Symphony Quantum, Siemens, Erlangen, Germany) within a mean of 6.6 days after conventional radiographs (range 0–28 days). Imaging was performed with a dedicated small extremity flex coil with patients in prone position or a special wrist coil with patients in supine position. The MRI was done using T1-weighted spin-echo (SE) sequences in coronal and axial planes (TR=520 ms, TE=18 ms, flip angle=90°, distance factor 10%, slice thickness 1.7–2 mm, matrix 512×512, field of view 80–100 mm, one acquisition), and a coronal T2-weighted fat-saturated turbo-spin-echo (TSE) sequence (TE=103 ms) as well as a proton-density sequence (TR=4040 ms, TE=17–103 ms, distance factor 10%, slice thickness 1.7–2 mm, matrix 256×256, field of view 80–100 mm, two acquisitions).

The following criteria were used for the evaluation of MR images. A cortical fracture line and/or a trabecular fracture line occurred as a hairline with decreased signal intensity (SI) on the T1-weighted images and correspondingly increased SI around the fracture line on the T2-weighted images. Diffuse edema of the bones was considered to be bone contusion (bone bruise) and was not clarified as a fracture.

The MR images were evaluated by two radiologists in a blinded and independent fashion.

Evaluation of therapeutic consequences

Based on conventional radiographs and clinical findings, the surgeon defined the initial treatment protocol including type of treatment (surgery or conservative treatment) and duration of immobilization. This initial treatment protocol was written down in the medical history of the patient. After the MRI examination, the same surgeon revised the initial treatment protocol based on the MRI findings.

The clinical follow-up data were collected by the hand surgeon during routine follow-up examinations 2, 4, 8, and 12 weeks or later (if necessary) after trauma including evaluation of pain and function of the joint.

Results

Conventional radiographs

All patients (n=54) had clinical suspicion of a fracture of the carpal bones and conventional radiographs failed to demonstrate a definite lesion. The evaluation of the conventional radiographs was done by two radiologists. The radiologists were informed about the clinical symptoms of the patients. The evaluation of the conventional radiographs is documented in Table 1. Cohen's kappa coefficient showed poor correlation between radiologists 1 and 2 (r=0.36). Sensitivity and specificity of conventional radiographs were evaluated retrospectively after MRI examination and turned out to be insufficient. The sensitivity was 38.9 and 50% (radiologists 1 and 2, respectively). The specificity was 70 and 78.6% (radiologists 1 and 2, respectively).

Table 1 Conventional radiological findings in 56 wrists (two radiologists). *R1* no. of lesions read by the first radiologist; *R2* no. of lesions read by the second radiologist; *FQL* fracture of questionable location; definition of location by conventional X-rays not possible

	R1	R2
Suspicious scaphoid fracture	19 (33.9)	16 (28.6)
Suspicious radius fracture	10 (17.9)	9 (16.1)
Suspicious other fracture	5 (8.9)	2 (3.6)
Suspicious FQL	2 (3.6)	1 (1.8)
No fracture	20 (35.7)	28 (50)

Numbers in parentheses are percentages

Fig. 1 **a**, **b** The plain radiographs demonstrate no signs of scaphoid bone or distal radius fracture. Because of little clinical signs, both radiologists decided to read no fracture. **c**, **d** Noncontrast fat-saturated T2-weighted image demonstrates signal alteration of the scaphoid bone (*arrows*) due to the fracture of the scaphoid bone. The noncontrast T1-weighted image in coronal slice orientation verified the fracture line of the scaphoid bone (*arrows*). The scapholunatum ligament is intact (*arrowhead*)

MR imaging

The evaluation of MR images showed congruent findings and diagnosis in all cases for both radiologists. The correlation was r=1.0. The MR imaging demonstrated a scaphoid fracture in 7 cases, a distal radius fracture in 11 cases, and a fracture at other locations in 2 cases. Magnetic resonance imaging could exclude a fracture in 36 cases (64.3%); however, MRI was able to show additional injuries of soft tissues in 20 wrists, which showed no fracture on MRI. There were also some additional soft tissue injuries in patients who presented a fracture on MR images. In detail there were lesions of the triangular fibrocartilage complex (TFCC; *n*=7), ligamentous injuries (*n*=13), joint effusion (*n*=13), bone bruise (*n*=15), and cysts (*n*=3).

Complete high-resolution MRI work-up of the acute wrist trauma could be performed within 8 min scan time using T1- and fat-saturated T2-weighted sequences in coronal slice orientation only. The addition of T1-weighted axial series did not alter the diagnosis in any case.

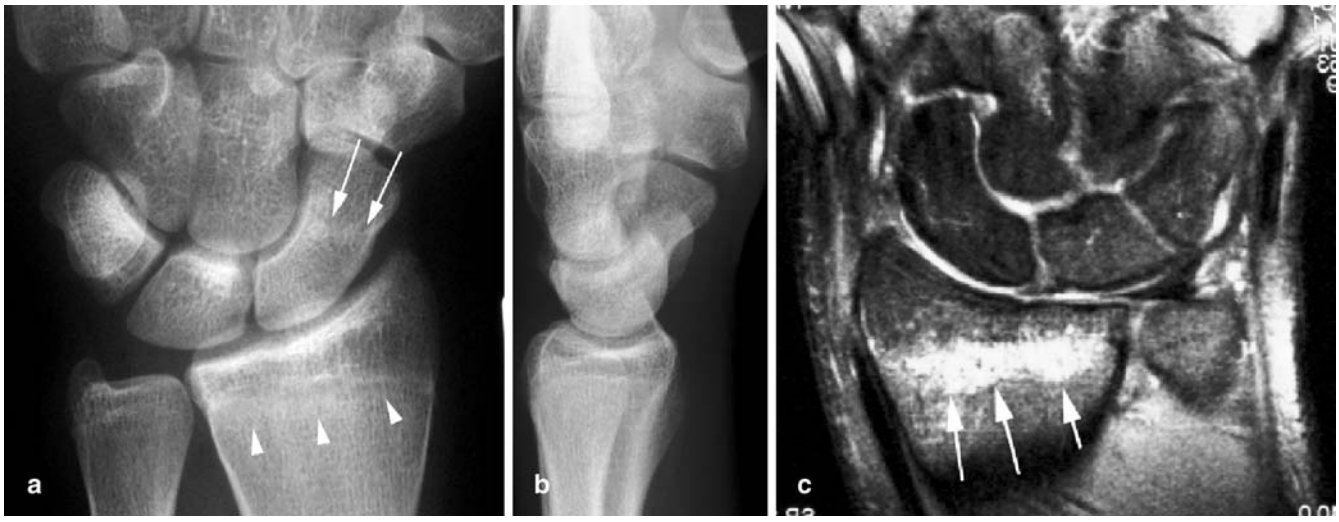

Fig. 2 **a**, **b** Plain radiographs. A scaphoid fracture was assumed (*arrows*). The hyperdense line within the distal radius (*arrowheads*) was not read as a distal radius fracture. **c** Noncontrast fat-saturated T2-weighted image demonstrates a fracture of the distal radius (*arrows*). No signal abnormalities could be detected in the scaphoid bone

Comparison of MRI and conventional radiographs

In total, MRI examination showed a fracture in 20 cases and could definitely exclude a fracture in 36 cases. In 31 of 56 wrists (radiologist 1) or 25 of 56 wrists (radiologist 2) there was a diagnostic change concerning the osseous lesions after reading MRI images. The diagnoses based on conventional radiographs were false positive in 25 and 19 cases (radiologists 1 and 2, respectively) and false negative in 6 cases for both radiologists. Figure 1 shows a false-negative case on conventional radiographs of a scaphoid fracture. Only in 5 of 19 cases (radiologist 1) or in 5 of 16 cases (radiologist 2) did the presumptive diagnosis of a fracture of the scaphoid bone turn out to be true positive. Only in 5 of 10 cases (radiologist 1) or in 5 of 9 cases (radiologist 2) the presumptive diagnosis of a fracture of the distal radius turned out to be true positive. The diagnostic changes after MRI examination are shown in Table 2 in detail. In 2 cases conventional radiographs were suspicious for a scaphoid fracture; however, MRI showed a fracture of the distal radius (Fig. 2) in 1 case.

Therapeutic consequences

The MRI examination had a therapeutic consequence in 66.1% (n=37) of cases. In 22 of 37 cases estimated immobilization time could be shortened; in 18 of those cases plaster cast could even be removed immediately. The immobilization could be ended immediately in 18 of 22 cases. Immobilization time was prolonged in 12 of 37 wrists. In 3 cases MRI confirmed a suspected scaphoid fracture requiring surgery and consequently a shorter time of immobilization. The influence on the immobilization time is shown in Table 3. Radiologic follow-up was no longer necessary in 35 cases.

Table 2 Diagnostic change after reading MRI images in 56 wrists (two radiologists). *n1* no. of lesions, first radiologist; *n2* no. of lesions, second radiologist

	n1	n2
Diagnostic change	31 (55.4)	25 (44.6)
False positive	25 (44.6)	19 (33.9)
Other bone	3	5
Definitively no fracture	22	14
False negative	6 (10.7)	6 (10.7)
Scaphoid fracture	2	1
Radius fracture	4	4
Other fracture	–	1

Numbers in parentheses are percentages

Table 3 Therapeutic consequence after MRI in 56 wrists. *N* no. of wrists

	N
Therapeutic consequence	37 (66.1%)
Surgery	3
Immobilization shortened 0–2 weeks	15
Immobilization shortened 2–4 weeks	1
Immobilization shortened >4 weeks	6
Immobilization prolonged 0–2 weeks	–
Immobilization prolonged 2–4 weeks	6
Immobilization prolonged >4 weeks	6
No therapeutic consequence	19 (33.9%)

Discussion

Lesions of the wrist may be complicated by delay in diagnosis and inadequate therapy. Clinical signs, such as

pain on palpation and limited movement, do not correlate with the existence of a fracture in all cases [10].

As initial radiographs of acute wrist injury are often negative, it is common to start a therapy as if the bone was broken and to do follow-up radiographs 10–14 days later to avoid false-negative results [11, 12]; however, Tiel-van Buul et al. showed that the repetition of conventional radiographs does not improve diagnostic management. In some cases a sclerotic fracture line may not even be seen until 6 weeks after the initial trauma [13].

The ineffectiveness of conventional radiographs in detecting a wrist fracture at an early stage concerns occult fractures of the carpal bones as well as occult fractures of the distal forearm [14]. Fractures of carpal bones are often not isolated but accompanied by additional fractures and ligamentous injuries that might be disclosed in further MRI examination [15, 16]. Injuries of soft tissue become more important because ligamentous lesions result in an instability of the carpal row.

A fracture of the scaphoid bone is the second most common fracture of the distal forearm and most common fracture of the wrist (40–90%). Complications such as the scaphoid nonunion occur in up to 50% of all scaphoid fractures. Posttraumatic carpal collapse with scapholunate advanced collapse (SLAC) and scaphoid nonunion advanced collapse wrist (SNAC) are complications of a failed fusion of scaphoid fractures [17].

Concerning occult fractures of the carpal bones, bone scanning is said to be a practical investigation for all X-ray-negative potential carpal bone injuries, especially scaphoid injuries, and is acceptable to patient and clinician. Bone scanning may provide scaphoid nonunion in combination with conventional radiographs and conservative therapy. The three-phase radionuclide bone scan allows the judgment of acute or chronic nature of the abnormality being assessed; however, MRI was found to detect and characterize marrow and articular alterations more accurately and earlier than bone scanning [18, 19]. High sensitivity and specificity of the MRI in the detection of occult wrist fractures [2, 5] and a high impact in the assessment of scaphoid fracture healing [20] have been reported.

In comparison, the use of CT examinations is limited by the moderate sensitivity and specificity [21]. Although arthrography remains the standard of reference in the detection of perforations of the principal intrinsic ligaments of the wrist and specific lesions of the TFCC, three-dimensional MR imaging has shown promise in depicting the small interosseous ligaments and may be even more useful than arthrography in prospective evaluation of TFCC lesions. Three separate injections of contrast agent into the radiocarpal joint (RCJ), mid-carpal joint (MCJ), and distal-radio-ulnar joint (DRUJ) are necessary for complete arthrographic evaluation; thus, this invasive method may not be used in the detection of acute wrist injuries [22, 23].

With the advantage of direct visualization of osseous and soft tissue lesions of the wrist, and therefore the opportunity of getting a diagnosis at an early stage of trauma, MRI can be considered the most important second-step procedure in patients whose radiographs are negative or indistinct [18]; thus, MRI allows not only better evaluation of osseous injury and soft tissue to detect occult fractures and additional instability factors but also the avoidance of false-positive diagnoses and inadequate therapy [3, 4, 5, 7, 18, 23, 24, 25].

Our data demonstrated that MRI has a high clinical impact in the early diagnosis of acute wrist trauma in patients with a discrepancy of indistinct conventional radiographs and clinical symptoms. The high number of suspicious fractures in our selected patient material was probably due to the obvious clinical symptoms of the patients. Due to the obvious severe clinical symptoms of the patients, often the conventional radiographs were interpreted as “suspicious for fracture”; however, most of the cases were false positive. In these cases MRI allows an early exclusion of a fracture or the diagnosis of additional soft tissue injuries.

One limitation of this protocol is that diagnosis of TFCC lesions is slightly inferior compared with an MRI protocol including 2D or 3D gradient-echo sequences.

The patient’s benefit is balanced by the high costs of MRI. While the costs of radiographs in two plains or a scaphoid series are approximately EUR 15, one MRI examination is approximately EUR 150; however, a complete plaster cast (EUR 50) and follow-up radiographs (each EUR 15) might be necessary; thus, the costs of three repeated conventional radiographs and scaphoid series to confirm the lesion and an additional plaster cast are at least as expensive as an initial MRI examination, which (a) would have shown extent of acute trauma and accompanying soft tissue lesions immediately, (b) is not invasive and does not expose the patient to radiation, (c) reduces both time and costs required for the diagnostic process, (d) reduces the employee’s time of absence from work due to the avoidance of false-positive diagnoses, and (e) indicates adequate therapy due to the confirmation and detection of occult fractures, respectively.

Conclusion

In conclusion, our study shows a high clinical impact of MRI in the diagnosis of acute wrist fractures. The MRI largely obviates false-positive results. Although costs are high, MRI is recommended in cases with clinical signs of a fracture and normal or indistinct conventional radiographs. The MRI studies should be performed within the first days following trauma to result in a maximal reduction of both time and costs required for the diagnostic process.

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