ORIGINAL REPORT

Analysis of the management of occult fractures of the scaphoid through early magnetic resonance imaging

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Received 19 March 2011; accepted 13 June 2011

KEYWORDS
Scaphoid bone; Fracture; Magnetic resonance imaging; Cost analysis

Abstract
Introduction: We aimed to evaluate the usefulness of magnetic resonance imaging (MRI) in the diagnosis of occult fractures of the scaphoid and to determine the advantages and cost in comparison with the traditional follow-up protocol.

Materials and methods: The traditional approach at our center consisted of immobilization and periodic clinical and radiological follow-up (plain-film X-rays and computed tomography in the final phase of the process). The new protocol called for a limited MRI study consisting of coronal T1- and T2-weighted fat suppression sequences if the findings at plain-film X-rays continued to be negative at the first follow-up examination with the traumatologist (10 days after trauma). We evaluated the MRI findings, the time the patient was immobilized, the cost of each protocol, and the dose of radiation received.

Results: We included 33 cases of patients with clinically suspected fractures of the scaphoid and negative findings on plain-film X-rays. In 13 patients, the MRI findings were negative. In 12 patients, the MRI findings confirmed the diagnosis of a fracture of the scaphoid, which was associated with other pathology in 6 cases. In 8 patients, another pathological process was diagnosed. The cost of the new protocol was €131.06 per patient; the cost of the traditional protocol was €114.41 or €151.06 per patient, depending on the follow-up studies required. The new protocol reduced the dose of radiation by eliminating successive radiologic studies.

Conclusions: The new protocol improved the management of these patients, reducing the time of immobilization, improving joint rigidity, and reducing the time off work. The limited MRI study makes it possible to diagnose other radiologically occult lesions. The cost of the new protocol is similar to that of the traditional protocol and even lower in some cases. The new protocol results in a reduction in the dose of radiation.

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Palabras clave
Escaphoídes; Fractura; Resonancia magnética; Análisis de Coste

Análisis del manejo de fracturas ocultas de escaphoídes mediante la realización precoz de resonancia magnética

Resumen
Introducción: Nuestro objetivo es valorar la utilidad de la resonancia magnética (RM) en el diagnóstico de las fracturas ocultas de escaphoídes, mostrando las ventajas y el coste comparativo frente al protocolo de seguimiento tradicional.
Material y método: El protocolo de actuación tradicional en nuestro centro, consistía en inmovilización y revisiones clínico-radiológicas periódicas (radiología convencional y tomografía computarizada en la fase final del proceso). En el nuevo protocolo, si en el primer control del traumatólogo (10 días post-traumatismo) la radiología convencional seguía siendo negativa se realizaba un protocolo limitado de RM de muñeca (coronal T1 y T2-supresión grasa). Se valoraron los hallazgos visualizados en RM, tiempo de inmovilización del paciente, coste económico de ambos protocolos y dosis de radiación recibida.
Resultados: Se incluyeron 33 casos de pacientes con sospecha clínica de fractura de escaphoídes y radiología negativa. En 13 pacientes la RM fue negativa. En 12 se confirmó el diagnóstico de fractura de escaphoídes, 6 asociadas a otra patología. En 8 se diagnosticó otro proceso. El coste del nuevo protocolo fue de 131.06€ por paciente y de 114.41€ (151.06€) para el tradicional, según las revisiones necesarias. Se redujo la dosis de radiación al eliminar la realización de sucesivas exploraciones radiológicas.
Conclusiones: El nuevo protocolo mejora el manejo de estos pacientes, reduciendo el tiempo de inmovilización, mejorando la rigidez articular y disminuyendo el período de baja laboral. Permite el diagnóstico de otras lesiones radiológicamente ocultas. El coste es similar, e incluso inferior en algunos casos, y la irradiación es menor.
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Introduction
Occult fractures are especially common in the scaphoid. They are defined as clinically suspected fractures with negative radiographic findings. Scaphoid fractures account for 5% of all bone fractures and usually occur in young men. Nonetheless, there may not be radiographic evidence of fracture during the acute phase. In these cases, the traditional approach involves clinical and radiographic follow-up to confirm or rule out the presence of fracture, since the fracture becomes more visible after a few days due to bone resorption processes around the fracture.
Magnetic resonance (MR) imaging has proven useful as an alternative for the diagnosis of occult fractures, with a sensitivity and specificity close to 100%. A follow-up protocol that includes early MR imaging has been introduced at our institution for patients with diagnosis of clinical fracture of the scaphoid. The aim of this study is to evaluate the impact that the implementation of this alternative protocol has had on our setting and to analyze the advantages, cost and radiation dose in comparison with the traditional follow-up protocol, which involves radiographs and computed tomography (CT).

Materials and methods
A total of 140 scaphoid fractures were diagnosed at our institution between August 2008 and September 2009 (137 closed and 3 open).
Thirty-three patients with clinically suspected scaphoid fracture and negative radiographic findings treated at the emergency department of our hospital were followed up during the study period. The patients were 12 women and 21 men, with a mean age of 30.6 years (standard deviation: 15.53, range: 13–66, and median: 25.5 years).
In our center, patients with suspected scaphoid fracture were treated with immobilization and clinical follow-up in 10–15 days at the outpatient orthopedic clinic, where an additional clinical-radiological (plain radiograph) evaluation was carried out. At this point, with the traditional protocol, patients with positive clinical findings and negative radiographic findings were asked to return for follow-up, following the same procedure. If the set of radiographs was negative at this second orthopedic consultation, the patient was referred for a CT scan. We developed an alternative protocol that offers MR imaging of the wrist at the first orthopedic consultation (10–15 days after the trauma) if the findings at presentation to the emergency department persist. In patients with negative MR findings, the clinician in charge was verbally informed so the splint was removed and the patient began early mobilization. The 33 patients followed this protocol.
Fig. 1 shows the traditional and the alternative protocol, which involves early MR imaging.
Plain radiographs of the wrist included AP and lateral projections. The absence of fracture was confirmed prior to the MR study (at our institution, plain radiographs are not reported by radiologists). An exclusion criterion was the identification of a fracture on any of the projections. Fracture was defined as low signal on T1- and T2-weighted images, and trabecular fracture was defined as the presence of bone edema, low signal on T1- and high signal on T2-weighted images with ill-defined margins, without
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associated fracture line. At least two of the following symptoms should be present to meet the clinical criteria for suspected scaphoid fracture: anatomic snuffbox pain, snuffbox edema or positive bayonet sign (pain on axial compression of abducted thumb).

MRI examinations were performed using a 1.5-T Signa scanner (General Electric Medical Systems, USA) and included T1-weighted spin echo images (TR 500/TE 14; matrix 256 × 192 and 3 excitations) and T2-weighted fast spin echo images with fat suppression (TR 3800/TE 80; matrix 256 × 192 and 4 excitations) in the coronal plane with slice thickness of 3 mm, intersection gap of 0.3 mm, and field of view of 12. Images were obtained using a knee coil since patients were immobilized in a splint. The duration of the examination, including patient preparation, was 15 min.

The cost of each of the protocols was calculated from the financial data provided by the financial and administrative management of our hospital, including direct (fungible goods and personnel costs) and indirect costs, from both the Emergency Department and the Orthopedic clinic. The Relative Value Units issued by the SERAM (Spanish Society of Medical Radiology) were used as a reference to determine the cost specifically related to the radiological examinations. Since each MRI is allotted 30 min in our appointment book, two patients can be imaged in the time allocated to one patient, so the costs are reduced by half.

The radiation was calculated as a mean of the measurements of the Kermax X-plus dosimeters (IBA, Schwarzenbruck, Germany) and the data of the CT dose index (CTDI) provided by our Brilliance CT 16-slice scanner (Philips, Eindhoven, Netherlands) from the wrist examinations.

Figure 1 Schematic of the traditional and alternative follow-up protocols for clinically suspected scaphoid fractures.

Results

In 13 patients (39.4%), MR images were normal and patients began early mobilization, which decreases joint stiffness.

In 8 patients (24.2%), MRI showed other lesions including extensor tendon synovitis, a ganglion cyst, rupture of the carpal triangular fibrocartilage (Fig. 2), fracture of the triquetrum, fracture of the trapezium (Fig. 3), fracture of the ulnar surface of the radius, trabecular fracture of the capitate bone and multiple trabecular fracture (Fig. 4).

Figure 2 Wrist MRI. Coronal T2-weighted MR image with fat suppression shows fluid in the prestyloid recess associated with rupture of the ulnar attachment of the triangular fibrocartilage of the carpus (arrow).
Figure 3  AP radiograph (A) and coronal T1-W MR image of the wrist (B) showing fracture line in the trapezium bone (arrow), not visible on conventional radiograph.

Figure 4  Wrist MRI. Coronal T2-W MR image with fat suppression shows bone edema (asterisks) of the capitate, trapezium and second metacarpal.

In 12 patients (36%), the MR images demonstrated scaphoid fracture (Fig. 5), six of them in association with an additional lesion including two trabecular fractures of the trapezium, one of the triquetral bone, one epiphysiolysis (Salter-Harris V), one trabecular fracture of the lunate, and one fracture of the distal radius (Table 1).

The cost of the new protocol was €131.06 per patient, and of the traditional protocol was €114.41 or €151.06, depending on the number of follow-up visits required.

The radiation dose was reduced by eliminating additional radiographs and CT studies. Both the alternative protocol and the traditional protocol (with two follow-up visits) have a similar radiation dose (0.06 mGy versus 0.09 mGy). However, the radiation dose increases significantly when CT is performed (0.09 mGy + 122 mGy cm²). This is particularly significant because the patients are usually young.

Fig. 6 shows the data regarding the cost and radiation dose.

Table 1  Distribution of patients according to MR imaging results.

<table>
<thead>
<tr>
<th>MR Imaging findings</th>
<th>Number of cases (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>13</td>
</tr>
<tr>
<td>Scaphoid fracture</td>
<td>6</td>
</tr>
<tr>
<td>Scaphoid fracture + concomitant lesions</td>
<td>6</td>
</tr>
<tr>
<td>Other lesions</td>
<td>8</td>
</tr>
</tbody>
</table>

Figure 5  AP radiograph (A) and coronal T1-W MR image of the wrist (B) showing fracture line in the scaphoid (arrow in B), not visible on conventional radiograph.
diagnosis of occult scaphoid fractures in 19% of cases. If we do a similar calculation, our percentage amounts to 36%, in accordance with previous studies.11

For clinically suspected scaphoid fractures with negative radiographic findings, treating symptoms with immobilization and periodic clinical-radiographic follow-up has been the most common protocol.4 In some centers the duration of the follow-up is 6 weeks.2 The prevalence of fracture in suspected cases ranges between 20%7 and 50%.2,11 Our data are similar to those found in other series (13 cases [39%] of negative cases). Early diagnosis of scaphoid fracture is important. In patients without fracture, immobilization is unnecessary, preventing joint stiffness and reducing days off work. Conversely, delayed or absence of diagnosis may lead to complications. Scaphoid pseudarthrosis results in biomechanical changes in the wrist that, in the last stage, lead to wrist arthrosis, with pain and loss of mobility and strength.11

These complications have important professional and social implications. Therefore, we must strike a balance between these two extremes.

Multiple approaches have been developed to minimize these diagnostic problems, with high inter-center variability.4 We decided to develop a protocol based on MRI as a second-line technique so we could take advantage of the available resources. Our hospital is a district hospital with 200 beds that provides care to a population of 270,000 people and sees an average of 292 emergency patients per day. It was founded as a public health care consortium, a novel entity within the health care system of Andalusia. One of its main goals is to improve the efficiency by managing the resources in order to improve the quality of care without increasing the costs. The hospital has an MR imaging system almost since it was opened and this allowed us to develop this alternative follow-up protocol which has been showed to be a cost-effective procedure.1,10,13

Our results corroborate previous data, suggesting that the expenditure in the alternative protocol is not significantly higher than in the traditional one, which varies depending on the number of follow-up visits required. It should be noted that we cannot determine when these occult fractures will be visible on radiographs. The radiographs obtained at the first follow-up could still be negative, but the symptoms may persist.1 Delays of up to 12 weeks for visualization have been reported.11 In this respect, patients whose symptoms disappear are more likely to neglect follow-up, and they present later with pain secondary to pseudoarthrosis. We have not found data regarding the percentage of delayed diagnoses in the literature, which merely states that a certain number of patients progress slowly and have negative radiographic findings.9 In our view, therefore, the proposed protocol minimizes the risk of neglecting follow-up by reducing the number of appointments.

The competitive cost of MR imaging in our institution is primarily based on optimization of the allocation of MRI times. Since two patients can be imaged in the time allocated to one patient, the cost is reduced by half. The referral forms are reviewed each week so MRI examinations are performed in a timely manner and scheduled on a weekly basis. Wrist MRI examinations are performed on the day allocated to musculoskeletal MRI, so the delay is never more than one week. In addition to these direct costs, there is a

Discussion

Scaphoid is the most common carpal fracture and frequently gives rise to a number of diagnostic problems.

First, the positive predictive value (PPV) of the clinical examination is low, ranging from 13% to 69%, with an average of 21%.1 The sensitivity of initial radiographs is also low, between 59% and 79% depending on the series.2 In addition, the false negatives of the radiographs include a heterogeneous number of occult fractures.7 Patients with a history of trauma and suspected occult fracture of the scaphoid may present with lesions in other structures, associated or not with scaphoid fracture. These lesions range between 6% and 45%,4 depending on the technique employed. In our series, 14 patients (42%) presented with other lesions, eight isolated and six associated with scaphoid fracture. The percentage in our series is high, similar to that reported by Memarsadeghi et al.9. They observed that CT depicted other fractures in 17% of patients, but this percentage rose to 37% when MR imaging was used. Nonetheless, this study does not address the involvement of non-bone structures. We emphasize the fact that these lesions would not have been detected without MR imaging in eight patients of our series (8 of 20 affected patients [40%]). Therefore, we believe that the new protocol allows an accurate diagnosis of associated lesions, helping to determine their appropriate treatment.

The average percentage of fractures that are missed in the emergency department is approximately 7% (7.3). In our hospital the percentage is 8% (12 out of 137 cases), in accordance with previous studies. Calvo et al.9 and Brydie et al.10 found higher percentages (18% and 19%, respectively). The former study was not designed to detect occult fractures and only included two cases of scaphoid fractures. For the calculations, the latter study included all the patients with suspected scaphoid fracture and negative radiographic findings at presentation to the emergency department, regardless of whether the fracture was finally confirmed or not, instead of the total number of scaphoid fractures diagnosed in that period. These data actually suggest that the use of a simplified MRI protocol allows the
reduction in non-hospital expenditure as the time off work is also reduced.

Lastly, another consideration is the radiation exposure of these patients, usually young, secondary to the additional radiographs and CT. Our results show that radiation rises dramatically when a CT is required. In addition, CT has been showed to have a high negative predictive value (NPV) (99%) but a PPV of only 28%. Therefore, this technique provides a confident diagnosis in positive cases but does not exclude the diagnosis in negative cases. The main limitation of CT is the diagnosis of trabecular fractures. These fractures increase bone fragility temporarily, so the bone becomes more vulnerable; therefore these fractures must undergo close follow-up. In our center, trabecular bone fractures are treated with removable splint and early rehabilitation.

Despite the small number of patients, in our view the protocol proposed for the monitoring of patients with suspected occult fracture of scaphoid improves their clinical management, reducing the immobilization period and sick leave, and improving joint stiffness, while minimizing the risk of neglecting follow-up. In addition, this protocol allows the diagnosis of other fractures and radiographically occult lesions, helping to provide the appropriate treatment for each particular case, using the lowest radiation dose. The cost of the modified protocol is similar to that of the traditional protocol, or even lower in some cases. Lastly, our data suggest that these costs are bearable by similar hospital with MRI scanner.

Authorship

1. Responsible for the integrity of the study: MDMR.
2. Conception of the study: MDMR.
3. Design of the study: MDMR.
4. Acquisition of data: MDMR, MMH, and PSR.
5. Analysis and interpretation of data: MDMR, MMH, and PSR.
6. Statistical analysis: N/A.
7. Bibliographic search: MDMR, MMH, and PSR.
8. Writing of the paper: MDMR and MMH.
9. Critical review with intellectually relevant contributions: PSR and JRM.
10. Approval of the final version: MDMR, MMH, PSR, and JRM.

Conflict of interest

The authors declare not having any conflict of interest.

References