Imaging the scaphoid problem : a diagnostic strategy for suspected scaphoid fractures

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Chapter

8

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Acute MR imaging compared with bone scintigraphy in suspected scaphoid fractures

Submitted

Abstract

Bone scintigraphy has been widely used as the gold standard in the diagnostic management of suspected scaphoid fractures. Currently, MR imaging has been suggested as the most appropriate investigation in imaging acute scaphoid trauma. The objective of this prospective study was to evaluate if acute MR imaging is superior to bone scintigraphy for suspected scaphoid fractures.

Methods: One hundred consecutive patients with a suspected scaphoid fracture but no fracture on scaphoid radiographs were included. All patients had MR imaging within 24 hours after presentation and bone scintigraphy between 3 to 5 days after trauma. After a standardised follow-up a final diagnosis was made according to a standardised algorithm. In case of discrepancy between MR imaging and bone scintigraphy, the physical examination during follow-up was used to make a final diagnosis.

Results: MR imaging showed 16 scaphoid and 24 other fractures. Bone scintigraphy showed 28 scaphoid and 40 other fractures. According to the final diagnosis there were 20 scaphoid fractures. Concerning a scaphoid fracture, MR imaging was false negative in 4 and bone scintigraphy false positive in 8 patients. MR imaging had a sensitivity of 80% and specificity of 100%. Bone scintigraphy had a sensitivity of 100% and specificity of 90%.

Conclusion: This study could not confirm that acute MR imaging is superior to bone scintigraphy for suspected scaphoid fractures. Bone scintigraphy remains a highly sensitive and reasonably specific study for the diagnosis of an occult scaphoid fracture.

Materials and methods

Study population

This prospective study was conducted in accordance with the standards of the regional Ethical Committee. Between March 2004 and January 2007, a total number of 100 consecutive patients who visited the Emergency Department with a suspected scaphoid fracture gave written informed consent for study inclusion. Patients were eligible if they were willing to participate in this study, had a suspected scaphoid fracture (tender anatomic snuffbox and pain in the anatomic snuffbox when applying axial pressure on the first or second digit), a recent trauma (within 48 hours) and no evidence of a fracture on scaphoid radiographs. Poly-trauma patients, patients younger than 18 years and those with typical contra-indications for MR imaging were excluded.

Study protocol

After inclusion, all patients had a physical examination. MR imaging of the hand and wrist was performed within 24 hours after the initial presentation at the Emergency Department. Bone scintigraphy of the hand and wrist was performed between 3 and 5 days after trauma.

Physical examination

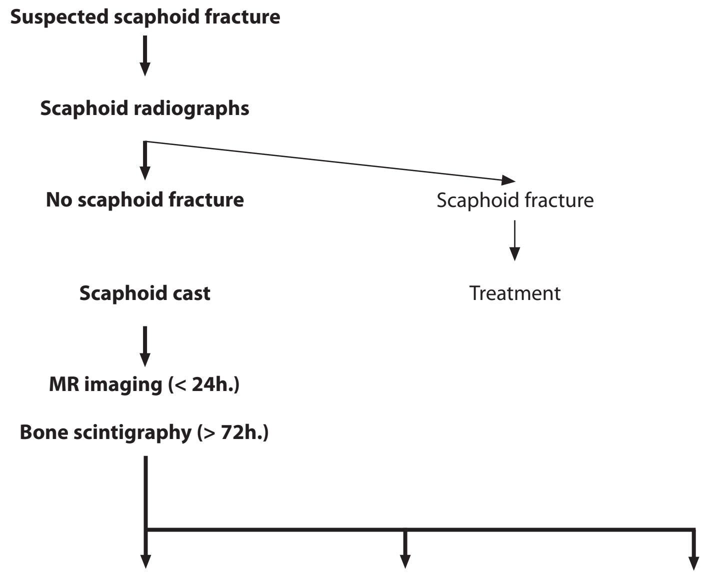
In the Emergency Department and at fixed intervals throughout follow-up (**Figure 8.1**) patients had a physical examination. Patients were asked to localise the "point of maximal tenderness" for pain. Subsequently, both wrist and hand were examined. Pressure was applied on the anatomic snuffbox, distal radius and other carpal bones. Next, axial pressure was applied on both the first and second digit. Finally, flexion and extension of the wrist were measured. All physical examinations were performed blind to the results of previous physical examinations, MR imaging, bone scintigraphy and scaphoid radiographs.

Image analysis

A resident and consultant radiologist evaluated the MR scans. A consultant clinical nuclear physician evaluated all bone scans. For both the MR scan and the bone scan, observers filled in a standard form blind to each other and blind to any other data. Each observer scored:

1. Scaphoid fracture (yes / no);
2. Other fracture (yes / no).

The radiologist also evaluated the presence or absence of a soft tissue injury.



Weeks after injury	No fracture	Other fracture	Scaphoid fracture
2	P.E.	P.E.	P.E.
4		P.E.	
6	P.E.	P.E.	P.E.
8			P.E.
10		P.E.	
12			P.E.
24			P.E.

P.E.: Physical Examination

Figure 8.1
Flowchart of prospective protocol.

Management

Patients with no evidence of a fracture in both MR imaging and bone scintigraphy were treated functionally with a supportive bandage of the wrist. Patients with a scaphoid fracture in either MR imaging or bone scintigraphy were treated with a scaphoid forearm cast (below the elbow cast incorporating the thumb (anatomical position) as far as its interphalangeal joint) for 6 weeks. Patients with other fractures were treated according to the local trauma protocol.

In case of remaining clinical signs of a fracture after the standard immobilisation period (6 weeks for scaphoid fractures) a new cast was applied for an additional 2 weeks. This procedure was repeated every 2 weeks (for a maximum of 12 weeks of immobilisation for scaphoid fractures) until there were no longer clinical signs of a fracture. All patients were reviewed at fixed intervals throughout follow-up, as shown in **Figure 8.1**.

Final diagnosis

A final diagnosis was made after final discharge according to a standardised algorithm:

- If MR imaging and bone scintigraphy showed a fracture, the final diagnosis was a fracture;
- If MR imaging and bone scintigraphy showed no fracture, the final diagnosis was no fracture;
- In case of discrepancy between MR imaging and bone scintigraphy, the physical examination during follow-up was used to make a definitive diagnosis:
    - If after 2 weeks there were remaining clinical signs (tender anatomic snuffbox or pain in the anatomic snuffbox when applying axial pressure on the first or second digit) the final diagnosis was a fracture;
    - If after 2 weeks there were no more clinical signs (no tender anatomic snuffbox and no pain in the anatomic snuffbox when applying axial pressure on the first or second digit) the final diagnosis was no fracture.

Hypothesis and statistical analysis

Prior to the initiation of this study, the following assumptions were used to calculate the power. According to the literature, 25% of the cases with a scaphoid fracture will have no evidence of a fracture on radiographs.[4,5,11,13]

The sensitivity of bone scintigraphy is approximately 95% and the specificity is around 70%.[5,8,10,12] Therefore, the suspected chance of a correct diagnosis on bone scintigraphy is 0.7625 ($0.25 \times 0.95 + 0.75 \times 0.70$). The hypothesis is that MR imaging will have an equal sensitivity but a specificity of 90%.[5,10,13,17-19,22,23] This implies a suspected chance of a correct diagnosis on MR imaging of 0.9125 ($0.25 \times 0.95 + 0.75 \times 0.90$).

To detect this difference in correct diagnosis with a power of 0.80 using a McNemar test ($\alpha = 0.05$, two-paired), 108 patients are needed if the results of the MR imaging and bone scintigraphy are not correlated within a patient. If there is a positive correlation between the results of MR imaging and bone scintigraphy, which is very likely, the number of patients needed would be less. Therefore the aim was to include 100 patients.

According to the final diagnosis the sensitivity and specificity were calculated for bone scintigraphy and the MR scan. Finally, percentages of correct predictions between the 2 diagnostic methods were compared with a McNemar test. A p-value smaller than 0.050 was considered as significant.

Results

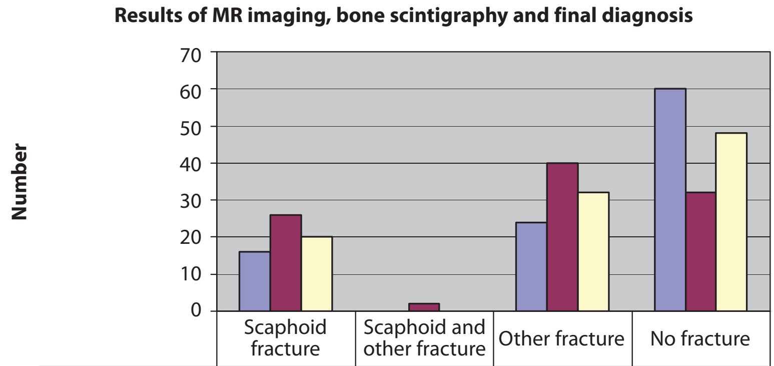
Patient characteristics

Baseline characteristics are displayed in **Table 8.1**. All patients had a clinically suspected scaphoid fracture but initial scaphoid radiographs showed no evidence of a fracture.

Diagnostic results and final diagnosis

MR imaging showed 16 scaphoid fractures and 24 other fractures (13 carpal and 11 distal radius fractures). In 3 patients a soft tissue injury was described. Bone scintigraphy showed 28 scaphoid fractures and 40 other fractures (27 carpal, 11 distal radius, 1 metacarpal and 1 ulnar fracture). According to the final diagnosis there were 20 scaphoid fractures and 32 other fractures (**Figure 8.2**).

Regarding a scaphoid fracture, MR imaging was false negative in 4 patients and bone scintigraphy was false positive in 8 patients. MR imaging has a sensitivity of 80% (16/20) and specificity of 100% (80/80). Bone scintigraphy has a sensitivity of 100% (20/20) and a specificity of 90% (72/80). The bone scintigraphy predicted 92 scans correctly and 8 scans incorrectly, while the MR imaging was correct in 96 and false in 4 patients (**Table 8.2**). The percentage of correct predictions did not differ significantly between MR imaging and bone scintigraphy (p=0.388).
The results of the MR scans and the final diagnosis of the 8 patients with a false positive bone scan are displayed in **Table 8.3**. All patients were free of complaints and



	Scaphoid fracture	Scaphoid and other fracture	Other fracture	No fracture
MR imaging	16	0	24	60
Bone scintigraphy	26	2	40	32
Final diagnosis	20	0	32	48

Figure 8.2
MR imaging, bone scintigraphy and final diagnosis of 100 patients with a suspected scaphoid fracture but no evidence of a fracture on scaphoid radiographs.

Table 8.1
Baseline characteristics.

Patient characteristics	Number	Percentage
Male	50	50%
Female	50	50%
Age (years)	42 ± 16	
Dominant hand	48	48%
Previous fracture in hand or wrist	11	11%
Suspected side	5	5%
Contra-lateral side	6	6%

Table 8.2
True and false scans for a scaphoid fracture. Sensitivity, specificity, positive and negative predictive value of MR imaging and bone scintigraphy for the detection of occult scaphoid fracture (95% confidence intervals in parentheses).

Scaphoid fracture	MR imaging	Bone scintigraphy
True positive	16	20
True negative	80	72
False positive	0	8
False negative	4	0
Sensitivity	80% (56–94)	100% (83–100)
Specificity	100% (96–100)	90% (81–96)
Positive predictive value	100% (74–100)	71% (52–87)
Negative predictive value	95% (88–99)	100% (95–100)

Table 8.3
Results of the MR scans and final diagnosis of the 8 patients with a false positive bone scintigraphy for a scaphoid fracture.

MR imaging	Final diagnosis
Bone bruise scaphoid	No fracture
Bone bruise scaphoid	No fracture
Triquetrum fracture	Carpal fracture
Distal radius fracture	Distal radius fracture
Ligament tri-angularis tear	No fracture
Sub-cortical scaphoid cyst	No fracture
No injury	No fracture
No injury	No fracture

had a good function of hand and wrist after final discharge. All patients with a fracture went on to union and none of the fractures were internally fixated.

Discussion

Twenty per cent of patients had a fractured scaphoid that was not apparent on scaphoid radiographs. Four of these were also not apparent on MR imaging. Bone scintigraphy was false positive in 8 patients. In 5 of these 8 patients, there was a traumatic lesion (i.e. other fracture, ligament tear or bone bruise) but no scaphoid fracture.

Many physicians have suggested MR imaging as the investigation technique of choice for detecting occult scaphoid fractures.[12,13,18-23] In the literature, only 4 papers addressed a comparison between (delayed) MR imaging and bone scintigraphy for suspected scaphoid fractures.[9,12,17,20] These 4 papers all used different imaging sequences and none of them were, in none of the sequences, identical to any other protocol. They suggest that MR imaging is superior to bone scintigraphy. In any of these studies the maximum number of patients per study was 59.[17] For the 4 studies, a total number of 145 patients were entered into a comparison between the 2 imaging modalities. Three of these papers had a delay in MR imaging of at least 10 days after trauma.[12,17,20] In the fourth paper, MR imaging was performed within 3 to 14 days after trauma (mean 10 days).[9] In addition, none of these studies used a standardised algorithm, independent of diagnostic results, to define a final diagnosis to which MR imaging and/or bone scintigraphy could be compared. We believe this is the largest series to date comparing MR imaging with bone scintigraphy and believe it is the first series evaluating the value of acute (within 24 hours after presentation) MR imaging for occult scaphoid fractures.

In order to assess a fast protocol that could be easily implemented in daily practice, this study only used a coronal imaging MR imaging protocol and a relatively large field of view. Consequently, scanning time of this protocol was less than 7 minutes due to which it can be easily implemented in a busy daily practice clinic. However, the false negative MR scans may have been discovered with additional views or additional sequences. Moreover, the low incidence of soft tissue injuries detected could be due to the used MR imaging protocol. Potentially in patients without an evident fracture on MR scans, additional sequences could be added to try to detect fractures in a non-conventional plane or injury to soft tissue or ligament.
The determination of a gold standard was challenging. In this study, clinical follow-up was used to determine the final diagnosis in case of equivocal imaging studies. According to the literature, each clinical sign in physical examination has a sensitivity approximating 100% for diagnosing scaphoid fractures.[27-29,62,63] Moreover, when combining the clinical signs, physical examination also has a high specificity up to 98%. This is further enhanced

by serial examinations. Therefore, it is unlikely that scaphoid fractures have been missed throughout the follow-up. This is underpinned by the fact that no pseudo-arthrosis occurred within the follow-up. In addition, physical examination allows to distinguish between a scaphoid and another fracture. However, clinically discriminating a scaphoid fracture from adjacent soft tissue injury is difficult. In the 4 false negative MR imaging exams there was no soft tissue injury described on any of the MR scans. In the 4 patients with a false negative MR scan, follow-up imaging that could confirm the presence of a fracture would support the final diagnosis. There is however, no absolute truth to confirm or rule out a scaphoid fracture. Follow-up radiography has little additional diagnostic value in patients with normal initial scaphoid radiographs.[6]

The results concerning other fractures show a trend similar to scaphoid fractures. They are, however, beyond the scope of this study and will not be discussed.

Occult scaphoid fractures can be challenging and a delay in treatment increases the risk of complications. Therefore, there is a tendency to over-treat patients with a suspected scaphoid fracture. In addition, there is a call for a fast and adequate diagnostic protocol in order to initiate the appropriate treatment as quickly as possible. A false positive outcome is herewith preferred to a false negative result. MR imaging has been suggested as the investigative technique of choice for detecting occult scaphoid fractures.[12,13,18-23] In addition, MR imaging would appear to be more specific and be able to give more information of soft tissue injuries. The clinical problem of diagnosing a scaphoid fracture is underlined and acute MR imaging proved to have a very high specificity. It has, however, a lower sensitivity for diagnosing scaphoid fractures and using acute MR imaging as the sole imaging tool will bear the risk of under-treating these patients. Moreover, only a small number of soft tissue injuries were described.

In conclusion, this study cannot confirm that acute MR imaging is superior to bone scintigraphy for the detection of suspected scaphoid fractures. For investigation of the "clinically suspected scaphoid fracture", bone scintigraphy remains the gold standard to date. Acute MR imaging cannot assume this role due to a significant number of false negative diagnoses.