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Current imaging practice for suspected scaphoid fracture in patients with normal initial radiographs: UK-wide national audit

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AIM: To assess the current practice of scaphoid fracture imaging (where initial scaphoid radiographs are normal) in the UK.

MATERIALS AND METHODS: A survey monkey questionnaire was sent to 140 eligible NHS trusts derived from the NHS England database following exclusion of all non-acute and specialist centres. Four questions were asked regarding the provision of magnetic resonance imaging (MRI) for radiographically occult scaphoid fractures, time to MRI, number of departmental MRI scanners, and alternative imaging offered.

RESULTS: Responses were received from 74 trusts (53%). Thirty-eight offered MRI as a first-line test in plain-film occult scaphoid injury, 25 preferred computed tomography (CT), and 11 opted for repeat plain radiographs. Of the 38 trusts who offered MRI, 26 provided this within 1 week; the rest within 2 weeks. No trends were identified based on the size of the hospital or its geographical location. Statistical analysis of the data revealed no significant relationship between the number of MRI scanners and the provision of MRI, nor between the numbers of MRI scanners and the time to MRI.

CONCLUSIONS: MRI has been recognised in the literature as a highly specific, highly sensitive, and cost-effective tool, yet only 51% of trusts provide this service in the UK. For those who cannot offer MRI first-line, CT remains a very accurate and reliable alternative.

Introduction

Injury to the carpus is common, particularly amongst the young and active patient population.[1] Of the eight bones that comprise the carpus, the scaphoid is the most commonly injured, accounting for over 90% of all carpal bone fractures.[2]

The current practice in emergency departments in the UK for the initial evaluation of a scaphoid fracture relies on the use of plain radiographs of the wrist, with dedicated scaphoid views, collectively referred to as a scaphoid series. The negative predictive value of this examination was evaluated by Dorsay *et al.* and returned a weighted average

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of 74%, meaning that one in four patients with normal radiographs will be falsely reassured.[3]

Given the predominantly young patient population, ongoing strain with continued use of the wrist leads to an unacceptable increased risk of complications from untimely treatment. These include avascular necrosis and various forms of malunion, the most severe of which is pseudoarthrosis. This has long been recognised due to the tenuous vascular supply to the scaphoid bone, which involves retrograde filling of the proximal pole.

In light of the aforementioned risks, patients with a radiographically occult scaphoid fracture on the initial scaphoid series, but with a continued high clinical suspicion for a fracture, are offered treatment with a Colles' cast or wrist splint and referred for further imaging.[2]

Repeat radiographic imaging at 10–14 days following the injury is still used in many centres in the UK and internationally, relying on the fact that increased resorption at the fracture cleft makes the diagnosis of a scaphoid fracture more conspicuous with time; however, approximately 5–10% of patients with a clinically suspected scaphoid injury do not actually transpire to have one, so are needlessly overtreated, suffering a loss of productivity as a result.[1,4]

It is thus crucial that patients are diagnosed and treated correctly and in a timely manner. A variety of imaging methods including nuclear bone scintigraphy (NBS), computed tomography (CT), and magnetic resonance imaging (MRI) have been employed as second-line tests in an attempt to improve the accuracy of radiographically occult scaphoid fracture detection. Current research, however, confirms that there remains a striking inconsistency in the imaging method of choice internationally.[5–7]

The aim of this national audit was to assess the current practice of scaphoid fracture imaging (where initial scaphoid radiographs are normal) in the UK, in the midst of inconsistency in the literature and a reasonable directive from most national guidance suggesting a shift towards MRI. In addition, the current literature on scaphoid fracture imaging is reviewed.

Materials and methods

A list of all NHS trusts in the UK was obtained from NHS England. Specialist paediatric, cardiothoracic, mental health, maternity, community, and ambulance-specific trusts were excluded. The email address of the clinical director of radiology or lead musculoskeletal radiologist for each eligible trust was identified either from the trust website or direct telephone contact with the radiology department secretaries. A Survey Monkey questionnaire was sent to each trust containing four multiple choice questions related to the management of plain film occult scaphoid fractures (Fig 1). A time frame of 2 months was allowed for the response. Those trusts that did not respond were then contacted directly by A.G. via email with the questions attached.

Data were collected relating to whether MRI was offered as a first-line test in plain radiography-occult scaphoid injuries, the timescale to MRI being performed, any alternative imaging offered, and the number of MRI scanners in the trust.

Results

After exclusion of the ineligible trusts described above, a total of 140 trusts were identified within the UK for inclusion in the study (Fig 2). Responses were received from 74 of the 140 trusts contacted (53%). Of these 74, 38 offer MRI as a first line investigation (51%) with 36 offering an alternative imaging technique (49%). Of the 38 trusts who offer MRI as a first-line investigation, 26 aim to perform the MRI within 1 week with the remaining 12 aiming to scan within 2 weeks. Of the 36 trusts who offer an alternative imaging method, 25 opted for CT with 11 offering a repeat plain radiograph as the first-line investigation. One trust does still offer NBS, although recognises that this is performed on very few patients and CT is preferred as their first-line investigation.

The results were split into responses from district general hospitals and teaching trust. No pattern of variability could be found between these groups with 49% of teaching trusts and 48% of district general hospitals offering MRI as a first-line investigation.

Finally, the results were organised geographically with no pattern of geographical variability being identified with 51% of southern trusts and 48% of northern trusts offering MRI as a first-line investigation. The decision to classify a trust as northern or southern was achieved by drawing an arbitrarily placed horizontal line over a map of the UK at the level of Leicester (the authors acknowledge that this is a heavily debated subject; however, the line had to be drawn somewhere).

Statistical evaluation

The responses were also evaluated statistically to address two hypothetical questions; firstly, whether there was a relationship between the number of MRI scanners at the trust (Table 1) and offering MRI as first-line investigation, and secondly, whether there was a relationship between the number of MRI scanners and how soon MRI was offered. To address the first question, a logistic regression analysis was performed between trusts that offered MRI as first-line and trusts that did not offer MRI as a first-line investigation with number of scanners as the independent variable. The logistic regression coefficient was 0.0193 with a standard error of 0.1105, which gave a p-value of 0.8614; the odds ratio was 1.0195 (95% CI: 0.821–1.2659). This meant that a greater number of scanners in a trust was associated with a higher probability of an MRI being offered; however, the effect was very small and far from being statistically significant. In other words, there was no evidence that the number of scanners had any effect on whether or not MRI was offered as a first-line investigation.

To answer the second question, the Pearson correlation coefficient was calculated between number of MRI scanners and time to MRI. The Pearson correlation coefficient was 0.1664, which suggests a modest, positive association

Q1. Do you offer MRI as first line investigation for scaphoid fracture where plain X-rays are normal?

A. Yes
B. No

Q2. What is the time scale for MRI?
A. Within 24 hours
B. Within 48 hours
C. Within 72 hours
D. Within a week
E. Within two weeks

Q3. How many MRI Scanners does your department have?

Q4. For those who answered 'No' to Q1; what do you offer as first line investigation for scaphoid fracture where plain x-rays are normal?
A. CT
B. Plain Radiograph
C. Bone Scan

Figure 1 Screen shot of the questionnaire sent to trusts. One option could be selected for each question with a free-text box for any additional comments related to the question.

between the number of scanners and the time to MRI; however, the *p*-value was 0.327 (95% CI: 0.1666–0.4654) meaning that the correlation was not statistically significant. A negative binomial regression analysis performed to answer the same question showed a *p*-value of 0.229, corroborating the lack of statistical significance indicated by the Pearson correlation test. In other words, again, there was no evidence that the number of scanners had an effect on timing of MRI.

In summary, the present survey had a response rate of 53% with 51% offering MRI as a first-line investigation for radiographically occult scaphoid fractures and 49% offering an alternative technique. No pattern could be identified within the results to suggest why there is variability between the first-line investigation of choice in suspected scaphoid fractures within UK trusts. In other words, there was no evidence that the number of scanners had any effect on whether or not MRI was offered as a first-line investigation nor did it have any effect on the timing of the MRI.

Discussion

Scaphoid fractures are not only common, but typically present in a patient demographic who, with incorrect treatment, suffer significant morbidity and loss of productivity.[8,9] This is due to a spectrum of outcomes from accelerated osteoarthritic changes secondary to delayed treatment, to lost working hours for the self-employed: the end result of needless wrist immobilisation.

This present national, UK-wide audit was undertaken to assess whether there has been any progress in determining the technique of choice for patients with radiographically occult scaphoid fractures. The results of the national audit reaffirm the inconsistency in the imaging technique of

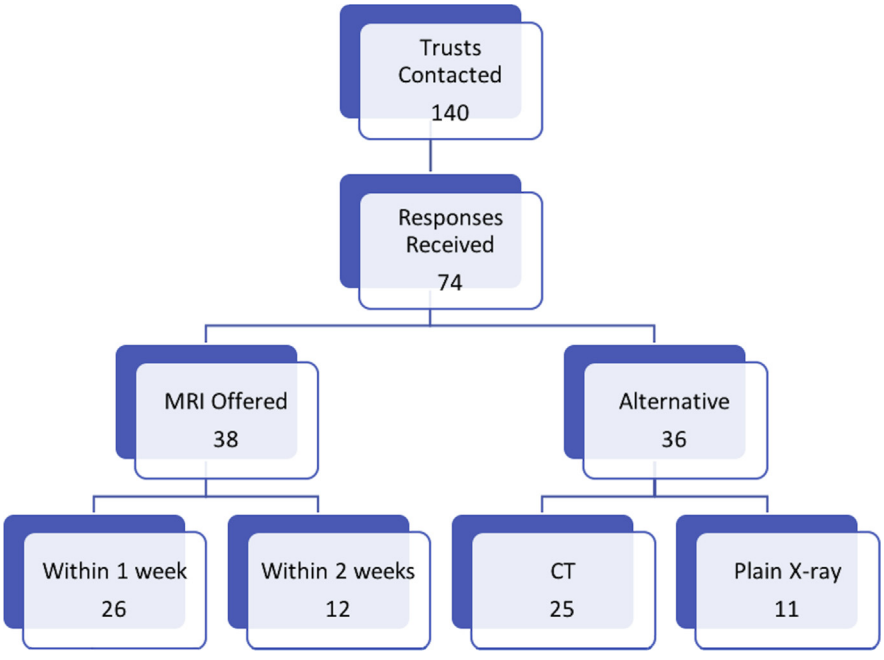

Figure 2 Flow chart demonstrating a summary of the responses received from the questions asked in Fig 1.

Table 1
Table demonstrating the number of magnetic resonance imaging (MRI) machines in the trusts that responded to the survey.

Number of MRI machines	Trusts offering first-line MRI	Trusts not offering first-line MRI	Total
One	10	9	19
Two	9	9	18
Three	12	10	22
More	6	8	14
Incomplete response	1		1

choice for patients with a plain radiography-occult scaphoid fracture, with 51% preferring MRI, 34% utilising CT, and 15% relying purely on repeat radiographs. Perhaps surprisingly, NBS was not used by any of the respondents as the preferred first-line technique for radiograph-negative scaphoid fracture evaluation.

It has long been known that the sensitivity of the clinical examination is high with most studies reporting sensitivity figures approaching 100%.[2,8] Conversely, however, the specificity of the clinical examination for a scaphoid fracture is poor. Tenderness over the anatomical snuffbox has a specificity of just 9%, over the scaphoid tubercle of 30%, and on longitudinal thumb compression of 48%.[8] Even when all three findings are evaluated for together, the combined overall specificity still only reaches 74%. Even less reassuring, however, is the positive predictive value of the clinical examination, which ranged between 13% and 69% (with a weighted average of 21%) in an American hospital over a 6-year interval.[3]

As an imaging technique for radiographically negative scaphoid fractures, MRI has been shown to be a cost-effective, highly sensitive, and highly specific test.[2–9] Brydie *et al.* evaluated 195 patients in a UK hospital with a high clinical suspicion of acute wrist trauma and who had a negative initial scaphoid series.[10] Early MRI detected 74 fractures (37 scaphoid fractures and 37 non-scaphoid fractures including other bones in the carpus and distal radius) and 119 patients with no fracture. The study concluded that the management of 180 patients, that is 92% of the total cohort, was altered as a result of early MRI. In a similar study by Kumar *et al.*, 22 patients were evaluated with early MRI at an Australian major referral emergency department.[11] Of the 22 patients referred, nine had evidence of wrist fractures (including the scaphoid [6], distal radius [2] and hamate [1]) with no fracture demonstrated in the remaining 13 patients. Of these 13 patients, a repeat clinic review at 10 days permitted discharge of five patients with no ongoing clinical concerns. The remaining eight went onto have a repeat MRI, which confirmed no fracture. Overall, the sensitivity and specificity for early MRI in this study was 100%. A larger-scale study in a UK hospital by Khalid *et al.* assessed 611 patients with a clinically suspected scaphoid fracture and negative initial radiographs.[2,13] MRI revealed 272 cases with bony injuries including scaphoid fractures, 23 patients with soft-tissue injuries, 47 patients with incidental pathologies, and 269 patients with no pathology demonstrated.[2] More recent studies from 2017 also showed comparable results, as demonstrated by Prasad *et al.*[12]

In patients for whom MRI is not suitable, the options of CT and NBS exist. NBS has a very high sensitivity and negative predictive value for scaphoid fractures with most studies reporting figures reaching 100% for both parameters[2,14–18]; however, the specificity and positive predictive value for scaphoid fractures is poor as it often struggles to differentiate true fractures from bone oedema, soft-tissue injury, and inflammatory arthropathies.[4] Studies assessing the role of single-photon-emission CT (SPECT) imaging, which relies on the combination of functional scintigraphic and correlative anatomical imaging using CT, have demonstrated an increase in the specificity and accuracy using this hybrid technique. Crucially, however, the radiation dose is significantly higher than that of its counterparts with a dose that is 133 times higher than CT alone (SPECT 4 mSv, CT 0.03 mSv).[14,32] This precludes its routine use for scaphoid fracture evaluation in modern day emergency departments. In addition, NBS is infrequently used on an emergent basis given the complex nature of the study and availability of the radionuclide, which results in patients requiring a cast or wrist splint for at least a short period of time.[3]

CT is the preferred technique for scaphoid fracture detection if MRI is not suitable. Although being marginally less sensitive than NBS and MRI, it maintains a high specificity and accuracy owing to the enhanced bone reconstructions, which provide superior cortical and trabecular resolution.[19]

Two published reviews of the three techniques described above (MRI, NBS, and CT) are currently available with the study by Yin *et al.* representing the latest Cochrane review.[2,4] Yin *et al.* evaluated 15 studies on NBS with a total of 1,102 patients, 10 studies on MRI with a total of 513 patients, and six studies on CT with a total of 211 patients.[4] The sensitivity, specificity, and logarithmic diagnostic odds ratio for NBS was 97%, 89%, and 4.78, for MRI the results were 96%, 99%, and 6.6 and for CT the results were 93%, 99%, and 6.11 respectively. Ring *et al.* showed comparative results in their published review.[20]

Although the reviews above have some limitations, including the lack of randomisation and generally small cohort populations, the results from extensive publications on this subject matter to date highlights MRI as the superior imaging method for investigating radiographically occult scaphoid fractures. Of course, MRI has the added benefit of being able to detect non-scaphoid-related pathology and is also capable of scanning through a cast, if *in situ* at the time of the examination.[3] Nonetheless, there will be patients for whom MRI is not suitable or available, and for these patients, CT is the next best imaging method.

This is largely in line with national and international guidance provided by the Royal College of Emergency Medicine (RCEM), American College of Radiology (ACR, Appropriateness Criteria), Royal College of Radiology (RCR, iRefer), National Institute for Health and Care Excellence (NICE), and the orthopaedic/radiology literature.[2,4,21–23,27] (Box 1).

Box 1.
National and international guidance from the literature

RCEM (2013): MRI appears to have the best diagnostic performance … CT scanning is a reasonable alternative if MRI is not possible or contraindicated.[2]

ACR (2013): MRI is the study of choice. For patients with contraindications to MRI, CT is preferred to scintigraphy.[21]

RCR: MRI is accurate and cost-effective. Low-dose CT is an alternative.[22]

NICE (2016): Consider MRI for first-line imaging in people with suspected scaphoid fractures following a thorough clinical examination.[23]

Radiology literature - Yin et al. (2009): Based on the current evidence, MRI is highly accurate for confirming and excluding the diagnosis of scaphoid fractures and might be used as the first choice in a patient with a suspected scaphoid fracture.[4]

Orthopaedic literature – Adams et al. (2017): If there is clinical suspicion for a fracture, one should obtain an MRI scan, which has the highest sensitivity and specificity for diagnosis.[27]

The accessibility of MRI and its cost-implications are often put forward as limiting factors precluding its use early in scaphoid fracture detection. A comprehensive study by Dorsay *et al.*, however, revealed promising results.[3] They evaluated a number of patients admitted through the emergency department with acute wrist trauma and compared the costs associated with a screening MRI using a fast image acquisition protocol (10 minutes actual scan time; coronal T1 and fat-saturated T2-weighted images) and traditional management. Their results consistently demonstrated that early MRI is a cost-effective method for scaphoid fracture detection; in those in whom the test was negative, the avoidance of costs associated with orthopaedic consult in the emergency department and at follow-up, multiple scaphoid radiographs, and premature limb casting offered significant cost savings. Moreover, early screening MRI was performed at a reduced cost of US$770, compared with the routine MRI wrist study that was often requested during repeated clinic attendances, which was performed at a cost of US$1,256.

Hansen *et al.* provided similarly impressive cost-analysis data showing that subacute MRI in patients with suspected scaphoid fractures, but normal initial radiographs, increased the in-hospital costs by €151, but reduced non-hospital costs (immobilisation time and sick leave) by €2,869, once again demonstrating significant cost savings.[24,25]

Raby compared early versus late MRI in patients with a negative scaphoid series using a dedicated 0.2 T extremity scanner in a Scottish hospital at a cost of just £50 per examination.[26] He identified that early MRI altered patient management in 89% of cases, versus 69% of patients in whom the MRI was delayed. Moreover, there were much fewer cases referred for MRI evaluation than expected, with no significant increase in the number of examinations requested following provision of the early MRI service. Concluding, he described that overall costs changed very little when compared to standard practice for the significant patient benefits that were incurred.

With the availability of relatively cheap extremity MRI in the UK, the role of early MRI should be recognised not only for its long-term overall cost-savings, but also for the ease of patient imaging. Limited-field extremity scanners permit the elderly and infirm to be scanned in a supine position with the arm held abducted, a population who would otherwise struggle to adopt the prone position required in a non-dedicated scanner.[26]

It must be appreciated, however, that in spite of the multitude of benefits that early MRI offers, CT remains a more accessible imaging technique for a large majority of UK radiology departments with its comparatively lower costs, faster scanning time, and ease of access. Moreover, CT confers a number of additional advantages over MRI, each of which should be recognised for their individual role in the diagnostic work-up. One such advantage is in the assessment of fracture displacement. Although variably reported in the literature, it is estimated that approximately 20% of scaphoid fractures are displaced when assessed on radiographs alone.[28] Displacement of the fracture fragments by >1 mm is of increasing surgical concern, with rates of non-union reported to reach 92%, compared with only 19% when the displacement was <1 mm.[27,28] Similar results have been obtained in a more recent meta-analysis by Singh *et al.* (2012), who reported a fourfold increase in the risk of non-union when scaphoid fractures were displaced.[29] Given its superior spatial resolution and the ease of performing multiplanar reconstruction, CT is preferred to MRI for the assessment of fracture displacement, particularly with regards to surgical planning.[1,19] More recently, further research into the role of dual-energy CT (DECT) has shown promising results. In a small study by Dareez *et al.*, it was noted that in two patients presenting with acute scaphoid trauma, but no obvious radiographic or conventional CT abnormality, DECT demonstrated bone marrow oedema, which was later corroborated on MRI as being the result of an underlying undisplaced fracture.[30] More recently, Ali *et al.* (2018) demonstrated similarly impressive results in their retrospective study of 24 patients.[31] Clearly, further work is required to ensure the inferences made from these studies hold true with larger sample sizes.

Putting aside technique, a further consideration is how soon should patients be imaged? Early imaging permits patients with no significant pathology to be discharged with the resultant cost benefits to the hospital and society, but adds strain to an already pressurised and constrained imaging directorate. A study by Langhoff *et al.* described that most scaphoid fractures developed healing-related complications when treatment was delayed by 4 weeks, with no significant risk in the first 4 weeks following trauma.[32] As the present results demonstrated, of the trusts

that offer MRI as a first-line test in radiograph-negative scaphoid fractures, 100% were able to offer it within 2 weeks.

In conclusion, the present study demonstrates that although MRI is a preferred imaging technique amongst UK trusts (51%), there remains inconsistency in the imaging requested for patients with radiographically occult scaphoid fractures. Based on UK data, time to MRI is not influenced by the number of MRI machines in a department or by the size of the hospital.

It is clear that there is a wealth of evidence supporting the rationale behind early MRI with an abundance of research and guidance both in the UK and internationally, purporting it to be the reference standard for evaluating scaphoid fractures. For hospitals that can meet the demands of acute scaphoid trauma investigation with early MRI, this clearly offers significant advantages for both the patient and the trust. It must be borne in mind, however, that when consideration is given to the concomitant imaging demand, local resources and expertise, accessibility, financial implications, and patient preference, there is a strong argument for CT as an accurate and reliable alternative. As discussed, apart from being marginally less sensitive than MRI, it matches the specificity and, in certain areas, excels beyond the capabilities of even the most modern MRI techniques.

Overall, as is the current practice in the authors' trust, CT imaging is considered to be of value in the initial assessment of radiographically occult scaphoid fractures. MRI can be reserved for patients who are CT negative, but have persistent symptoms at the 1-month interval to exclude the rare, but significant, complication of ligamentous injury.

Conflict of interest

The authors declare no conflict of interest.

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