Assessment of the suspected fracture of the scaphoid

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A suspected fracture of the scaphoid remains difficult to manage despite advances in knowledge and imaging methods. Immobilisation and restriction of activities in a young and active patient must be balanced against the risks of nonunion associated with an undiagnosed and undertreated fracture of the scaphoid.

The assessment of diagnostic tests for a suspected fracture of the scaphoid must take into account two important factors. First, the prevalence of true fractures among suspected fractures is low, which greatly reduces the probability that a positive test will correspond with a true fracture, as false positives are nearly as common as true positives. This situation is accounted for by Bayesian statistics. Secondly, there is no agreed reference standard for a true fracture, which necessitates the need for an alternative method of calculating diagnostic performance characteristics, based upon a statistical method which identifies clinical factors tending to associate (latent classes) in patients with a high probability of fracture.

The most successful diagnostic test to date is MRI, but in low-prevalence situations the positive predictive value of MRI is only 88%, and new data have documented the potential for false positive scans. The best strategy for improving the diagnosis of true fractures among suspected fractures of the scaphoid may well be to develop a clinical prediction rule incorporating a set of demographic and clinical factors which together increase the pre-test probability of a fracture of the scaphoid, in addition to developing increasingly sophisticated radiological tests.

Some patients with a fracture of the scaphoid have normal initial radiographs.1-3 Given the potential for nonunion and degenerative change with a missed fracture,4-6 patients with an injury and clinical signs consistent with a fracture but whose initial radiographs are normal are usually considered to have a ‘suspected’ fracture.2,3,7 Those who are subsequently confirmed as having a fracture, often between 10 and 14 days post injury, are said to have initially had an ‘occult’ fracture of the scaphoid.2,8,9

A consequence of over-sensitive clinical signs and treating all suspected fractures is that patients often receive unnecessary treatment and imaging.7,8,10 This can lead to stiffness of the wrist, costs to the healthcare system and to the patient for time off work, and an inability to play sport.11-14 Previously, improved imaging has been used in an attempt to establish a definitive early diagnosis in order to limit immobilisation and further diagnostic testing.11,13-19 However, imaging has proved inadequate because of the low prevalence of true fractures among suspected fractures of the scaphoid, which magnifies the weaknesses of even the most sensitive and specific diagnostic tests.20,22 Furthermore, research is hindered by the lack of a consensus regarding a reference standard for a true fracture.20,21,23

In this paper we describe the demographic and clinical features of a suspected fracture of the scaphoid as well as the merits of the various available diagnostic imaging techniques. We also discuss the potential future directions for research in this area.

Anatomy

The scaphoid is a small, irregular S-shaped tubular bone in the proximal carpal row on the radial aspect of the wrist.1 It acts as a mid-carpal joint ‘bridge’ connecting and synchronising the movements of the proximal and distal carpal rows. Over 80% of its surface is covered with articular cartilage that articulates with the radius (proximal/lateral surface), capitate (medial surface), lunate (medial surface) and trapezium/trapezoid (distal surface) bones.
The non-articular dorsoradial surface of the scaphoid is the site of its few ligamentous attachments, including the scapholunate interosseous ligament and the intercarpal ligament. The short intrinsic ligaments attach the scaphoid to the lunate and merge with the extrinsic ligaments and capsule of the wrist. The radioscapophacitate ligament acts as a sling across the waist of the scaphoid. No tendons attach to the surface of the scaphoid.

The blood supply is through soft-tissue attachments via two vascular pedicles originating from the scaphoid branches of the radial artery, with the waist of the scaphoid having minimal or no perforating vessels.

**Epidemiology and demographic risk factors**

The incidence of a fracture of the scaphoid is quoted in the literature to range between 1.5 and 121 per 100,000 persons per year. This wide variation may be due to the use of retrospective data, variations in population subsets, and the limitation of many databases in distinguishing between true and suspected fractures. The lower estimates are probably more accurate, given that the estimated incidence of a fracture of the distal radius is 195 per 100,000 persons per year and that fractures of the scaphoid account for approximately 2.4% of all wrist fractures.

The mean age of patients with a fracture of the scaphoid ranges between 25 and 35 years, with a male predominance, which most closely fits a type B (unimodal young male) distribution. In fact, in one study male gender was a predictor of true fracture among suspected fractures.

A fracture of the scaphoid is usually the result of a fall on to the outstretched hand or a sports injury, with one study finding that sports injuries are commonly associated with a true fracture. An American study found that sports associated with a high risk of fracture were basketball, cycling and skateboarding, with a link to male gender seen in the majority. A fracture of the scaphoid has also been increasingly documented after a punch injury.

**Evaluating diagnostic tests**

So far, the dilemma of a suspected fracture of the scaphoid has been approached with the view that if we had a better radiological test, we would not miss any fractures. Unfortunately, this approach has not worked. The scientific data regarding clinical tests and diagnostic imaging of a suspected fracture of the scaphoid are confusing. The sensitivities and specificities substantially vary between studies and the best diagnostic performance characteristics seem to be reported by advocates of a specific technique. The calculation of diagnostic performance characteristics such as sensitivity, specificity, positive and negative predictive values, and accuracy, with traditional formulae requires a consensus reference standard for the presence or absence of disease. The images produced by current MRI scanners are so clear that many believe this is the ideal diagnostic test for detecting true fractures. However, it is difficult to test this hypothesis as there is no consensus reference standard for the presence of a true fracture of the scaphoid. Perhaps the most common standard is the absence of a fracture on radiographs six weeks after injury.

Latent class analysis is an alternative statistical method which does not rely on a reference standard. It looks for clinical factors (hidden or latent classes) which associate in patients with a high probability of disease. This technique has been applied to other illnesses with no consensus reference standard, such as carpal tunnel syndrome. A recent, as yet unpublished study applied latent class analysis to data from two prospective cohort studies of patients with a suspected fracture of the scaphoid and found small but potentially important differences from the traditional calculations based on a reference standard.

Another issue that hinders effective diagnosis is the low prevalence of true fractures among patients with a suspected fracture. Previous studies have found that between 5% and 20% of patients who attend the emergency department with a suspected fracture of the scaphoid are ultimately found to have a fracture. Given that false positives and false negatives are between 5% and 10% for most diagnostic tests, this low prevalence of disease leads to low positive predictive values according to Bayes’ theorem, even when the diagnostic test is highly sensitive and specific (Fig. 1). The importance of these two factors, the lack of an agreed reference standard and the low prevalence of a true fracture of the scaphoid among suspected fractures, cannot be overstated. They emphasise that our traditional goal of an all-or-nothing diagnosis of a fracture of the scaphoid may be unreachable, and that it is more appropriate to understand that each individual patient has a probability of a true fracture that rarely if ever reaches zero or 100%. The statistical strategies of latent class

<table>
<thead>
<tr>
<th>Clinical sign</th>
<th>Sensitivity (%)</th>
<th>PPV* (%)</th>
<th>Specificity (%)</th>
<th>NPV† (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASB‡ tenderness</td>
<td>100</td>
<td>30</td>
<td>19</td>
<td>100</td>
</tr>
<tr>
<td>Scaphoid tubercle tenderness</td>
<td>100</td>
<td>34</td>
<td>30</td>
<td>100</td>
</tr>
<tr>
<td>Longitudinal thumb compression</td>
<td>100</td>
<td>40</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>Reduced thumb movement</td>
<td>86</td>
<td>41</td>
<td>66</td>
<td>85</td>
</tr>
<tr>
<td>ASB swelling</td>
<td>61</td>
<td>50</td>
<td>52</td>
<td>58</td>
</tr>
<tr>
<td>ASB pain in ulnar deviation/pronation</td>
<td>83</td>
<td>44</td>
<td>17</td>
<td>56</td>
</tr>
<tr>
<td>ASB in radial deviation/pronation</td>
<td>70</td>
<td>45</td>
<td>31</td>
<td>56</td>
</tr>
<tr>
<td>Pain on thumb/index pinch</td>
<td>48</td>
<td>44</td>
<td>31</td>
<td>41</td>
</tr>
<tr>
<td>Scaphoid shift test</td>
<td>66</td>
<td>49</td>
<td>31</td>
<td>69</td>
</tr>
</tbody>
</table>

* PPV, positive predictive value
† NPV, negative predictive value
‡ ASB, anatomical snuffbox

Parvizi et al45 examined the effect of combining clinical signs to improve the diagnostic specificity in a prospective study of 215 consecutive patients. They found that the use of one clinical sign in isolation was insufficient for the diagnosis of a fracture, but that a combination of anatomical snuffbox tenderness, tenderness of the scaphoid tubercle and anatomical snuffbox pain on longitudinal compression of the thumb generated a sensitivity of 100% and a specificity of 74%.

More recent studies have looked at other clinical signs as predictors of a fracture. Unay et al10 reviewed ten physical examination manoeuvres on 41 patients with a suspected fracture of the scaphoid and used MRI to determine the presence of a fracture. They found that pain on thumb-index finger pinch and anatomical snuffbox pain on pronation of the forearm were most suggestive of a bony injury in patients with a confirmed fracture of the scaphoid.

Rhemrev et al22 aimed to develop a clinical prediction rule using multivariate analysis to determine predictors of fracture, thereby potentially increasing the prevalence of a true fracture of the scaphoid in relation to a suspected fracture in order to improve the diagnostic accuracy of radiological tests. In 78 patients with a suspected fracture of the scaphoid they found that a reduction in extension of > 50%, supination strength of ≤ 10% and the history of a previous scaphoid fracture were the most predictive of a true fracture.22 As the tests examined in this study are not widely used, in particular the strength tests which require specific tools, general adoption of this rule is unlikely. However, this paper does demonstrate the potential for a clinical prediction rule to improve the management of a suspected fracture of the scaphoid.

Clinical assessment
A suspected fracture of the scaphoid is characterised by wrist pain with tenderness over the scaphoid after a fall, sports or punch injury, and normal scaphoid-specific radiographs. No single sign has been found to be adequately sensitive or specific (Table I).10,41-47 Initial studies in this area examined the sensitivity and specificity of individual clinical signs. Freeland41 reviewed 246 patients with a suspected fracture of the scaphoid and found that tenderness in the anatomical snuffbox had a sensitivity of 90% and a specificity of 40%, with tenderness of the scaphoid tubercle having a sensitivity of 87% and specificity of 57% for a scaphoid fracture. Powell et al44 performed a prospective analysis in 73 patients to determine the sensitivity and specificity of an alternative sign, anatomical snuffbox pain on ulnar deviation of the pronated wrist. They found a negative predictive value of 100% and suggested that patients with a negative test could be safely discharged from the emergency department.

Specific diagnostic imaging techniques
Radiographs. When a fracture of the scaphoid is suspected, neutral posteroanterior and lateral radiographs are insufficient.48 Further views suggested to improve the ability to diagnose a scaphoid fracture are:8,48 45° radial oblique
posteroanterior (semi-supinated) to detect proximal pole fractures, humpback deformities and avulsion fractures; 45° ulnar oblique posteroanterior (semi-pronated) to detect oblique sulcal, waist (in particular displaced) and tubercle fractures; ulnar-deviated posteroanterior to detect proximal pole fractures.

Ziter's view, or the 'banana view', uses a posteroanterior view of the wrist in ulnar deviation with 20° tube angulation to the elbow (Fig. 2). This is a modified view useful for identifying fractures of the waist of the scaphoid. Fractures oblique to the beam, however, are not well identified. Although not routinely used, carpal box views have been shown to increase agreement in the interpretation of the standard four-view scaphoid radiographs from 36% to 55%.50,51

Some studies claim that when clinical and radiological assessment is carried out by experienced staff, all occult fractures of the scaphoid are detected within six weeks.7,8 However, more consistently, between 30% and 40% of fractures are not identified on initial assessment and investigation with four-view radiographs.1-3,7,8,10,47,52,53 Low sensitivity on repeat radiological assessment has also been found, with one study52 finding that it only identified 50% of occult scaphoid fractures. Three potential reasons why radiographs of the scaphoid are often misinterpreted were suggested by Barton:7 a dark line may be formed by the dorsal lip of the radius overlapping the scaphoid; the presence of a white line formed by the proximal end of the scaphoid tuberosity; and the dorsal ridge of the scaphoid may appear bent on the semi-supinated view.

Scaphoid and pronator fat stripe signs have been demonstrated to be unreliable soft-tissue detectors for the presence of an occult fracture of the scaphoid.56 Given this, when clinical suspicion is present but radiographs are negative, immobilisation in a cast or splint is often recommended, with repeat examination and radiographs performed within 10 to 14 days of injury.

Ultrasound. Although non-invasive and relatively inexpensive, ultrasound examination is operator dependent and has been shown to be ineffective in detecting a true fracture, with a sensitivity ranging between 37% and 93% and a specificity between 61% and 91%.19,57,58 Some authors have reported the use of high spatial resolution sonography for the occult fracture of the scaphoid, with the sensitivity rising to 100% and specificity as high as 91%.15,59

Bone scintigraphy. Although there are advocates for bone scintigraphy,11,57,60,61 most authors feel that the specificity is too low compared with CT and MRI.21,37,62,63 In 43 patients with suspected fracture of the scaphoid, Fowler et al63 found that MRI was more sensitive and specific than bone scintigraphy, using one-year follow-up as the reference standard. However, Beeres et al61 looked at 100 similar patients and found that bone scintigraphy had a sensitivity of 100% and a specificity of 90%, and concluded that there was no advantage with MRI.

Computed tomography. Some authors advocate the use of CT for the diagnosis of a true fracture among suspected fractures of the scaphoid,62,64-67 although some have cautioned against its use for undisplaced fractures.20 Cruickshank et al64 looked at 47 patients with a suspected fracture of the scaphoid, using two-week radiographs and/or MRI as the reference standard. They found that early CT was 94.4% sensitive and 100% specific, with a negative predictive value of 96.8% and a positive predictive value of 100%. Furthermore, CT has been shown to be useful in detecting other injuries around
suspected fracture of the scaphoid and found an undisplaced valence of a scaphoid fracture among suspected fractures of unicortical fractures (Fig. 3). Perhaps due to vascular channels being misinterpreted as observer reliability, they found a notable false positive rate, uncertainty of the scaphoid. Despite substantial intra- and interobserver reliability of CT for the diagnosis of an undisplaced fracture from 30 patients to determine the intra- and interobserver analysis of diagnostic tests using an average published pre-research standard, and concluded that the sensitivity and specificity of MRI were 100%, with potential savings of $7200 per 100 000 of the population achieved by avoiding unnecessary immobilisation and review.68

However, Ring and Lozano-Calderón21 performed an analysis of diagnostic tests using an average published prevalence of a scaphoid fracture among suspected fractures of 7% (Table II). Using Bayesian formulae, the negative predictive value for MRI was 0.88, meaning that around 12% of patients with a suspected fracture of the scaphoid and an MRI interpreted as showing a fracture may not actually have a fracture. The potential for false positive MRI scans has been further demonstrated by one recent, as yet unpublished, study of MRI scans in healthy individuals that identified abnormalities diagnosed as fractures by several blinded radiologists.

Recently, Yin et al37 performed a meta-analysis of 26 studies to assess the prevalence-adjusted diagnostic accuracy of bone scintigraphy, CT and MRI for suspected fractures of the scaphoid. Nine studies used six-week radiological follow-up as their reference standard. Bone scintigraphy and MRI were shown to have comparably high sensitivity rates, although MRI was more specific for confirming a fracture of the scaphoid (Table III). Another recent prospective cohort study67 which used the absence of a fracture on six-week radiographs as the reference standard found that CT and MRI have comparable diagnostic performance characteristics for detecting a true fracture among suspected fractures of the scaphoid.

Ultimately, all radiological tests are better at excluding, rather than detecting, a true scaphoid fracture, with Bayes-adjusted negative predictive values of 98% or above for most tests. This is due largely to the low prevalence of true fractures among suspected fractures of the scaphoid, which may change if clinical prediction rules improve our ability to predict who is likely to have a true fracture prior to radiological testing.

### Table II. The sensitivity, specificity, accuracy and average prevalence-adjusted positive predictive value (PPV) and negative predictive value (NPV) for various imaging modalities as determined by Ring and Lozano-Calderón21 for a suspected fracture of the scaphoid.

<table>
<thead>
<tr>
<th>Imaging modality (number of studies assessed)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>Accuracy (%)</th>
<th>PPV</th>
<th>NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultrasound (n = 4)</td>
<td>93</td>
<td>89</td>
<td>92</td>
<td>0.38</td>
<td>0.99</td>
</tr>
<tr>
<td>Bone scintigraphy (n = 18)</td>
<td>96</td>
<td>89</td>
<td>93</td>
<td>0.39</td>
<td>0.99</td>
</tr>
<tr>
<td>CT (n = 8)</td>
<td>94</td>
<td>96</td>
<td>98</td>
<td>0.75</td>
<td>0.99</td>
</tr>
<tr>
<td>MRI (n = 22)</td>
<td>98</td>
<td>99</td>
<td>96</td>
<td>0.88</td>
<td>1.00</td>
</tr>
</tbody>
</table>

### Table III. The sensitivity and specificity as determined by Yin et al37 of different imaging techniques in the diagnosis of occult fractures to the scaphoid.

<table>
<thead>
<tr>
<th>Imaging modality (number of studies assessed)</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone scintigraphy (n = 15)</td>
<td>97</td>
<td>89</td>
</tr>
<tr>
<td>CT (n = 6)</td>
<td>93</td>
<td>99</td>
</tr>
<tr>
<td>MRI (n = 10)</td>
<td>96</td>
<td>99</td>
</tr>
</tbody>
</table>
criteria, clinical examination manoeuvres, and a wide range of definitions of a reference standard for a true fracture.

Future directions
Future research should attempt to identify demographic and clinical factors that are predictive of a true acute fracture of the scaphoid. A valid clinical prediction rule would improve the diagnostic performance of more sophisticated imaging by increasing the prevalence of a true fracture among suspected fractures. Given that even the clearest images are subject to misinterpretation (false positives), it may prove impossible to use imaging as a reference standard for a true fracture. Therefore, future research should use latent class analysis to estimate diagnostic performance characteristics.

Although ideally a fracture of the scaphoid would be an all-or-nothing diagnosis, we should accept that we are ultimately dealing with probabilities rather than certainties. The rational and effective management of a fracture of the scaphoid may require us to accept a given negative predictive value of diagnostic testing. In other words, if we cannot reduce the probability of missing a fracture to zero, perhaps 0.5% or lower (negative predictive value of 99.5% or greater) is reasonable and acceptable. It is unlikely that the Bayesian predictive value of even the best radiological tests will be better than 90% in the foreseeable future, so our management of the suspected scaphoid fracture should be tempered by an awareness of the potential for false positive diagnoses, particularly as screw fixation becomes an increasingly popular alternative to cast immobilisation.16

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References
2. Ring D, Jupiter JB, Herndon JH. Positive diagnoses, particularly as screw fixation becomes an increasingly popular alternative to cast immobilisation.16

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