Assessment of Recent Occult Scaphoid Fractures by High Resolution Sonography

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Abstract

Objective: To evaluate the diagnostic values of high-resolution sonography in the diagnosis of occult fractures of the scaphoid bone.

Subjects and Methods: Sonography of the scaphoid bone with a 10-MHz transducer was performed in 35 patients with clinically suspected scaphoid fracture and normal findings on initial radiographs, including specific scaphoid images. Three levels of clinical suspicion were considered: High (25%), moderate (32%) and low (43%). Attention was paid to the continuity of the scaphoid cortex and to the surrounding soft tissues (i.e., hemarthrosis or hematoma). Data from early sonograms were then compared with the results of radiography repeated 10–14 days after the initial trauma.

Results: Follow-up examinations (either radiographs, CT or MRI) proved fracture of the scaphoid in nine patients. In all patients, diagnosis of fracture was suspected on initial sonograms showing cortical disruption associated with soft-tissue abnormalities. There was no false-negative results. Overall accuracy of high resolution sonography for detection of scaphoid fractures was 92% with 100% sensitivity and 88% specificity. Using cortical disruption as a diagnostic criterion, we found the sensitivity, specificity, positive predictive value and negative predictive value of high-resolution sonography for the depiction of scaphoid fracture to be 100%. Using soft-tissue abnormalities alone as a criterion, we found the sensitivity, specificity, positive predictive value and negative predictive value of high-resolution sonography to be 77%, 88%, 70% and 92%, respectively. The overall prevalence of occult fracture was 26%, ranging from 8.6% for moderate suspicion to 17.4% for high suspicion of fracture and no for low suspicion.

Conclusion: High-resolution sonography is a reliable and accurate method of evaluating occult fractures of the scaphoid. Cortical disruption is the diagnostic key. Soft-tissue abnormalities alone lack sensitivity.

Key Words: High resolution sonography – Occult scaphoid fractures – Scaphoid bone.

Introduction

AMONG carpal fractures, scaphoid fractures are by far the most frequently observed. Scaphoid bone fractures represent 2% of all fractures but 75% of carpal fractures [1].

Early diagnosis of these fractures is crucial to initiate adequate therapy, which may help to prevent complications such as delayed healing, nonunion, pseudarthrosis, avascular necrosis and arthrosis of the wrist [1].

Immediately after injury, up to 25% of scaphoid fractures remain radiographically occult. Thus, in patients with proved scaphoid fractures and those suspected of having scaphoid fractures (i.e., occult scaphoid fractures), the wrist should be placed in a scaphoid cast for at least 10 days, until the scaphoid fracture is ruled out with follow-up radiographs. At this time, the sensitivity of radiograph elevates up to 90% because of resorption around the fracture line [2].

This strategy, however, means that some patients without a fracture would have their wrist immobilized for several days, which is inappropriate and results in both a reduction in the quality of life and an increase in health care costs [3].

In cases of clinically suspected scaphoid fractures with negative or equivocal findings on conventional radiographs obtained immediately after trauma, other diagnostic tools such as scintigraphy, intrasound vibration, computed tomography (CT), Magnetic resonance imaging (MRI) and ultrasonography have been proposed as second-line diagnostic tools [3].

CT imaging shows sensitivity and specificity greater than 92% and this figure increases with multi-detectors CT imaging [4].

Because of its excellent sensitivity (95%) and specificity (100%), magnetic resonance (MR) im-
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Aging has been advocated as the imaging modality of choice in these patients [5].

Technical improvements in ultrasonography have led to higher resolution of this diagnostic tool and thus, high-resolution ultrasonography (US) may depict subtle posttraumatic changes of the cortex and/or periosteum, which may already be present immediately after the injury but which are not depicted on conventional radiographs [6].

High-resolution ultrasonography (US) may be an alternative imaging modality in patients with scaphoid fractures because it offers high sensitivity (84%) and excellent specificity (100%) as recorded in recent studies [6].

High-resolution ultrasonography (US) is a non-invasive technique. Furthermore, high-resolution US, compared with MR imaging, is more readily accessible, less time-consuming and considerably less expensive [6].

The purpose of this prospectively descriptive designed study was to determine the diagnostic values of high-resolution sonography in diagnosis of recent occult scaphoid fractures in patients after acute wrist trauma using follow-up conventional X-ray after 2 weeks as a standard.

Material and Methods

Study population:

This prospective study involved 35 consecutive patients (32 males, 3 females; age range, 12-50 years; mean, 28 years) who presented at our hospital between January 2007 and July 2007 for clinical suspicion of scaphoid fracture after acute trauma of the wrist.

Clinical criteria for scaphoid fracture included pain, tenderness on axial loading of the first ray and swelling at the level of the anatomic snuff-box. If the three criteria were present, the suspicion of scaphoid fracture was considered high (25%, 9/35). If only pain and tenderness were present, suspicion was considered moderate (32%, 11/35). If only pain was present, suspicion was considered low (43%, 15/35). Mechanisms of injury were a fall on an outstretched hand (91%, 32/35) or direct trauma (9%, 3/35).

Initial radiographs included postero-anterior, lateral and posteroanterior images with the wrist in ulnar deviation. They were obtained within 72 hours of the trauma and were evaluated for scaphoid fracture signs (i.e., radiolucent line through the bone, cortical disruption, or cortical avulsion). Patients with initial radiographic evidence of a scaphoid fracture were excluded from the study.

Normal regional anatomy on radiographs and sonograms:

The scaphoid occupies a vulnerable position, bridging the proximal and distal rows of the carpus. On both radiographs and sonograms, the morphology of the scaphoid depends on the position of the wrist. The ulnar deviation elongates the scaphoid and affords the best view of the waist, the site of 70% of fractures. The radial deviation foreshortens the scaphoid and tends to obscure the presence of a fracture but affords visualization of the distal pole of the scaphoid. The radial margin of the waist of the scaphoid is the site of a small angular protuberance, the tubercle, corresponding to a frequent normal variant. An irregular pattern of this small protuberance can be mistaken for a fracture. On sonography, the cortex of the scaphoid is seen as a thin continuous and usually regular echogenic line, except for the tubercle area in which the cortex may appear irregular. A particularity of the scaphoid bone is the absence of periosteum, which explains why fracture healing occurs without periosteal callus formation. Seventy-five percent of the surface of the scaphoid is covered with cartilage, which facilitates mobilization with adjacent bones. The remaining 25% allows attachment of ligaments and tendons.

Sonography:

After informed consent of the patient was obtained, sonography of the scaphoid bone was performed with a sonographic system by using a high-spatial-resolution 10-MHz transducer. Comparative sonography of both normal and painful wrists was performed within 72 hours of trauma. Patients were seated upright in front of the radiologist. The scaphoid bone was scanned in the longitudinal and transverse planes, from the dorsal and lateral directions, in both normal and ulnar deviation positions to elongate the scaphoid. The ulnar deviation in the lateral direction was obtained by placing a support on the ulnar side of the wrist (Fig. 1). Attention was paid to the continuity of the anterior echogenic margin of the scaphoid corresponding to the cortex and the surrounding soft tissues.

Scaphoid fracture was considered if the cortex was discontinuous. Two types of soft-tissue abnormalities were reported: Hemarthrosis, defined as a diffuse and compressible collection and hematoma, defined as a focal and incompressible collection located at the level of the scaphoid. Sonographic
examinations were interpreted immediately without knowledge of the follow-up radiographic findings.

Clinical and radiologic follow-up:

The same protocol of conventional radiography was repeated 14 days after the initial trauma for all patients. Diagnosis of initially occult scaphoid fracture was based on visualization on follow-up radiographs of a fracture line through the bone, cortical disruption, or cortical avulsion. Absence of a fracture was confirmed by the resolution of the clinical signs associated with the absence of a fracture line on follow-up radiographs. If suspicion of a fracture still persisted despite normal findings on follow-up radiographs, other diagnostic techniques were performed to obtain a diagnostic clue. These examinations consisted of CT (three patients) or MR imaging (two patients). Results from the follow-up examinations were finally compared with the initial sonographic findings.

Results

Nine patients (26%) were finally diagnosed to have scaphoid fracture. Six patients (17%) were diagnosed by two-weeks follow-up X-ray (Fig. 2) while two patients (6%) were diagnosed by computed tomography (CT) (Fig. 3) and one patient (3%) was diagnosed by magnetic resonance imaging (MRI), (Table 1).

Sensitivity, specificity, positive predictive value and negative predictive value were calculated for high resolution sonography in comparison to final diagnosis of scaphoid fracture.

High resolution sonography of nine patients who diagnosed to have scaphoid fracture showed cortical disruption while seven (77% of fractured patients) showed soft tissue abnormalities. Also, soft tissue abnormalities were seen on three patients (9%) who diagnosed to have no scaphoid fracture, (Table 2). Follow-up sonography of these three patients showed resolution of these findings with clinical improvement and absent fracture on follow-up radiograph or other used modalities (Fig. 4).

Cortical disruption of scaphoid bone by US was found to be a highly sensitive and specific sonographic finding in diagnosis of scaphoid fracture reaching 100%, with almost 100% positive and negative predictive values.

Soft tissue abnormalities (either hemoarthrosis or hematoma) around scaphoid bone by US were found to be a sensitive (77%) and a high specific (88%) finding in diagnosis of scaphoid fracture, with positive predictive value reaching about 70% and negative predictive value of 92%.

Overall, high resolution sonography of scaphoid bone was found to be a very sensitive (100%) and a high specific (88%) modality for diagnosis of scaphoid fracture. A high negative predictive value of high resolution US was noted reaching 100% and a positive predictive value of 75%.
Fig. (2): A 24 years old male patient with acute trauma of left wrist and high suspicion of scaphoid fracture; (A) initial normal radiograph of Lt. Scaphoid bone, (B) Longitudinal sonograms of Lt. scaphoid in ulnar deviation of the wrist with cortical disruption (white arrow) & non-compressible hematoma (between two cursors) noted and (C) two-weeks follow-up radiograph of Lt. scaphoid showed fracture line within the scaphoid waist (white arrow).

Fig. (3): A 26 years old male patient with acute trauma of right wrist and moderate suspicion of scaphoid fracture; (A) initial normal radiograph of Rt. Scaphoid bone, (B) Longitudinal sonograms of Rt. scaphoid in ulnar deviation of the wrist with cortical disruption (white arrow) noted and (C) CT scan with MPR images of Rt. scaphoid bone showed fracture line (arrow) at proximal pole of the scaphoid.

Fig. (4): A 14 years old male patient with acute trauma of right wrist and high suspicion of scaphoid fracture with initial normal radiograph of Rt. Scaphoid bone, (A) Longitudinal sonograms of Rt. scaphoid in ulnar deviation of the wrist showed evidence of hematoma (black arrow) at initial sonogram that was resolved on follow-up sonogram after two-weeks (B). MRI of Rt. wrist (STIR image) showed no evidence of scaphoid injury but capitate bone bruise was noted (white arrow).
Table (1): Final diagnosis of patients who proved to have scaphoid fracture by different follow-up modalities.

<table>
<thead>
<tr>
<th>Modality of diagnosis</th>
<th>Fracture</th>
<th>No fracture</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 weeks X-ray</td>
<td>6</td>
<td>24</td>
<td>30 (85%)</td>
</tr>
<tr>
<td>CT</td>
<td>2</td>
<td>1</td>
<td>3 (9%)</td>
</tr>
<tr>
<td>MRI</td>
<td>1</td>
<td>1</td>
<td>2 (6%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9 (26%)</strong></td>
<td><strong>26 (74%)</strong></td>
<td><strong>35</strong></td>
</tr>
</tbody>
</table>

**Table (2): Comparison of initial sonographic findings on all patients to the final diagnosis of scaphoid fracture.**

<table>
<thead>
<tr>
<th>Final diagnosis</th>
<th>Cortical disruption</th>
<th>Soft tissue abnormal-lities</th>
<th>No abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaphoid fracture</td>
<td>9 (100%)</td>
<td>7 (70%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>No fracture</td>
<td>0 (0%)</td>
<td>3 (30%)</td>
<td>23 (100%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9</strong></td>
<td><strong>10</strong></td>
<td><strong>23</strong></td>
</tr>
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</table>

**Discussion**

Scaphoid fractures are the most common fractures of the carpal bones [3]. Scaphoid fractures are complicated because of possible severe and long-lasting sequelae. Despite extended radiologic work-up with conventional radiography, about one-third of scaphoid fractures remain occult and thus, the diagnosis of scaphoid fractures remains a challenge for the radiologist [7].

In our study, we found that high-resolution sonography is a reliable and accurate method of evaluating occult fractures of the scaphoid. Cortical disruption is the reliable diagnostic finding. Soft-tissue abnormalities alone can’t be conclusive.

We found that all patients with evidence of cortical disruption had proven scaphoid fractures on follow-up radiographs or other modalities. No false-positive or false-negative results were observed. In total, none of the patients with soft-tissue abnormalities alone (i.e., without cortical disruption) had a confirmed scaphoid fracture on follow-up radiographs or other modalities. Among the all patients without cortical disruption and soft-tissue abnormality on initial examination, follow-up radiographic findings were considered normal in all patients. Using cortical disruption as the diagnostic key of fracture, we found the sensitivity, specificity, positive predictive value and negative predictive value of sonography for early detection of occult scaphoid fractures to be 100%, 98%, 83% and 100%, respectively. If soft-tissue abnormalities alone (i.e., hematoma or hemarthrosis) were used as the criterion of fracture, the sensitivity, specificity, positive predictive value and negative predictive value of sonography for early detection of occult scaphoid fractures to be 100%, 98%, 83% and 100%, respectively. If soft-tissue abnormalities alone (i.e., hematoma or hemarthrosis) were used as the criterion of fracture, the sensitivity, specificity, positive predictive value and negative predictive value of sonography for early detection of occult scaphoid fractures to be 100%, 65%, 23% and 100%, respectively [6].

Comparing the previous results with our results showed good agreement in sensitivity, specificity and negative & positive predictive values. Furthermore, our study seemed to be superior to this study as we have no false positive cases as we excluded elderly patients above 50 years old. This exclusion aimed to avoid delay of visualization of fracture line on follow-up X-ray and was also helpful to avoid visualization of degenerative changes of the wrist that may misinterpreted as cortical disruption.

Herneth et al. [8] found that high-spatial-resolution US is a reliable diagnostic tool for the evaluation of occult scaphoid fractures and should be considered an adequate alternative diagnostic tool prior to computed tomography or MR imaging.
By using a high-spatial resolution (10-5-MHz) linear probe, they found (78%) of patient with proved scaphoid fractures by MRI had positive results, with no false-positive results and two false-negative results. The accuracy (87%) of high-spatial-resolution US in depicting scaphoid fractures substantially higher compared with the accuracy of conventional radiographs. The positive predictive value was 100%. The negative predictive value of high spatial-resolution US was 75% versus 60% for conventional radiography. At high-spatial-resolution US, cortical discontinuity was the most accurate findings of scaphoid fracture [8].

The findings of this study further demonstrate the capability of US to depict periosteal changes, which were seen in three (43%) of seven patients with scaphoid fractures, have not yet been reported as a feature of US. Particularly in patients with trabecular scaphoid fractures (scaphoid bruises) where no cortical changes are evident on conventional radiographs, periosteal elevation may be the only US finding suggestive of a scaphoid fracture. Because these changes are discrete, they may not be visible on conventional radiographs.

A limitation of this study is the relatively small number of occult scaphoid fractures examined. Also, they included scaphoid bone bruises on positive scaphoid fracture cases as trabecular scaphoid fracture that increased number of false negative cases. Finally, this study has emphasized the importance of the subperiosteal hematoma as an indirect sign of fracture. However, the hypothesis seems unlikely because the scaphoid, which is almost entirely covered by cartilage, has the particularity of not being surrounded by periosteum [9]. It is believed by Hauger et al. [6] that this finding corresponds to a positive echo signal of the anterior interface of the cartilage induced by a high gain level, but no fracture was found on follow-up examination.

Senall et al. (2004) recommend that high-frequency ultrasound be used to investigate occult suspected scaphoid fractures because of its ability to allow early diagnosis and to eliminate the need for a more invasive or expensive diagnostic test in most cases. By using a high-spatial resolution (10-5-MHz) linear probe, they found that sensitivity of high-frequency ultrasound in detection of occult scaphoid fracture was 78% and specificity was 89%. The positive predictive value was 88% and negative predictive value was 80% [10].

Only one study by Munk et al. (2000) concluded that ultrasound examination is unreliable for the diagnosis of acute scaphoid fractures. By using two high-resolution linear probes (5 & 7.5-MHz), they found that the accuracy of the ultrasound assessment for detection of scaphoid fracture was 84% and its specificity was 91%. However, its sensitivity was only 50% [11].

Overall, the study by Hauger et al. (2002) [6] and our study scored the highest sensitivity, specificity, positive predictive value and negative predictive value of sonography for early detection of occult fractures. Using various direct and indirect criteria, most authors found a sensitivity ranging from 50% to 100% and a specificity from 74% to 100% for the depiction of all types of fractures (occult or not). Our results as well as Hauger et al. [6] results, appeared superior with a sensitivity and specificity of 100% and ranging fro 88% to 98% respectively, which may be explained by three main reasons: First, technical improvements in sonography leading to higher spatial resolution, especially with the 10 & 12-MHz transducer used in this study allowing depiction of subtle posttraumatic changes; second, the use of stringent criteria (i.e., disruption of the cortex) to confirm the diagnosis of fracture. Most previous studies used less stringent criteria such as soft-tissue changes, which may also occur after a wrist sprain. Third, most of occult fractures depicted in these to studies involved the waist of the scaphoid, which is the most common site of fracture but also the easiest area to analyze on sonography. Fractures of the distal and especially the proximal poles of the scaphoid would likely be diagnostically more challenging.

The cortical disruption was associated with either hemarthrosis or hematoma in most of our study patients as well as Hauger et al. [6] patients. However, soft-tissue abnormalities alone cannot be considered as a strong indicator of scaphoid fractures because they can be related to other internal lesions such as intrinsic ligament tears and wrist joint sprains.

In conclusion, high-resolution sonography appears to be a reliable, accurate, available and cost-effective method for evaluating occult fractures of the waist of the scaphoid. Diagnosis is based on cortical disruption associated with soft-tissue abnormalities, which alone are not a specific sign of fracture. Early evaluation of the scaphoid bone after wrist trauma is important to initiate prompt treatment in cases of occult fracture, because early treatment substantially decreases the rate of complication and avoids overtreatment of patients without fracture.
References