Jpn J Radiol (2011) 29:98–103
DOI 10.1007/s11604-010-0520-3

ORIGINAL ARTICLE

Diagnostic accuracy of multidetector computed tomography for patients with suspected scaphoid fractures and negative radiographic examinations

Ahmet Turan Ilica · Selahattin Ozyurek
Ozkan Kose · Murat Durusu

Received: December 21, 2009 / Accepted: September 7, 2010

Abstract
Purpose. The aim of this prospective study was to evaluate the diagnostic accuracy of multidetector computed tomography (MDCT) in detecting occult scaphoid fractures.
Materials and methods. A total of 54 patients with a clinically suspected scaphoid fracture and negative initial conventional radiographs were evaluated with 64-row MDCT wrist examinations within 1 week of the trauma. The gold standard used was the diagnosis on MRI done within 1 week after MDCT. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) of MDCT were calculated.
Results. MRI showed a total of 22 fractures in 20 of 55 (36%) wrists. Fractures included 14 scaphoid and 8 other carpal bones. MDCT showed a total of 19 fractures in 17 of 55 (30%) wrists. Two isolated scaphoid fractures and one trapezium fracture were missed on MDCT. The sensitivity, specificity, PPV, and NPV of MDCT were 86%, 100%, 100%, and 91%, respectively.
Conclusion. MDCT offers highly accurate results, especially concerning cortical involvement, and is a useful alternative in facilities lacking MRI.

Key words Scaphoid bone · Occult fractures · Tomography · Magnetic resonance imaging

A.T. Ilica
Department of Radiology, Gulhane Military Medical Academy, Ankara, Turkey

S. Ozyurek
Orthopaedics and Traumatology Clinic, Izmir Military Hospital, Izmir Turkey

O. Kose (✉)
Orthopaedics and Traumatology Clinic, Diyarbakir State Hospital, Diclekent Bulvari, Ataslar Serhat Evleri, D Blok Daire 13, Kayapinar, Diyarbakir, Turkey
Tel. +90-505-524-7976; Fax +90-532-642-2612
e-mail: drozkankose@hotmail.com

M. Durusu
Department of Emergency Medicine, Gulhane Military Medical Academy, Ankara, Turkey

Introduction

Fracture of the scaphoid bone is the most common fracture of the carpal bones.[1] The diagnosis of a scaphoid fracture can usually be established on the basis of clinical presentation and conventional radiographs.[2] However, a meta-analysis has shown that approximately 16% of scaphoid fractures remain radiographically occult immediately after the trauma.[3] When diagnosis and treatment are delayed, these fractures have been reported to have a high rate of complications and long-term sequelae including delayed union, nonunion, avascular necrosis, and secondary osteoarthritis.[4] As the prevalence of true fractures among patients with suspected scaphoid fractures might be only 5%–10%, most of these patients are overtreated, which results in lost work days and productivity and increased health care costs.[5–9]

Initial standard radiography cannot detect all scaphoid fractures. Additional projections (i.e., scaphoid views) and/or magnification views have been reported to increase sensitivity.[10] On the other hand, serial radiographic controls do not lead to improved diagnostic accuracy and cannot prevent unnecessary immobilization in most patients.[11] The relatively low sensitivity and specificity of radiography necessitates the use of advanced imaging techniques for earlier fracture detection.

Computed tomography (CT), magnetic resonance imaging (MRI), scintigraphy, and ultrasonography (US) have already been recommended for early definitive diagnosis of occult scaphoid fractures.[3,7,11–13] MRI has been reported to be an effective method for detecting occult scaphoid fractures with an average sensitivity and specificity of 96% and 99% respectively.[14] The recent advent of multidetector technology has revolutionized the CT technique. It is possible to obtain thinner slices with multiplanar reconstructions at faster examination times with new generation multidetector CT (MDCT) systems. These advances allow improved demonstration of bone cortex and trabecular patterns. The purpose of this prospective study was to evaluate the diagnostic accuracy of MDCT for detecting occult scaphoid fractures.

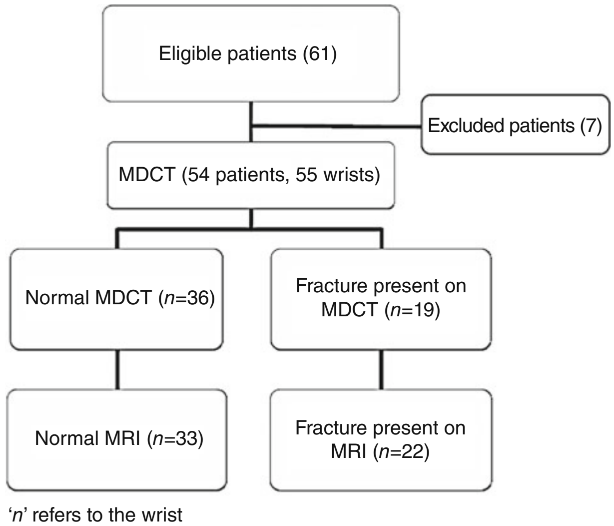

Fig. 1. Flow diagram of the patients with a clinically suspected scaphoid fracture and negative initial posttrauma conventional radiographs included in this study. *n*, number; *MDCT*, multidetector computed tomography; *MRI*, magnetic resonance imaging

Materials and methods

This prospective study was performed between December 2007 and November 2008. The local ethics committee approved the study, and all patients gave written informed consent.

Patients

Initially, 61 patients (all men; mean age 22 years, range 20–40 years) were included in the study. Seven patients did not return for MRI examinations and were excluded from the study. In all, 54 patients with a clinically suspected scaphoid fracture and negative initial posttrauma conventional radiographs were included. One patient underwent these procedures for both wrists (Fig. 1). On physical examination, all patients had tenderness and pain in the anatomical snuff-box and scaphoid tubercle. Patients admitted more than 72 h after the trauma were excluded from the study. Patients less than 18 years of age were excluded from the study.

Initial radiographic examination and treatment

Initial radiographs consisted of the following three projections: posteroanterior with the wrist in maximum ulnar deviation; lateral view; and semi-supinated oblique (scaphoid) view. All radiographs were interpreted by a consultant orthopedic surgeon and confirmed by a radiologist. Patients with unremarkable initial radiographs (without a sharp radiolucent line in the trabecular pattern, a distinct break of the cortex, or a sharp step-off in the cortex) were evaluated by both MRI and MDCT wrist examinations within 1 week after trauma. Scaphoid casts were applied to all patients until a definitive diagnosis was reached with MRI. Casting was discontinued upon receiving negative results.

MRI

The MRI scans were obtained on a Signa 1.5-T MR system (GE Medical Systems, Milwaukee, WI, USA) with a dedicated wrist coil. All examinations were performed in the prone position with the affected arm above the body. The following sequences were used on each patient: coronal and axial Tl-weighted fast spin-echo (TR/TE 360–600/10–20; 3- to 5-mm slice thickness with a 0.5-mm gap); coronal and axial fat saturated proton density-weighted fast spin-echo with fat saturation (TR/TE 2100–2800/30–44; 3- to 5-mm slice thickness with 0.5–1.0-mm gap); coronal T2*-weighted (TR/TE 350–500/10; 20° flip angle; 3-mm slice thickness). The field of view (FOV) was 120 mm. MRI scans were evaluated by two radiologists who were blinded to clinical measures, ending in consensus. A fracture was diagnosed if there was evidence of a cortical fracture line, a trabecular fracture line, or a combination of these abnormalities. Diffuse bone marrow abnormality was determined as bone marrow edema but not a true fracture.

MDCT

All patients underwent CT examination using a 64-detector multislice system (Brillance 64; Philips, Best, The Netherlands). The patient was positioned prone with the hand above the head and the wrist placed flat on the CT table. Acquisition occurred using the 0.6-mm detectors, and slices were reconstructed in 0.9-mm widths. Routine MDCT examinations of the wrist were performed as presented in Table 1. The images were then transferred to a workstation (Extended Brillance TM; Philips). CT images were reviewed by two radiologists who had performed MDCT examinations for 4 years, ending in consensus. The radiologists revised CT images before MRI was undertaken in each patient. Both radiologists were blinded to MRI findings. Images were viewed in interactive cine mode with axial images, supplemented by two- and three-dimensional (2D and 3D) postprocessing techniques, including multiplanar reformations (MPR), maximum-intensity projection (MIP), and volume-rendering techniques (VRT). All reformations were created by the radiologists in real time at the workstation on the same day of examinations. Both radiologists subjectively adjusted display parameters, including width, level, opacity, and brightness. Reformations lasted approximately 15 min for each radiologist.

Statistical analysis

A descriptive analysis of the detected fractures was performed. The sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were then calculated for MDCT.

Table 1. Acquisition and reconstruction parameters of 64-MDCT for wrist examination

	Parameter Data
Acquisition parameters	
Tube voltage (kVp)	120
Effective tube current–time (mAs)	300
Detector collimation (mm)	20 × 0.625
Beam pitch	0.654
Rotation time (s)	0.75
Field of view (cm)	10–12
Reconstruction parameters	
Reconstruction thickness (mm)	0.9
Reconstruction increment (mm)	0.45
Postprocessing kernel	Standard B
Surview	
Tube potential (kV)	120
Tube current–time (mAs)	30
Field of view (mm)	500

64-MDCT, 64-row multidetector computed tomography

Results

The study population consisted of 54 patients (all men; mean age 22 years, range 20–40 years). One patient had bilateral wrist trauma and underwent radiography, MDCT, and MRI evaluation of both wrists; hence, a total of 55 wrists were evaluated in our study. MRI showed a total of 22 fractures in 20 of 55 (36%) wrists. Carpal fractures included those of the scaphoid ($n = 16$), hamate ($n = 2$) trapezoideum ($n = 2$), triquetrum ($n = 1$), and trapezium ($n = 1$) (Table 2). Altogether, 35 wrists ($n = 35$) had no fracture at all. MDCT showed 19 fractures in 17 of 55 (30%) wrists. Two scaphoid fractures and one trapezium fracture were missed (Figs. 2, 3). These fractures were purely trabecular fractures without cortical disruption or discontinuity on MRI. These fractures shown on MRI but without a fracture line on the MDCT did well without operation and had healed on clinical follow-up. The sensitivity, specificity, PPV, and NPV of MDCT were 86%, 100%, 100%, and 91%, respectively (Table 3).

Discussion

Magnetic resonance imaging may be used in patients with suspected scaphoid fractures when the radiographs are negative.[14,15] The American College of Radiology rates MRI as the best diagnostic imaging modality for occult scaphoid fracture detection.[16] Unfortunately, in most emergency settings, MRI is not available in our country.

Therefore, MDCT is an alternative imaging modality. Current MDCT scanners can obtain slice thicknesses of <1 mm, which makes it possible to acquire a nearly isotropic data set with high spatial resolution and reduced partial volume effects in any plane.[17,18]

However, for a fracture to be demonstrated on MDCT, cortical and/or trabecular displacement or discontinuity should be present. In our study, all of the missed fractures on MDCT were purely trabecular with no cortical discontinuity. Although thinner slices and multiplanar reformation were used, there were three false-negative results.

Table 2. Distribution of carpal fractures

Fractured carpal bone	No.
Scaphoid	16
Trapezoideum	2
Hamate	2
Trapezium	1
Triquetrum	1

Fig. 2. a Fat-suppressed coronal T2-weighted MRI shows an oblique-transverse fracture line (*arrowhead*). Neither coronal (**b**) nor axial (**c**) reformatted wrist MDCT images show a fracture (*arrow*). Follow-up radiograph (**d**) did not revealed a fracture of the scaphoid

These fractures are said to be stable and less likely to result with nonunion.[11] Nevertheless, there is not enough evidence yet to prove that purely trabecular fractures require a shorter period of immobilization or no immobilization at all. Of the 22 fractures shown on MRI but without a fracture line on MDCT, 3 did well without operation and healed on clinical follow-up. MDCT also provides information on the degree of angulation and displacement, which might influence the management and surgical planning. Nevertheless, MDCT is not a totally safe method because there is radiation exposure.

This study has several strong and weak points. First, we used MRI as a reference, which is highly sensitive and specific; and two radiologist made the diagnosis with consensus. Second, all patients were followed until fracture union. One of the weak points of the study is the limited number of patients. Moreover, as there were a larger number of fractures in the study group (36%) than were cited in the literature, there might have been a selection bias during inclusion of the patients. Excluding the seven patients who did not return to MRI may have also affected selection bias. Other limitations are that the radiographic technique was not standardized due to busy clinical circumstances so no additional views were obtained. Finally, the reproducibility of MRI and CT readings, including cortical and medullary involvement, was not tested''.

Conclusion

Although MRI remains the best diagnostic tool after radiography for detecting occult scaphoid fractures, MDCT offers highly accurate results, especially concerning cortical involvement, and is a useful alternative in facilities lacking MRI capability.

Fig. 3. **a** Coronal T1-weighted MRI shows an oblique-transverse fracture line (*arrow*). **b**, **c** Coronal and axial and coronal MDCT images show no obvious fracture line (*arrows*). **d** Follow-up radiograph did not reveal a fracture of the scaphoid

Table 3. Diagnostic accuracy of MDCT

MDCT finding	MRI finding: Fracture[a]	MRI finding: Normal[b]	Total	Predictive value
Fracture	19	0	19	PPV 100%
Normal	3	33	36	NPV 91%
Total	22	33	55	

MRI, magnetic resonance imaging; PPV, positive predictive value; NPV, negative predictive value
[a] Sensitivity 86%
[b] Specificity 100%

References

1. Canale ST. Campbell's operative orthopaedics. 10th edn. St. Louis: Mosby; 2003. p. 3553.
2. Cheung GC, Lever CJ, Morris AD. X-ray diagnosis of acute scaphoid fractures. J Hand Surg Br 2006;31:104–9.
3. Hunter JC, Escobedo EM, Wilson AJ, Hanel DP, Zink-Brody GC, Mann FA. MR imaging of clinically suspected scaphoid fractures. AJR Am J Roentgenol 1997;168:1287–93.
4. Langhoff O, Andersen JL. Consequences of late immobilization of scaphoid fractures. J Hand Surg Br 1988;13: 77–9.
5. Young MR. Lowry JH, McLeod NW, Crone RS. Clinical carpal scaphoid injuries. BMJ (Clin Res Ed) 1988;19; 296:825–6.
6. Adey L, Souer JS, Lozano-Calderon S, Palmer W, Lee SG, Ring D. Computed tomography of suspected scaphoid fractures. J Hand Surg Am 2007;32:61.

7. Brydie A, Raby N. Early MRI in the management of clinical scaphoid fracture. Br J Radiol 2003;76:296–300.
8. Staniforth P. Scaphoid fractures and wrist pain: time for new thinking. Injury 1991;22:435–6.
9. Dorsay TA, Major NM, Helms CA. Cost-effectiveness of immediate MR imaging versus traditional follow-up for revealing radiographically occult scaphoid fractures. AJR Am J Roentgenol 2001;177:1257–63.
10. Mehta M, Brautigan MW. Fracture of carpal navicular: efficacy of clinical findings and improved diagnosis of six view radiography. Ann Emerg Med 1990;19:255–7.
11. Memarsadeghi M, Breitenseher MJ, Schaefer-Prokop C, Weber M, Aldrian S, Gabler C, et al. Occult scaphoid fractures: comparison of multidetector CT and MR imaging: initial experience. Radiology 2006;240:169–76.
12. Fowler C, Sullivan B, Williams LA, McCarthy G, Savage R, Palmer A. A comparison of bone scintigraphy and MRI in the early diagnosis of the occult scaphoid waist fracture. Skeletal Radiol 1998;27:683–7.
13. Herneth AM, Siegmeth A, Bader TR, Ba-Ssalamah A, Lechner G, Metz VM, et al. Scaphoid fractures: evaluation with high-spatial-resolution US initial results. Radiology 2001;220: 231–5.
14. Yin ZG, Zhang JB, Kan SL, Wang XG. Diagnosing suspected scaphoid fractures: a systematic review and meta-analysis. Clin Orthop Relat Res 2010;468:723–34.
15. Ring D, Lozano-Calderon S. Imaging for suspected scaphoid fracture. J Hand Surg Am 2008;33:954–7.
16. http://acsearch.acr.org/TopicList.aspx?topic_all=&topic_any ='%22occult+scaphoid*%22'&connector=+And+&cid=0
17. Groves AM, Cheow H, Balan K, Courtney H, Bearcroft P, Dixon A. 16-MDCT in the detection of occult wrist fractures: a comparison with skeletal scintigraphy. AJR Am J Roentgenol 2005;184:1470–4.
18. Hu H, He HD, Foley WD, Fox SH. Four multidetector-row helical CT: image quality and volume coverage speed. Radiology 2000;215:55–62.