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### Scaphoid fractures: anatomy, diagnosis and treatment

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# Chapter

# 9

Interobserver reliability of computed tomography to diagnose scaphoid waist fracture union

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## Abstract

**Purpose** The purpose of this study was to determine the inter-observer agreement and diagnostic performance characteristics of computed tomography (CT) for determining union of scaphoid waist fractures.

**Methods** Fifty-nine orthopedic and trauma surgeons rated for union a set of 30 sagittal CT scans of 30 scaphoid waist fractures. Twenty were treated non-operatively, were imaged between 6 and 10 weeks after injury, and were known to have eventually achieved union. Ten were operatively-confirmed to be ununited. Each scan was rated as united or ununited using a web-based rating application. Inter-observer reliability was assessed by Siegel's multirater Kappa. Diagnostic performance characteristics were calculated using Bayesian formulas.

**Results** The inter-observer agreement among 59 raters was substantial. The average sensitivity, specificity, and accuracy of diagnosing union of scaphoid waist fractures on sagittal CT-scans were 78%, 96%, and 84%, respectively. Assuming a 90% prevalence of fracture union of the scaphoid, the positive predictive value of a diagnosis of union on sagittal CT scan was 0.99 and the negative predictive value was 0.41.

**Discussion** Our results suggest that CT-scans are accurate and reliable for diagnosis of union but inadequate for ruling out nonunion of scaphoid waist fractures between 6 and 10 weeks after injury.

**Level of Evidence** Diagnostic, Level III

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## Introduction

The decision to discontinue casting during non-operative treatment of scaphoid fractures is often based on radiographic or clinical signs of union, both of which have limited reliability.<sup>1-3</sup> Radiographic signs are usually defined as trabeculae crossing the fracture line on standard radiographs in 3 or 4 views. Dias et al. demonstrated poor inter-observer reliability of scaphoid fractures using radiographs in at least 4 views 12 weeks after fracture.<sup>1</sup> Computed tomography (CT) was found to be more reliable and more accurate than standard x-rays in assessing scaphoid fracture displacement,<sup>4,5</sup> but its role in assessing union is uncertain.

The purpose of this study was to determine the inter-observer agreement and diagnostic performance characteristics of CT scans for the diagnosis of scaphoid waist fracture union.

## Materials and Methods

### Study Design and Observers

Fifty-nine independent observers (all fully trained orthopedic hand and trauma surgeons) from several countries were invited to evaluate 30 cases of scaphoid waist fractures in an online survey. The majority practiced in the United States (54%) or in the Netherlands (19%). The group consisted for the most part of surgeons with at least 6 years of independent practice (78%), who supervise trainees (95%), and treat at least 6 scaphoid fractures annually (76%). Most surgeons specialized in either hand surgery (37%) or orthopaedic traumatology (37%). (Table 1) The study was performed under a protocol approved by the institutional research board at the principal investigator's (DR) hospital.

### Evaluation

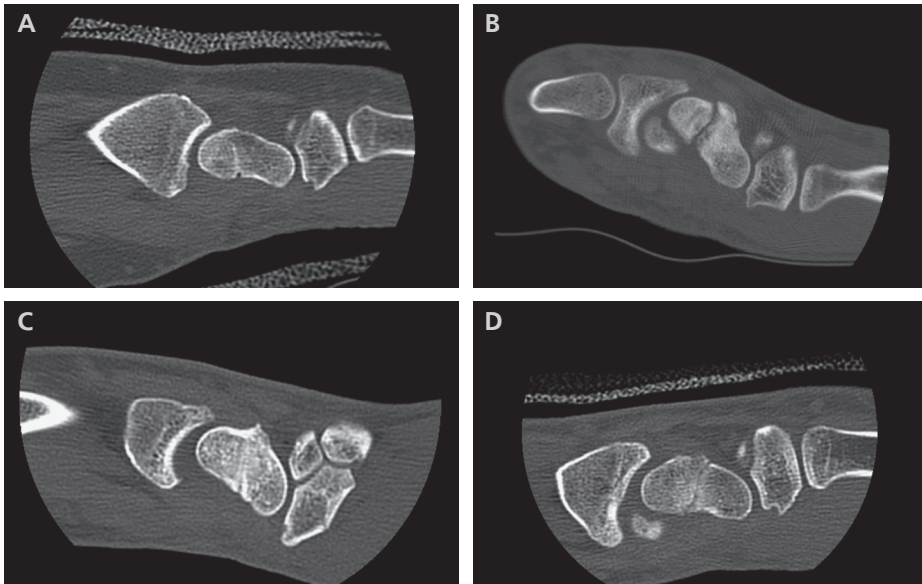
For the rating session, a set of CT-scans in the sagittal plane made routinely at a minimum of 6 weeks after injury of 20 scaphoid waist fractures known to be united on radiographs obtained a minimum of 6 months after injury (reference standard for union) and 10 operatively-verified ununited scaphoid waist fractures (reference standard for nonunion) were selected based on convenience and image quality from 2 separate databases (Figure 1). The reference standards were chosen based on the current opinion of hand surgeons and the literature. The consensus reference standard for nonunion is either a persistent lucency on radiographs (or CT) obtained at a minimum of 6 months after injury or, more reliably, intra-operatively confirmed nonunion. As united scaphoid fractures are not generally operated on, the only consensus reference



Table 1. Demographics of observers.		
Demographic	Total	%
Gender		
Male	55	93
Female	4	7
Country of practice		
Unites States	32	54
Netherlands	11	19
Canada	4	7
Australia	3	5
Colombia	3	5
Other	6	10
Years of independent practice		
0-5	13	22
6-10	15	25
11-20	23	39
21-30	8	14
Trainee supervision		
Yes	56	95
No	3	5
Number of treated scaphoid fractures per year		
0-5	14	24
6-10	11	19
11-20	20	34
>20	14	24
Specialization		
General orthopaedics	1	2
Orthopaedic traumatology	22	37
Shoulder and elbow	10	17
Hand and wrist	22	37
Other	4	7

standard for union of a scaphoid waist fracture is crossing trabeculae confirmed on plain x-rays or CT scans obtained at least 6 months after injury.<sup>6,7</sup>

The techniques and parameters of the two databases from which the CT images were similar. The database of united scaphoid fractures from one center were based on CT performed by a scanner (GE Lightspeed CT; GE Medical Systems, Milwaukee, WI) with the wrist positioned in slight radial deviation, as previously described by Bain et al.<sup>8</sup>



**Figure 1:** A Clear union of a scaphoid waist fracture on sagittal CT reconstructions. B Clear nonunion. C Unclear union that was rated with some inter-observer variation. D Unclear union that was rated with substantial inter-observer variation.

A scout film was obtained and images subsequently were acquired sagittally along the long axis of the scaphoid. Scan parameters included 1.25-mm sections at 1-mm intervals, 120 kVp, 40 mA, high quality pitch 3, and 3.75-mm translation per gantry rotation.

The database of ununited scaphoid fractures from another center were based on CT scans that were obtained with a scanner (GE Lightspeed Qx/i CT Scanner; GE Medical Systems, Pewaukee, WI) using the technique described by Sanders.<sup>9</sup> According to this technique, the patient lies prone on the table with the arm overhead and the forearm crossing the gantry of the CT unit at a 45° angle. The hand was placed flat on the table, with the wrist in neutral flexion and neutral radial-ulnar deviation. Scout images were obtained to ensure that the scanning plane corresponded with the long axis of the scaphoid. We defined sagittal plane images of the scaphoid as scans that provided a lateral view of the scaphoid as defined by the central longitudinal axis of the scaphoid. Images of 1.2-mm thickness were obtained with 1.2-mm spacing between the images (no overlap). The CT scans consisted of reconstructions presented as continuous movies of all sagittal images in the longitudinal plane of the scaphoid as described by Sanders<sup>9</sup> in which observers were able to scroll through the slides and pause when desired.

For purposes of this study, observers were asked to give their overall judgment regarding fracture union at their own pace and on their own time. The classification



was simplified to united or ununited, thus excluding the possibility of selecting partial union. With the aim of obtaining results representative of clinical practice, definitions for union and nonunion were not provided but were left to judgment of the rater. Observers were given 3 reminders and a total of 6 weeks to respond. The only incentive for observers to participate was a group authorship.

## Statistical Analysis

The multirater kappa measure ( $\kappa$ ) was used to estimate agreement among surgeons. It is a commonly used statistic to describe chance-corrected agreement in a variety of inter-observer and intra-observer studies.<sup>10-12</sup> Agreement among observers was calculated with use of the multirater kappa measure described by Siegel and Castellan.<sup>13</sup> Kappa values were interpreted using the guidelines proposed by Landis and Koch:<sup>11</sup> values of 0.01 to 0.20 indicate slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and more than 0.80, almost perfect agreement. Zero indicates no agreement beyond that expected due to chance alone, - 1.00 means total disagreement, and + 1.00 represents perfect agreement.<sup>11,12</sup>

Sensitivity, specificity, and accuracy were calculated using standard formulas with 95% confidence intervals (CI). The formulas that best represent the clinicians use of a test are the positive predictive value and negative predictive value adjusted to the prevalence of disease according to Bayes' theorem, with an a priori estimate of the prevalence (pretest probability) of union of scaphoid fractures set at 90%, as nonunion occurs on average in 10% of patients treated with cast immobilization.<sup>14</sup>

## Results

The kappa value representing the inter-observer reliability for scaphoid fracture union was 0.66, and the agreement was significant at the level of  $P < 0.001$  (substantial agreement according to the benchmarks of Landis and Koch). Inter-observer reliability was different based on specialization, years of independent practice, and number of scaphoid fractures treated per year (Table 2). The average sensitivity of diagnosing union of scaphoid waist fractures was 78% (95%CI: 47-100%), the average specificity was 96% (95%CI: 85-100%), and the average accuracy was 84% (95%CI: 63-100%). According to Bayes' theorem using average values for sensitivity and specificity, the positive predictive value was 0.99 (95%CI: 0.97-1.0) and the negative predictive value was 0.41 (95%CI: 0-0.84).

Table 2. Interobserver subgroup analysis.	
Subgroup	Kappa
Years of independent practice	
0-10	0,63
11-30	0,68
Number of treated scaphoid fractures per year	
0-10	0,61
>10	0,69
Specialization	
Orthopaedic traumatology	0,70
Shoulder and elbow	0,63
Hand and wrist	0,61
General orthopaedics or other	0,69

## Discussion

The results of the current study show substantial inter-observer agreement for determining union of scaphoid waist fractures on sagittal CT-scans among a group of observers consisting mostly of experienced orthopedic and trauma surgeons. When compared to the reference standard, sagittal CT scans are specific (96%) but slightly less sensitive (78%) for diagnosing union of a scaphoid waist fracture. Partly because over 90% of adequately treated scaphoid fractures heal with cast immobilization,<sup>15</sup> CT scans are much better for predicting union (PPV = 0.99) than they are for predicting nonunion.

The inter-observer agreement of sagittal CT scans for determining scaphoid waist fracture union in the current study ( $\kappa = 0.66$ ) is substantially higher than what Dias and colleagues found for radiographs ( $\kappa = 0.39$ ).<sup>1</sup> The fact that CT scans obtained between 6 and 10 weeks after fracture are more reliable than radiographs might contribute to a reduced duration of immobilization—something which merits additional study. The disadvantages of CT scans over radiographs include higher costs, less availability, and greater radiation exposure.

This study was limited to inter-observer agreement only because it is more practical to have the members of the collaborative volunteer for a single 20 to 30 minute session. Intra-observer agreement tends to be much less of a problem for most types of radiological diagnosis. In the study of Dias et al., the intra-observer agreement of radiographs for union was high ( $\kappa = 0.71$ ).<sup>1</sup> Secondly, studies consistently show that more sophisticated imaging improves intra-observer variation more than inter-observer variation.<sup>5,16,17</sup>



These data should be interpreted in light of several shortcomings. First, only sagittal plane CT images were provided. The inclusion of radiographs and coronal plane CT images would better reflect daily practice. We omitted coronal plane CT images for the practical reason that they were not available in the prospective database we used for the study. Second, the omission of radiographs does not reflect the clinical situation, but this was done in order to focus specifically on the diagnostic performance characteristics of CT. Third, we used operatively confirmed nonunions both as a means of being certain about the diagnosis of nonunion but also because nonunion of an adequately treated, non-displaced fracture of the scaphoid is very uncommon and unavailable as a control group. Consequently, our study is subject to spectrum bias since we included a higher percentage of nonunions than would be expected in practice. The study is also subject to the presence of other clues that may be present on CT scans in patients with more long-standing nonunions such as malalignment or subtle signs of arthrosis. Malalignment in particular would only be present in nonunions as all of the fractures were documented to have no displacement on initial CT scans.

Some observers would have preferred an option to diagnose "partial union". We forced them to diagnose union or nonunion for 2 reasons. The dichotomy is much more easily handled statistically and because on the basis of bone physiology, any bony bridge between the fragments qualifies as union. This might be seen as a weakness of the study. On the other hand, the definition and utility of the concept of "partial union" remains unclear and requires further investigation. Given that radiographs and even computed tomography are imperfect for the diagnosis of union, the accuracy and reliability of grades of union should be measured before these diagnoses are used with confidence.

Because the union rate of adequately protected non-displaced scaphoid waist fractures approaches 100%, we do not recommend adding CT scan to the routine management of these fractures, but the role of routine CT for diagnosing fracture union does merit further study. CT scans may be useful in specific circumstances such as delayed diagnosis, inadequate immobilization, and equivocal radiographic findings. These circumstances may be more difficult to study as they are relatively uncommon.

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