Scaphoid fractures: anatomy, diagnosis and treatment

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Chapter 7

Factors associated with arthroscopically determined scaphoid fracture displacement and instability

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Abstract

Purpose To identify factors associated with arthroscopically diagnosed scaphoid fracture displacement and instability.

Methods This was a secondary use of data from 2 prospective cohort studies including 58 consecutive adult patients with a scaphoid fracture that elected arthroscopy-assisted operative fracture treatment, some for displacement, some as part of a prospective protocol, and others to avoid a cast. All patients had pre-operative computed tomography with reconstructions in planes defined by the long axis of the scaphoid.

Results Arthroscopy revealed 38 unstable fractures (movement between fracture fragments; 66%), 27 of which were also displaced (out of position, 47%). All arthroscopically displaced fractures were unstable, and 11 of the 31 arthroscopically non-displaced fractures were unstable. There was a significant correlation between radiographic comminution (more than 2 fracture fragments) and arthroscopically determined displacement and instability.

Conclusions Radiographic comminution is associated with arthroscopically evaluated displacement and instability.

Level of Evidence Level II - Prognostic Study

Introduction

Displacement is a risk factor for nonunion of a scaphoid waist fracture.[1-5] The words displacement and instability are often used interchangeably when referring to scaphoid waist fractures[6-10], but it is worthwhile to distinguish movement of the fracture fragments with gentle manipulation (instability) from fracture fragments that are out of position (displacement). At the scaphoid waist, displaced fractures are almost always unstable, but unstable fractures are not always displaced.

With respect to scaphoid nonunion, studies suggest that nonunions located distal to the apex on the dorsal ridge of the scaphoid are usually unstable (the fracture fragments are mobile) while nonunions located proximal to the apex are usually stable.[11-14] If the same proved true for acute scaphoid fractures, fracture location might be a relative indication for surgery.

We tested the null hypothesis that there was no relationship between fracture location relative to the apex on the dorsal ridge of the scaphoid and arthroscopically evaluated scaphoid fracture displacement and instability. Furthermore, we tested whether other demographic and injury characteristics could explain arthroscopic displacement and instability of scaphoid fractures.

Materials and Methods

The institutional review board at both institutions approved the secondary use of data from 2 prospective cohort studies of patients undergoing arthroscopy-assisted surgery for a scaphoid waist fracture. The original study evaluated the diagnostic performance characteristics (e.g. sensitivity and specificity) of radiography and CT for arthroscopic evaluation of scaphoid displacement and instability and was published separately. The database created by the 2 studies consisted of all adult patients (age 18 years or greater) with an isolated fracture of the scaphoid (irrespective of fracture displacement and location) and without previous history of trauma to the affected wrist who elected operative treatment during a 3-year period (2004-2007) at 1 institution and a 4-year period (2006-2010) at the other institution. Informed consent was provided by all patients. The prospective cohort of operated patients consisted of all radiologically displaced scaphoid fractures and a selection of non-displaced scaphoid fractures based on preference to avoid cast immobilization (both institutions) or on randomization as part of another study (1 institution).

The total cohort consisted of 58 patients (Malmö n=43, Boston n=15). There were 44 men and 14 women, with a mean age of 34 years (range, 18 to 76 years). All patients were treated by arthroscopy-assisted surgery within a mean of 15 days after injury (range, 2 to 80 days) and had pre-operative radiographs and computed

tomography (CT). Demographic and injury characteristics were prospectively recorded, with exception of the fracture location relative to the apex on the dorsal ridge on CT, which was retrospectively recorded. Demographic characteristics included age and sex. Injury characteristics included the energy of trauma (high or low as determined by the treating surgeon), fracture comminution on radiographs (more that 2 fracture fragments), fracture location (proximal third, middle third, distal third), fracture location relative to the apex on the dorsal ridge on CT (proximal, distal, or through apex), scapholunate ligament injury detected during arthroscopy (no rupture or partial/total rupture), and surgical delay (days between injury and surgery).

Imaging Protocols

Radiographs of the wrist were obtained with at least 4 views of the scaphoid: posteroanterior, lateral, posteroanterior with ulnar deviation, and semipronated oblique. In addition, all patients had CT of the wrist with reconstructions in the coronal and sagittal planes defined by the long axis of the scaphoid.[15] All radiological examinations were evaluated by 1 of 3 musculoskeletal radiologists and the treating physician in order to reach consensus on a fracture (defined as discontinuity of bone), displacement (either gapping and/or translation >1mm or dorsal tilting of the lunate of >15° with respect to the radius on a true lateral radiograph with the third metacarpal parallel to the radius), and comminution (more than 2 fracture fragments) of the scaphoid fracture (Figure 1A,B). On static imaging (radiographs and CT), non-displaced fractures were defined as stable and displaced fractures as unstable.[9 16] These evaluations were done as part of the prospective study with exception of the fracture location relative to the apex on the dorsal ridge of the scaphoid, which was done for the purposes of this specific study and thus performed at a later date. A musculoskeletal radiologist determined (1) whether the fracture location was situated distal or proximal to the apex on the dorsal ridge of the scaphoid by looking for the distal cortical discontinuity in relation to the anatomical landmark of the apex (Figure 1A,B) and (2) whether the fracture was located in the proximal, middle or distal third by measuring whether the major part (>50%) of the fracture line was situated in the proximal, middle, or distal third of the bone. This was applied to the radiographic oblique view in which the scaphoid had the maximum length, supplemented with the information obtained in the 3-dimensional reconstructions of the CT scans.

Surgical procedure

Arthroscopy was performed under brachial plexus block or general anesthesia with a tourniquet on the upper arm and the hand in a vertical traction tower. Using finger traps on the index and long fingers, up to 5 kg of traction was applied. A 1.9-mm or 2.7-mm arthroscope was used, sometimes in combination with a motorized shaver to

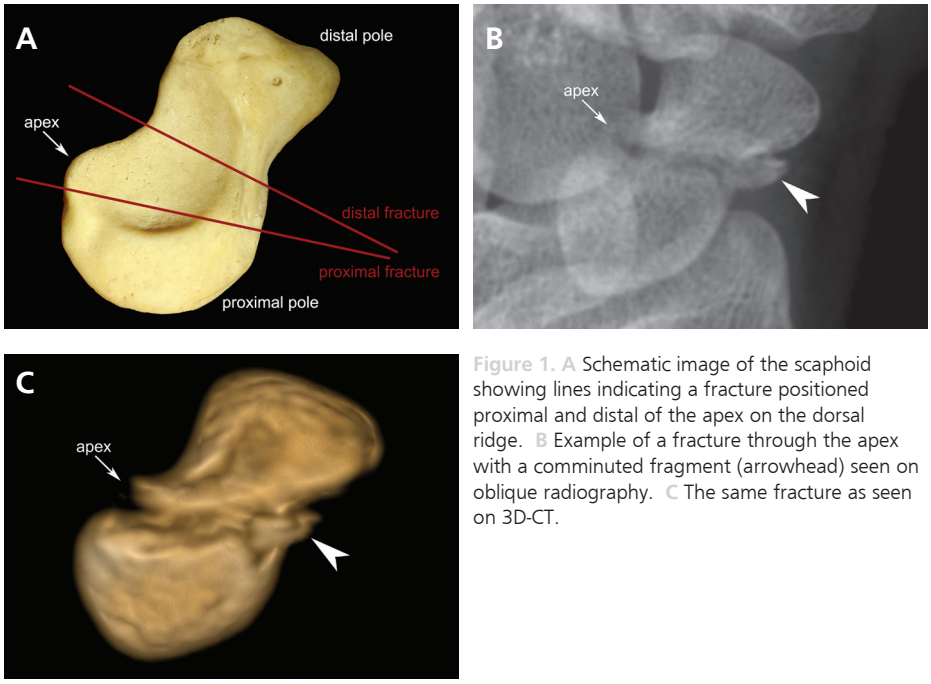

Figure 1. A Schematic image of the scaphoid showing lines indicating a fracture positioned proximal and distal of the apex on the dorsal ridge. B Example of a fracture through the apex with a comminuted fragment (arrowhead) seen on oblique radiography. C The same fracture as seen on 3D-CT.

clear the joint of blood, debris, and synovitis. At 1 institution, the standard 3–4, 4–5, 6R , and 6U portals were used in the radiocarpal joint, and at the other institution just the 3-4 portal was used because the scaphoid fracture can rarely be seen in the radiocarpal joint. In the midcarpal joint, the standard radial and ulnar portals were used, and in some cases supplemented with the scaphotrapeziotrapezoid joint portal; no volar portals were used. A small image intensifier was used in all procedures. All surgical procedures were performed by 1 of 4 arthroscopists in the 2 institutions.

Data from both institutions were collected in prospective cohort studies where the following definitions were consistently applied. During arthroscopy with up to 5kg of traction across the wrist, static malalignment (gapping, translation, angulation of the fracture) was defined as arthroscopic displacement. Arthroscopic instability was diagnosed if the fracture fragments could be moved with gentle manipulation of the bone by applying external pressure on the distal pole of the scaphoid, by deviating the wrist in radial and ulnar direction, or by inserting a probe between the fracture fragments. In other words, a fracture was diagnosed as arthroscopically displaced when the fragments were out of position, and a fracture was diagnosed as arthroscopically unstable when the fragments could be moved out of position. At 1 institution, the scapholunate ligament was routinely inspected.

Statistical analysis

For bivariate analysis of predictors of arthroscopic displacement and instability, the independent (or explanatory) variables that we investigated included age, sex, energy of trauma, fracture comminution on radiographs, fracture location (proximal third, middle third, distal third), fracture location relative to the apex on the dorsal ridge on CT, scapholunate ligament injury detected during arthroscopy, and surgical delay. Continuous explanatory variables (e.g. surgical delay) were evaluated with a Mann Whitney U test, and categorical variables (e.g. comminution) with the chi-squared test or the Fisher exact test.

Factors with $P < 0.10$ in bivariate analysis were included into backwards stepwise multivariable logistic regression models seeking factors associated with arthroscopic instability and displacement. A post-hoc power analysis determined that 58 patients provided 84% power to identify factors with an odds ratio 3.0 or higher using logistic regression.

Results

Arthroscopy revealed 38 unstable fractures (66%), 27 of which were also displaced (47%). All arthroscopically displaced fractures were unstable and 11 of the 31 arthroscopically non-displaced fractures were unstable (Figure 2).

On CT, 39 fractures were located distal to the apex on the dorsal ridge of the scaphoid, 16 were located proximal to the apex, and 3 fractures were located at the apex separating it in 2 parts (Figure 1B). Nineteen arthroscopically displaced fractures and 20 arthroscopically non-displaced fractures were located distal to the apex on the dorsal ridge of the scaphoid. Twenty-seven arthroscopically unstable fractures and 12 arthroscopically stable fractures were located distal to the apex on the dorsal

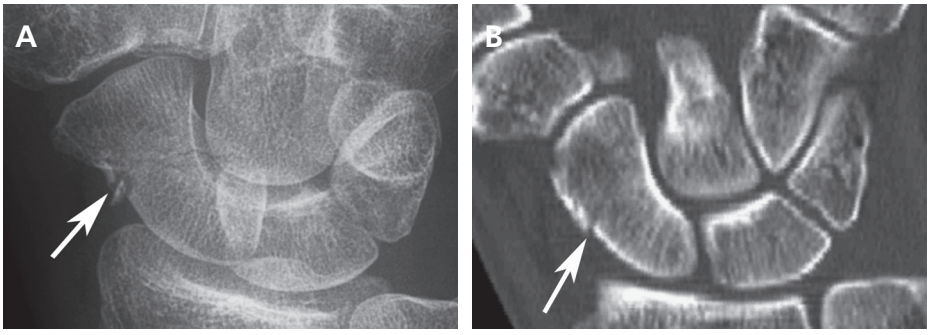

Figure 2. Example of radiographically comminuted and non-displaced or very minimally displaced fracture on radiographs (A) and CT (B) that was arthroscopically displaced and unstable.

ridge of the scaphoid. These differences were not significant for either arthroscopically determined displacement (P=0.08) or instability (P=0.17).

In bivariate analysis of factors associated with arthroscopic displacement only comminution was significant (P<0.001) (Table 1). One of 31 arthroscopically non-displaced fractures and 18 of 27 arthroscopically displaced fractures exhibited comminution. There was no comminution in the 20 arthroscopically stable fractures, and 19 of 38 arthroscopically unstable fractures exhibited comminution.

In multivariable analysis, comminution was the only variable that was significant and explained 41% of the variability of arthroscopic displacement (adjusted r^2=0.41; P<0.001). The odds of a comminuted fracture correlating with displacement were 50 times greater than a non-comminuted fracture.

Table 1. Bivariate analysis of factors associated with arthroscopic displacement (defined when the fragments were out of position at arthroscopic evaluation).

Variable	Nondisplaced (n=31)	Displaced (n=27)	P-value
Age (years)	34.7 (18-76)	33.2 (20-71)	0,761
Sex			0,351
Male (%)	22 (71)	22 (81)	
Female (%)	9 (29)	5 (19)	
Trauma Energy			0,829
Low (%)	21 (68)	19 (70)	
High (%)	10 (32)	8 (30)	
Comminution			<0,001
No (%)	30 (97)	9 (33)	
Yes (%)	1 (3)	18 (67)	
Location			0,251
Proximal third (%)	3 (10)	0 (0)	
Middle third (%)	26 (84)	26 (96)	
Distal third (%)	2 (6)	1 (4)	
Location relative to apex			0,081
Proximal (%)	11 (35)	5 (19)	
Distal (%)	20 (65)	19 (70)	
Through (%)	0 (0)	3 (11)	
Scapholunate ligament injury			0,612
No (%)	15 (65)	14 (70)	
Partial (%)	1 (4)	2 (10)	
Total (%)	7 (31)	4 (20)	
Surgical delay (days)	14.4 (3-47)	15.0 (2-80)	0,667

Continuous variables are reported as mean (range)

In bivariate analysis of factors associated with intra-operative instability only comminution was significant (P<0.001) (Table 2). According to logistic regression 21% of the variability of arthroscopic instability is explained by comminution (adjusted r^2=0.30; P=0.001). The odds of a comminuted fracture correlating with instability were 54 times greater than a non-comminuted fracture.

Table 2. Bivariate analysis of factors associated with arthroscopic instability (defined when the fragments could be moved out of position).

Variable	Stable (n=20)	Unstable (n=38)	P-value
Age (years)	33.3 (20-62)	34.4 (18-76)	0,876
Sex			0,161
Male (%)	13 (65)	31 (82)	
Female (%)	7 (35)	7 (18)	
Trauma Energy			0,902
Low (%)	14 (70)	26 (68)	
High (%)	6 (30)	12 (32)	
Comminution			<0,001
No (%)	20 (100)	19 (50)	
Yes (%)	0 (0)	19 (50)	
Location			0,998
Proximal third(%)	1 (5)	2 (5)	
Middle third (%)	18 (90)	34 (90)	
Distal third (%)	1 (5)	2 (5)	
Location relative to apex			0,172
Proximal (%)	8 (40)	8 (21)	
Distal (%)	12 (60)	27 (71)	
Through (%)	0 (0)	3 (8)	
Scapholunate ligament injury			0,560
No (%)	8 (57)	21 (72)	
Partial (%)	1 (7)	2 (7)	
Total (%)	5 (36)	6 (21)	
Surgical delay (days)	15.5 (3-47)	14.3 (2-80)	0,743

Continuous variables are reported as mean (range)

Discussion

Theoretically, an acute scaphoid fracture distal to the apex on the dorsal ridge could result in flexion of the distal fragment because the apex coincides with the attachment of the dorsal intercarpal ligament and the dorsal part of the scapholunate

interosseous ligament, both important stabilizers of the scaphoid.[17] We found no such relationship based on arthroscopic diagnosis of displacement and instability. Fracture comminution was the only factor associated with displacement and instability diagnosed arthroscopically.

The typical pattern of scaphoid waist fracture comminution is a separate fragment on the radial side.[18] Herbert classified comminuted fractures as unstable and noted that they are difficult to repair.[19] With the exception of 1 comminuted but stable fracture our data agree with the observations of Herbert. The high incidence of comminution in our sample (33%) is likely related to the over representation of radiographically displaced fractures (i.e. spectrum bias).

The high percentage of arthroscopically unstable fractures among radiographically non-displaced fractures (traditionally regarded as stable) was the main finding of the original study and prompted this study of factors associated with displacement and instability. It is worth emphasizing that given the fact that over 90% of radiologically non-displaced scaphoid waist fractures (with presumably similar rates of instability) heal with cast immobilization, instability may not be a risk factor for nonunion.[6,20-22]. Further study is warranted.

The study has limitations. The first relates to the relatively small sample that had been used for prior analyses. The prospective arthroscopic diagnosis of displacement and instability make it a valuable data set, but the findings of these studies need verification with different patient samples. Second, the studied population may be subject to spectrum bias as compared to previous series, because radiologically displaced fractures were over represented (50% vs. 10-30%)[2-4,23]. Third, the use of 5 kilograms traction and insertion of the arthrocope might affect fracture alignment and instability. Fourth, the arthroscopic findings were based on subjective measurements performed by 4 different surgeons in 2 centers, subject to the possibility of inter-observer variability. Fifth, this study did not address the reliability of the diagnosis of fracture location with respect to the apex of the dorsal ridge on CT.

Our data suggest that scaphoid fracture relative to the apex of the dorsal ridge is not associated with arthroscopically diagnosed displacement and instability. Fracture comminution is strongly associated with both displacement and instability, the clinical relevance of the mobility between well aligned fracture fragments (instability) is unknown.

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