Scaphoid Fracture Patterns—Part Two: Reproducibility and Demographics of a Simplified Scaphoid Fracture Classification

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Abstract

Objective To analyze the reproducibility, reliability, and demographics of a simplified anatomical scaphoid fracture classification based on posteroanterior radiographs using a large database of scaphoid fractures.

Methods The study consisted of a retrospective review of electronic medical records of 871 consecutive patients. All patients presented between 2003 and 2014 at two centers. Patient- and surgeon-related factors were analyzed. Additionally, interobserver reliability of the Herbert and simplified scaphoid fracture classifications were tested.

Results Proximal pole fractures were defined as fractures in which the center of the fracture line was proximal to the distal scapholunate interval (n = 30), waist fractures (n = 802) were defined as fractures involving the scaphocapitate interval, and distal tubercle fractures (n = 39) were defined as fractures involving the scaphotrapeziotrapezoid (STT) interval. The interobserver reliability of the simplified classification was fair ($\kappa = 0.37$) as for the Herbert classification ($\kappa = 0.31$). The average doubt of the answers of the observers was 2.1 on a scale from 0 to 10 for the simplified classification and 3.6 for the Herbert classification ($P < 0.05$).

Conclusions All complete fractures across the entire scaphoid distal to the scapholunate articulation and proximal to the STT joint can be classified as waist fractures; nonwaist scaphoid fractures are uncommon (6%) and have somewhat different presentations compared to waist fractures. Simplifying the fracture classification slightly improves interobserver reliability, although remaining fair, and significantly reduces doubt.

Level of Evidence This is a Level III, prognostic study.

Keywords
- scaphoid fracture
- reproducibility
- demographics
- classification

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There is a great variety of scaphoid fracture classification systems with considerable controversies. Popular classification systems include the Herbert[1] and Mayo[2] classifications, but there are many more.[1,2] All classifications have two limitations in common—they were based on standard radiographs only and their complexity hinders a satisfactory interobserver reliability.[3] To improve comparison in the literature, there is a trend to simplify fracture classifications by dividing the bone geometrically into a proximal, waist, and distal third. However, accurate classification of the involved third of the scaphoid relies on defining the longitudinal axis which requires computed tomography (CT).

Based on three-dimensional (3D) fracture pattern analysis of 51 consecutive scaphoid fractures as presented in part one of this study, it seems that the scaphoid fracture classification can be simplified to proximal pole fractures, a range of waist fractures and tubercle avulsion fractures. It has been shown that the vast majority of fractures can be classified on posteroanterior radiographs as (1) proximal pole fractures (proximal to the distal scapholunate interval), (2) a range of waist fractures (involving the scaphocapitate interval), and (3) distal tubercle fractures (involving the scaphotrapeziotrapezoid [STT] interval).

The first purpose of this study was to analyze the reproducibility and demographics of a simplified scaphoid fracture classification using a large database of scaphoid fractures diagnosed on posteroanterior radiographs (1—database study). The secondary purpose was to test the results of a simplified scaphoid classification based on the findings of part of one of this study using an interobserver study while comparing to the most used scaphoid fracture classification by Herbert (2—interobserver study).

Materials and Methods

Database Study

The institutional review board (IRB) approved this retrospective study and a waiver of informed consent was granted. We identified 2,555 consecutive patients that were diagnosed with a (suspected) scaphoid fracture between January 2003 and July 2014 based on International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes 814.01 (closed fracture of navicular [scaphoid] bone of wrist) and 814.11 (open fracture of navicular [scaphoid] bone of wrist).[4]

We included patients aged 18 years or older with an acute fracture (diagnosed within 30 days of injury) confirmed on radiographs or CT scan. Posteroanterior radiographs were used to analyze the reproducibility of the simplified scaphoid fracture classification by one investigator and checked by a senior hand surgeon. Proximal pole fractures were defined as fractures in which the center of the fracture line was proximal to the distal scapholunate interval. Waist fractures were defined as fractures involving the scaphocapitate interval. Distal tubercle fractures were defined as fractures involving the STT interval (►**Fig. 1**). Any fracture that could not be classified by this simplified system was recorded. Demographic analysis was performed to investigate associated factors of the three types of fractures patterns.

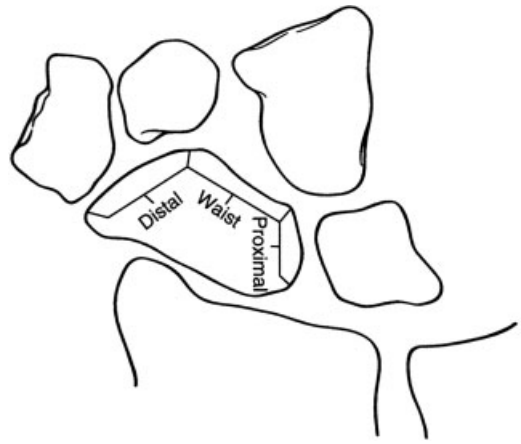

Fig. 1 Scaphoid classification based on 3D imaging—proximal pole fractures, waist fractures, and distal avulsion fractures.

We excluded 886 of the 2,555 patients (35%) because they had no fracture (suspected scaphoid fracture) and 105 (4.1%) were excluded because they were underage at the time of diagnosis. Another 641 patients (25%) were excluded because they were diagnosed more than 30 days after injury or had an ununited fracture, 11 patients were excluded as they had their initial treatment at a different institution, and 41 (1.6%) were excluded because no radiographs were available in the medical record. The final cohort consisted of 871 (34%) scaphoid fractures.

Among our final cohort of 871 patients with an acute scaphoid fracture, all fractures could be classified as proximal pole, waist, or distal tubercle fractures on posteroanterior radiographs. There were 802 (92%) waist fractures, of which 61 (7.6%) were part of a perilunate fracture dislocation. There were 30 (3.4%) proximal pole fractures and 39 (4.5%) distal tubercle fractures (►**Table 1**).

Interobserver Study

After approval by IRB, members of the Science of Variation Group (SOVG) with an interest in hand surgery or fractures were invited to participate in this study. Among the 84 surgeons that felt the study was appropriate for their expertise and interests, 72 completed the questionnaire.

Radiographs of patients with scaphoid waist fractures made 0 to 4 weeks after injury (CAST trial) were obtained (Buijze et al, 2014). Relevant patients were then manually identified and assessed in the electronic medical record system, at two institutions. Inclusion criterion was patients aged 18 years or older treated nonoperatively for a fracture of the scaphoid waist or proximal pole.

Participants were shown radiographs of the 39 patients in posteroanterior, lateral, and oblique fashion and were asked to diagnose the fracture using the Herbert classification and the simplified classification, and to indicate the doubt of their answer. We also recorded each observer's sex, location of practice, years of practice, supervision of trainees, and specialization.

Table 1 Bivariate analysis of factors associated with proximal, distal, and waist fractures of the scaphoid ($n = 871$)

Parameters	Proximal pole		Tubercle		Waist (reference)
Number (%)	30 (3.4%)		39 (4.5%)		802 (92%)
	Mean (SD)	***p*-value***	**Mean (SD)**	***p*-value***	**Mean (SD)**
Age, years	28 (9.7)	**0.001**	38 (21)	0.83	39 (19)
Time to treatment, days	1.5 (3.5)	0.24	3.2 (5.7)	0.59	2.7 (5.4)
	Number (%)	***p*-value**	**Number (%)**	***p*-value**	**Number (%)**
Sex					
Men	25 (83%)	0.22	29 (74%)	0.72	570 (71%)
Women	5 (17%)		10 (26%)		232 (29%)
Smoking**	*n = 27*		*n = 31*		*n = 649*
Never	19 (70%)	**0.03**	24 (77%)	0.38	421 (65%)
Current	8 (30%)		3 (10%)		125 (19%)
Former	0		4 (13%)		103 (16%)
Race					
White	23 (77%)	0.99	31 (79%)	0.85	619 (77%)
Other	7 (23%)		8 (21%)		183 (23%)
Hand surgeon	*n = 29*		*n = 39*		*n = 790*
	19 (66%)	0.19	28 (72%)	0.57	600 (76%)
Affected side right					
	12 (40%)	0.85	18 (46%)	0.74	343 (43%)
Injury type					*n = 794*
Trauma	30 (100%)	**0.005**	37 (95%)	**0.001**	613 (77%)
Sports	0		2 (5.1%)		181 (23%)
CT					
CT scan	20 (67%)	**0.001**	16 (41%)	0.50	287 (36%)
Perilunate dislocation					
	0	0.16	1 (2.6%)	0.35	61 (7.6%)
Isolated fracture					
Isolated fracture	19 (63%)	0.07	29 (74%)	0.55	629 (78%)
Distal radius	8 (27%)	0.14	4 (10%)	0.38	113 (17%)
Capitate	0	0.99	0	0.99	12 (1.5%)
Hamate	1 (3.3%)	0.33	1 (2.6%)	0.41	10 (1.3%)
Lunate	1 (3.3%)	0.52	1 (2.6%)	0.61	19 (2.4%)
Trapezium	0	0.99	0	0.99	10 (1.3%)
Triquetrum	1 (3.3%)	0.99	1 (2.6%)	0.99	29 (3.6%)
Ulna	5 (17%)	**0.02**	4 (10%)	0.15	41 (5.1%)
Operative treatment					
	16 (53%)	0.09	3 (7.7%)	**<0.001**	300 (37%)

Abbreviation: SD, standard deviation.
*Compared to waist group.
**According to the medical records.

The vast majority of the 72 participants were men (n = 71, 99%). Seventy-two percent specialized in hand and wrist surgery (n = 52) and 19% in traumatology (n = 14) (►**Table 2**). Twelve participants did not complete the survey and were excluded from further analysis.

Statistical Analysis

Database Study

Continuous data are reported as mean with standard deviation (SD) and categorical data as frequencies and

Table 2 Observer characteristics

Characteristics	*n* (%)
n = 72	
Gender	
Men	71 (99)
Women	1 (1)
Location of practice	
United States/Canada	48 (67)
Europe	13 (18)
Asia	1 (1)
Australia	3 (4)
Other	7 (10)
Years in practice	
0–5	22 (31)
6–10	15 (20)
11–20	26 (36)
21–30	9 (13)
Supervising trainees	
Yes	70 (98)
No	2(2)
Specialization	
Hand-wrist	52 (72)
Traumatolgy	1 (1)
Shoulder/elbow	14 (19)
Other	5 (8)

percentages. For the database study, the waist fracture group was used as a reference group for the distal tubercle and proximal pole fractures. In bivariate analysis, we used a Fisher exact test to assess the association between dichotomous explanatory variables and fracture type. A student *t*-test was used to test the association between continuous variables and fracture type. We analyzed the following explanatory variables: affected side, time between injury and treatment, smoking status, hospital of service, hand surgeon, hand dominance, injury type, fracture displacement, nonunion, perilunate dislocation, other wrist fractures, and surgery.

Multivariable logistic regression analysis was used to assess the independent relationship of explanatory variables with the different types of scaphoid fractures by including all variables with a *p*-value below 0.10 in bivariate analysis. All statistical analyses were performed using Stata 13 (StataCorp LP, College Station, Texas) and a two-tailed *p*-value below 0.05 was considered significant.

Interobserver Study

Continuous data are reported as mean with standard deviation (SD) and categorical data as frequencies and percentages. For the interobserver study, the multirater kappa measure described by Siegel and Castellan[5] was used to measure interobserver agreement.[5] Using the guidelines of Landis and Koch, the generated kappa values were interpreted as follows: 0.01 to 0.20 defines slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; 0.81 to 0.99, almost perfect agreement, and 1.00, perfect agreement. Zero indicates no agreement beyond chance alone; while −1.00 indicates total disagreement.[6]

Table 3 Multiple logistic regression comparing scaphoid waist and proximal pole fractures

	Waist–proximal pole (*n* = 831)	
	Odds ratio (95% CI)	*p*-value
Age	0.94 (0.91–0.98)	**0.001**
Smoking	1.8 (0.74–4.1)	0.20
Isolated fracture	0.54 (0.21–1.4)	0.20
Other fractures		
Ulna	3.3 (0.94–12)	0.063

Results

Database Study

In bivariate analysis, patients with proximal pole fractures were significantly ($P = 0.001$) younger on average, more likely to smoke ($P = 0.03$), more often had an associated ulna styloid fracture ($P = 0.02$) compared to patients with waist fractures (►**Table 1**). Patients with proximal pole fracture were more likely to have a CT scan ($P = 0.001$) and the injury was never related to sports ($P = 0.005$). Using multivariable logistic regression analysis to account for any confounding, younger age was the only factor independently associated with proximal pole fractures compared to waist fractures (►**Table 3**; odds ratio [OR] 0.94, 95% confidence interval [CI] 0.91–0.98, $P = 0.002$). Distal tubercle fractures were never related to sports either ($P = 0.001$) and patients were much less likely to have operative treatment ($n = 3$; $P < 0.001$).

Interobserver Study

There was fair agreement using the Herbert classification for the scaphoid fractures ($\kappa = 0.31$; 95% CI 0.216–0.397). Agreement classification of scaphoid fractures using the simplified classification was also fair ($\kappa = 0.37$; 95% CI 0.256–0.477). The average doubt of the answers of the observers was 2.1 on a scale from 0 to 10 for the simplified classification and 3.6 for the Herbert classification, a significant difference ($P < 0.05$).

Discussion

To improve comparison of studies on scaphoid fractures, it is crucial to develop a simple and reproducible classification system. This study shows that the simplifying scaphoid fractures classification into proximal pole, waist, or distal tubercle fractures was easily reproducible in a large series,

and fractures that do not fit this classification are rare [see part one of this article]. We were able to successfully classify all fractures in our retrospective review group using the simplified classification. Our interobserver study compared the simple classification with the Herbert classification and showed fair agreement for both classifications but significantly less doubt when classifying scaphoid fractures using the simplified classification.

There is evidence that most fractures are waist fractures and the appearance of being relatively distal or proximal may often be an artifact of how these fractures project on radiographs.[7] If one includes relatively distal fractures that cross the entire scaphoid as (distal) waist fractures, waist fractures account for more than 90% of all scaphoid fractures. This is slightly higher than previously reported using different classifications. For example, Grewal et al reviewed 219 scaphoid fractures over a 6-year period and found that 28 (13%) involved the proximal pole, 18 (8%) the distal pole, and 173 (79%) the waist according to the classification of Herbert.[8]

This study has several limitations. First, the retrospective design did not account for all potential factors associated with the different fracture types. Second, the relatively low number of proximal pole ($n = 30$) and distal tubercle fractures ($n = 39$) hindered multivariable statistical analysis. A larger sample with more proximal pole and distal tubercle fractures might have resulted in more statistical power to detect subtle but relevant differences between different fracture types. In this article only the distal tubercle fractures are classified to be fractures located distal. Using the suggested new (simplified) classification it seems easy to classify the different type of fractures.

Defined into three categories as we did in a prior fracture pattern analysis, we found a greater percentage of waist fractures in this study than in prior studies. It shows that this fits our experience. In part one of this study, we have shown that from a 3D perspective of scaphoid fractures there seems to be a wide distribution of waist fractures and only a small amount of proximal scaphoid fractures. Attempts to study distal tubercle fractures and proximal pole fractures are hindered by the relative infrequency of these injuries and the difficulty deciding which fractures count as proximal pole fractures. A study to look at the reliability of diagnosis of proximal pole versus waist fractures is currently being performed.[9]

When classifying scaphoid fractures in the three groups as described there might only be some rare exceptions. Slutsky et al described a series of 6 cases with coronal fractures which wouldn't fit our classification, but neither would it fit any other classification.[10] The same is true for horizontal oblique fracture running through the tubercle at the scaphocapitate interval. Oron et al described different types of distal pole fractures in a case series of 7. Their cases were not only situated in the distal tubercle and could neither be classified as a distal waist fracture.[11] We do not want to imply that this type of distal pole factures (other than distal tubercle fractures) do not exist but we think that they are so rare and therefore not seen in our series.

In 1993 Compson et al described three cases of avulsion fractures and concluded that they are rarely reported in literature, that their cases appear to be identical arising from the dorsal ridge of the scaphoid.[12] In 2016 Luria et al found similar results in a 3D imaging study by taking a closer look at the fracture location (using the Herbert classification), as the manuscript was mainly on fracture angles. In their population they had a number of distal tubercle fractures, all located very distally involving the distal tubercle and for the most part fractures were located in the waist. This is consistent with our theory that distal scaphoid fractures are through the tubercle.[13] Brondum et al used the Russe classification to describe their population of scaphoid fractures in Denmark and found an incidence of 5 patients suffering from an avulsion or tubercle of the scaphoid per 100,000 inhabitants. They also showed that there is a wide distribution in numbers of patients reported suffering from scaphoid fractures when subdivided into 3 groups (proximal, mid, and distal). It varied from only 15% classified as mid-scaphoid fracture and 85% distally located to 86% mid, 9% distal, and 5% proximal location in the scaphoid.[14,15] The interobserver study shows fair agreement for the simplified classification and also for the Herbert classification and no significant difference. Using the simplified classification observers have less doubt when classifying the scaphoid fractures compared to the Herbert classification.

In conclusion, when we defined waist fractures as distal to the scapholunate articulation and proximal to the STT joint, our retrospective review found nonwaist, scaphoid fractures are uncommon (6%). Further investigation using an even larger multi-institutional database to incorporate more proximal pole and tubercle fractures may be necessary to study the epidemiology of these fractures more accurately.

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Conflict of Interest
None declared.

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