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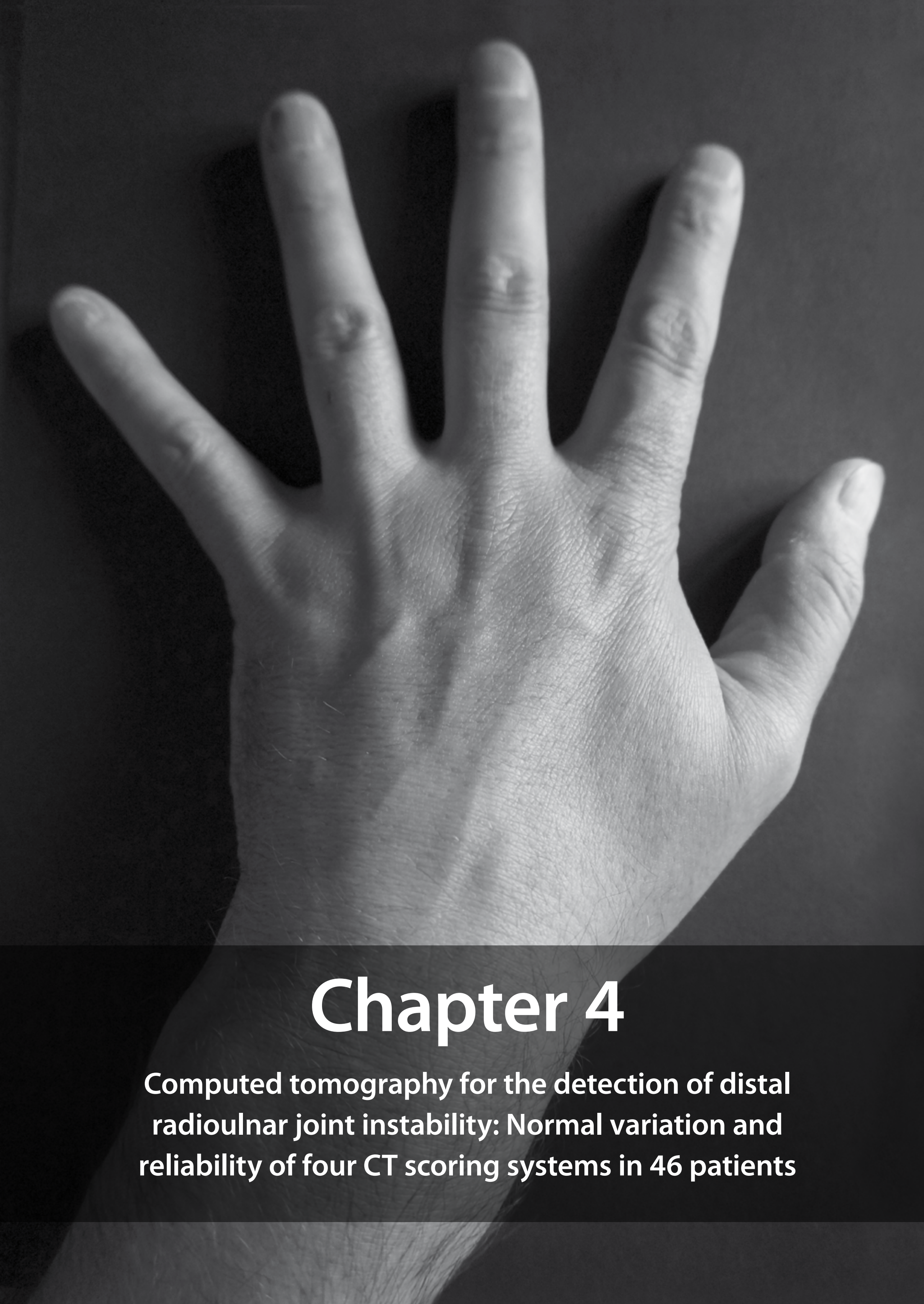

Chapter 4

Computed tomography for the detection of distal radioulnar joint instability: Normal variation and reliability of four CT scoring systems in 46 patients

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submitted

ABSTRACT

Objectives: The diagnosis of distal radioulnar joint (DRUJ) instability is clinically challenging. Computed Tomography (CT) may aid in the diagnosis, however the reliability and normal variations of existing CT scoring have not yet been established in detail. The aim of this study was to evaluate inter- and intraobserver agreement of CT scoring methods for determination of DRUJ translation in both posttraumatic and uninjured wrists. Secondly, we aimed to define the normal ranges for these scoring methods.

Subjects and Method: Patients with a conservatively treated, unilateral distal radius fracture were invited to participate. CT scans of both wrists were evaluated independently, by two readers using the Radioulnar line method, the Subluxation ratio method, the Epicenter method and the Radioulnar ratio method. The inter- and intraobserver agreement were assessed and normal values were determined using the data of uninjured wrists.

Results: Ninety-two wrist-CTs of 38 females and 8 males (mean age: 56.5 years, SD: 17.0, mean follow-up 4.2 years, SD: 0.5) were evaluated. Interobserver agreement was best for the Epicenter method (ICC=0.73, 95% confidence interval [CI] 0.65-0.79) and was better for injured wrists. Intraobserver agreement was almost perfect for the Radioulnar line method (ICC=0.82, 95% CI 0.77-0.87). Each scoring method showed a wide range for normal DRUJ translation.

Conclusion: The Epicenter method seems to be the most reliable method for scoring DRUJ translation, using CT-scan of the injured wrist. Considerable variation exists in the range of normal values.

INTRODUCTION

Distal radius fractures comprise one in six fractures that are diagnosed at the emergency department.[1-3] The incidence of distal radial ulnar joint (DRUJ) instability after distal radius fractures varies from 0 to 35% one year after trauma.[4-7] The complex biodynamics of the wrist show that during pronosupination the radioulnar fibers collaborate in preventing the ulna from luxating out of the sigmoid notch.[8] In extreme positions, additional stabilizing structures, such as the joint capsule, support the DRUJ from dislocation.[9] Posttraumatic changes may influence these stabilizing structures; complete triangular fibrocartilage complex (TFCC) tears or ulnar styloid fractures have been found to relate to DRUJ instability.[4,7]

Diagnosing DRUJ instability remains a challenge since the generally accepted available clinical test, i.e. the stress-test, suffers from subjectivity and lack of validity.[10] Radiographs can be of additional value, although obtaining true lateral views is difficult and radiographs do not depict the dynamic process of DRUJ movement.[4,11-14] Computed tomography (CT) of both wrists in pronation and supination may overcome these limitations.[13,15,16]

Several methods for determining DRUJ luxation by means of a wrist-CT have been proposed.[11,14,17-19] To our knowledge only one paper has evaluated the reliability of CT-scans in determining DRUJ instability.[21] Park et al, tested four scoring methods on 45 volunteers and unilateral wrists without a history of trauma, with three observers. They favored the Subluxation ratio and reported substantial variation in normal values in 70˚ of pro- and supination. In previously injured wrists, reliability of DRU translation measurement may differ from what Park et al found, due to posttraumatic anatomical changes. However, little is known about the reproducibility of the CT scorings systems in previously injured wrists. Furthermore, findings may differ when the DRUJ stabilizing structures are stressed at maximal forearm rotation. The aim of our study was to determine the most reliable method in terms of inter- and intraobserver agreement, to compare reliability of measurements in injured, with those in uninjured wrists and to determine normal ranges of radioulnar translation for these scoring methods in our population.

SUBJECTS AND METHODS

Patients

All patients, over 18 years of age at trauma, treated conservatively for a distal radius fracture between May 2008 and February 2010 in our hospital were eligible for inclusion in this study. Patients were excluded if they 1) were unwilling or unable to provide informed consent, or 2) had systemic diseases such as Rheumatoid Arthritis and Systemic Lupus Erythematosus (SLE), or 3) had contralateral wrist injury. Eligible patients received an invitation letter for a study visit. After informed consent, the presence of pain in forearm rotation against resistance was documented using a visual analogue scale and radiological DRUJ translation was assessed using CT. The institutional medical ethics review board approved the study.

The fractures were classified based on the baseline radiograph by one reader (MW) according to the Comprehensive Classification of Fractures in type A, B and C fractures.[20] No control radiographs were performed at final follow-up; fracture healing was determined on the CT with reformatting.

Computed tomography

CT scan (Aquilion One or 64, Toshiba, Tokyo, Japan) was performed in prone position with both arms above the head and extended elbows, both in maximal pronation and maximal supination (tube voltage 120 KV, tube current 70 mA, rotation time 0.5 s, slice thickness 0.5 mm, slice increment 0.4 mm). The scanned range was from 5 cm proximal of the radiocarpal joint to 1 cm distal of the metacarpal heads. Postprocessing was performed by trained radiology employees and included 2 mm coronal and sagittal reformats, as well as 2 mm axial reformats perpendicular to the axis of the styloid process for each wrist separately.

Radiological assessment of DRUJ instability

DRUJ translation was quantified using four methods; the Radioulnar line method[11,18], the Subluxation ratio method, the Epicenter method[19] and the Radioulnar ratio method.[17] All methods measure radioulnar translation by evaluating ulnar position relative to the radius resulting in a ratio. For training purposes the amount of DRUJ translation was evaluated using the four mentioned scoring methods in 10 CT-scans of wrists not involved in this study, by two observers (MW and WS) and prior to the definitive measurements.

The axial reformatted CT image of each wrist showing the largest area of the sigmoid notch, including Lister tubercle and the ulnar head were selected by each individual observer for measurement of ulnar translation in both pro- and supination. All slides were independently assessed in random order by both observers, who were blinded for patient and clinical characteristics. At a minimum of three weeks after the first series of reviews, one observer (MW) assessed all CT slides for a second time in random order, for the determination of intraobserver reliability.

Quantification of the ulnar position relative to the radius of both the injured and uninjured wrist was done in four ways:

1. According to the Radioulnar line method[11,18] two lines are drawn; one through the volar ulnar and radial borders of the radius (Figure 4.1, line a) and a second through the dorsal ulnar and radial borders of the radius (Figure 4.1, line b). The maximum distance of the ulnar head outside these two lines is measured, perpendicular to line a; line CD. A fourth line connecting the two edges of the sigmoid notch is drawn, which defines the length of the sigmoid notch (length AB). The ratio of CD to AB is calculated. Volar dislocation of the ulnar head relative to the radius is considered negative, dorsal dislocation as positive. If the ulnar head is situated between line A and B the value is recorded as 0.
2. According to the Subluxation ratio method[21] a line connecting the two edges of the sigmoid notch (point A and B) is drawn, which defines the length of the sigmoid notch (Figure 4.2, length AB). Two lines (line a and line b) are drawn perpendicular to this line, and cross the edges of the sigmoid notch. The maximum distance of the ulnar head outside line a or b is measured perpendicular on this line (distance CD). The ratio between the length of extra-articular ulnar head and the sigmoid notch length is calculated (CD/ AB). Volar dislocation of the ulnar head relative to the radius is considered negative, dorsal dislocation as positive.
3. According to the Epicenter method[19] a line connecting the two edges of the sigmoid notch is drawn (Figure 4.3, line AB), which defines the length of the sigmoid notch. Using two circles the center of the ulnar head and ulnar styloid process is marked; point a and b respectively. The center of rotation of the DRUJ is marked by point D; the crossing of a perpendicular to line AB through point c, halfway the line connecting point a and b. The distance between point D and the midpoint of the sigmoid notch, point C, is measured. The ratio between distance CD and AB is calculated. Volar dislocation of the ulnar head relative to the radius is considered negative, dorsal dislocation as positive.
4. According to the Radioulnar ratio method[17] a line (Figure 4.4, line AB) connecting the two edges of the sigmoid notch is drawn, which defines the length of the sigmoid notch. A second line (line C) is drawn, perpendicular to the first one and through the center of the ulnar head (point C), defined by a circle facing the articular surface. The ratio between the distance from the cross point of the two lines (point D) to the volar edge of the sigmoid notch (length AD) and the length of sigmoid notch (length AB) is calculated.

Statistical Analysis

To evaluate the reliability (inter- and intraobserver agreement) of DRUJ translation measurements on CT, Intraclass Correlation Coefficients (ICC) with their 95% confidence interval (CI) were calculated using the two-way random model for absolute agreement. The ICCs were interpreted according to Landis and Koch who proposed that values 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 0.81 to 1, almost perfect agreement.[22,23] Statistical difference in agreement was defined by absence of overlap in 95% confidence intervals of the ICCs.

The number of observations needed was calculated to ensure significant agreement if the agreement was at least 0.4, with an alpha of 0.05, and a beta of 0.2. The minimal sample size of wrist CT scans to be reviewed was found to be 87.[24]

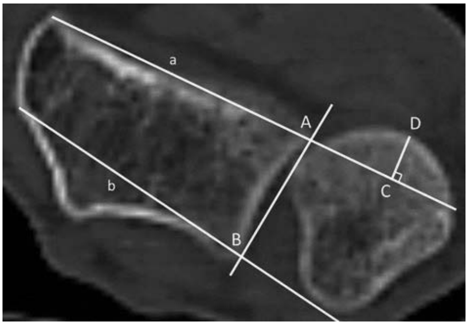

Figure 4.1. The Radioulnar line method = CD/AB: the amount of ulnar head volar or dorsal from the ulnar line is measured (CD). The ratio of this length to the length of the sigmoid notch (AB) is calculated.

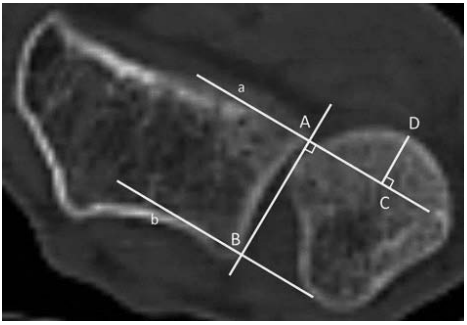

Figure 4.2. The Subluxation ratio method = CD/AB. The length of the sigmoid notch is defined by length AB. The distance of the ulnar head outside line a or b is measured perpendicular on this line (distance CD). The ratio between the length of extra-articular ulnar head and the sigmoid notch length is calculated (CD/AB).

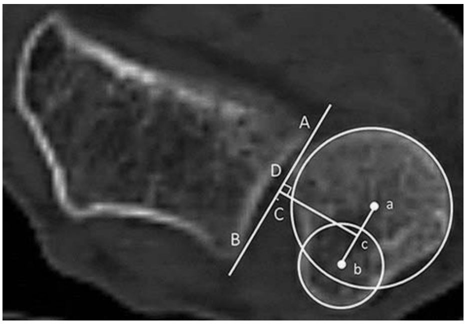

Figure 4.3. The Epicenter method = CD/AB. The centre of rotation (point D) is defined by the center of the ulnar head and ulnar styloid process (point a and b respectively). The distance between point D and the midpoint of the sigmoid notch, point C, is measured.

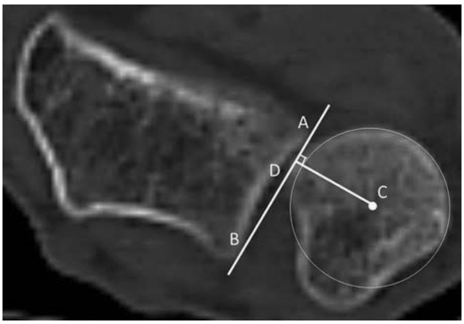

Figure 4.4. The radioulnar ratio method = AD/AB. The length of the sigmoid notch is measured (length AB). A line perpendicular to line AB and the center of the ulnar head is defines point D.

The normal range of ulnar translation for each method was based on CT-scans of the uninjured wrists and defined as the mean value ±2SD for both pro- and supination. To correct for a potential observation learning curve, mean values of CT measurements were based on the first observation of both observers.

RESULTS

One hundred-fifty-eight patients met the inclusion criteria and were invited for a study visit. Thirty-six patients were lost to follow-up and 73 were unwilling to participate. No patients were excluded based on a systemic disease or contralateral wrist injury. Three of the remaining 49 participants had an incomplete CT-scan, leaving 46 participants with 92 wrist-CTs (pro- and supination) for analysis. The study group consisted of 38 females and 8 men with a mean age of 56.5 years (SD17.0, range 18-87) at trauma. Their mean posttraumatic follow-up at the time of CT-scan performance was 4.2 years (SD 0.5, range 3.3-5.0). Twelve patients suffered from pain in the injured wrist with a VAS-score ranging from 5 to 80 points (0 indicating no pain, 100 indication worst pain ever experienced). In one patient this was not recorded. Another patient reported pain in the contralateral wrist. The fractures were classified according to the Comprehensive Classification of Fractures as follows: 22 type A, 4 type B and 20 type C fractures.[20] All distal radius fractures were consolidated at final follow-up.

The highest interobserver and intraobserver agreement, independent of position or posttraumatic state of the wrist, was found for the Epicenter Method (ICC=0.73 95% CI 0.65-0.79 and ICC=0.82, 95% CI 0.77-0.87, respectively) as presented in Table 4.1. When wrist position was taken into account interobserver agreement remained best for the Epicenter method in both pronation (ICC=0.47, 95% CI 0.16-0.67) and supination (ICC=0.72, 95% CI: 0.58-0.81). Accounting for wrist position, intraobserver agreement was best for the Radioulnar line method in both pronation (ICC=0.67, 95% CI 0.53-0.77) and supination (ICC=0.82, 95% CI: 0.74-0.88). All ICCs were higher for supination mea-

Table 4.1. Intraclass Correlation Coefficients (ICC) with 95% Confidence Interval (CI) for interobserver and intraobserver agreement on four scoring methods for measuring DRUJ instability on 184 CT-scans of the wrist.

Method	Interobserver agreement (ICC, 95% CI)	Intraobserver agreement (ICC, 95% CI)
Radioulnar line	0.53 (0.22-0.71)	0.75 (0.68-0.81)
Subluxation ratio	0.51 (0.20-0.69)	0.64 (0.54-0.72)
Epicenter	0.73 (0.65-0.79)	0.82 (0.77-0.87)
Radioulnar ratio	0.68 (0.55-0.76)	0.76 (0.70-0.82)

surements as compared to the corresponding pronation measurements. (Further data not shown).

The ICCs for interobserver agreement of all four methods, separately for injured and uninjured wrists, are presented in Table 4.2. Agreement on measurements in supination with the Epicenter method for the injured wrists was almost perfect (ICC=0.82, 95% CI 0.69-0.89), and was significantly better than that for the uninjured wrists.

The ICCs for intraobserver agreement of all four methods, separately for injured and uninjured wrists, are presented in Table 4.3. Best and almost perfect agreement was found for the Radioulnar line method on supination CT imaging of the injured wrist (ICC=0.92, 95% CI 0.86-0.95), which was significantly better compared to the uninjured wrist.

In Table 4.4 the mean ratios of ulnar translation for all four scoring methods for injured and uninjured wrists in pro- and supination are presented. The normal range of ulnar translation ratios differed from 30% in the Epicenter method in supination to 59% in the Subluxation Ratio in pronation.

Table 4.2. Intraclass Correlation Coefficients (ICC) with 95% Confidence Interval (CI) for interobserver agreement on four scoring methods for measuring DRUJ instability in pro- and supination on CT.

Method	Pronation ICC (95% CI)		Supination ICC (95% CI)	
	Injured (n=46)	**Non-injured (n=46)**	**Injured (n=46)**	**Non-injured (n=46)**
Radioulnar line	0.16 (–0.07-0.40)	0.37 (0.02-0.62)	0.68 (0.32-0.84)	0.33 (0.05-0.56)
Subluxation ratio	0.20 (–0.06-0.45)	0.28 (–0.02-0.53)	0.62 (0.29-0.80)	0.22 (–0.04-0.46)
Epicenter	0.54 (0.19-0.75)	0.42 (0.08-0.66)	0.82 (0.69-0.89)	0.47 (0.18-0.68)
Radioulnar ratio	0.52 (–0.01-0.78)	0.30 (–0.10-0.62)	0.60 (0.37-0.76)	0.35 (0.07-0.58)

Table 4.3. Intraclass Correlation Coefficients (ICC) with 95% Confidence Interval (CI) for intraobserver agreement on four scoring methods for measuring DRUJ instability in pro- and supination on CT.

Method	Pronation ICC (95% CI)		Supination ICC (95% CI)	
	Injured (n=46)	**Non-injured (n=46)**	**Injured (n=46)**	**Non-injured (n=46)**
Radioulnar line	0.54 (0.28-0.72)	0.74 (0.58-0.85)	0.92 (0.86-0.95)	0.62 (0.40-0.77)
Subluxation ratio	0.23 (–0.03-0.47)	0.62 (0.40-0.77)	0.90 (0.83-0.94)	0.49 (0.24-0.68)
Epicenter	0.55 (0.31-0.72)	0.60 (0.38-0.76)	0.84 (0.73-0.91)	0.45 (0.19-0.66)
Radioulnar ratio	0.61 (0.39-0.77)	0.65 (0.45-0.79)	0.63 (0.42-0.78)	0.64 (0.44-0.79)

Table 4.4. Mean ratio values with standard deviation (SD) of radioulnar deviation measured with the four scoring methods on CT for the injured and non-injured wrists, and normal values based on the non-injured wrist, in pro- and supination.

Method	Injured wrist Mean (SD)		Non-injured wrist Mean (SD)		Normal range	
	Pronation	**Supination**	**Pronation**	**Supination**	**Pronation**	**Supination**
Radioulnar line	−0.05 (0.11)	−0.22 (0.18)	0.14 (0.15)	−0.15 (0.12)	−0.15-0.43	−0.39-0.08
Subluxation ratio	−0.02 (0.11)	−0.20 (0.17)	0.05 (0.15)	−0.17 (0.11)	−0.25-0.34	−0.39-0.04
Epicenter	−0.17 (0.09)	−0.01 (0.13)	−0.15 (0.10)	0.04 (0.08)	−0.35-0.06	−0.11-0.19
Radioulnar ratio	0.56 (0.11)	0.29 (0.16)	0.58 (0.09)	0.33 (0.12)	0.39-0.77	0.09-0.58

DISCUSSION

In this study, the best interobserver agreement of four scoring methods, for determination of DRUJ translation by means of CT-scan, was established using the Epicenter Method. This method also showed good corresponding intraobserver agreement values and agreement was better for injured wrists compared to uninjured wrists. Based on these data the Epicenter Method seems the most reliable method to evaluate distal radioulnar translation on CT-scans.

Our findings are in contrast with the data published earlier by Park et al.[21] They found a substantial to almost perfect interobserver agreement for the Radioulnar line method in supination and pronation respectively, for uninjured wrists. A plausible explanation for the difference between the findings of Park and ours is hard to find. In both studies, the CT protocol used is identical and wrist positioning and image selection is performed concordantly. The inclusion of posttraumatic wrists in our study has no negative effect on the reproducibility of the measurements.

Normal ranges

During pronation of the wrist, the unstabilized ulnar head tends to move dorsal relative to the radius. Ulnar translation is therefore one of the indicators of insufficiency of the DRUJ stabilizers; i.e. DRUJ instability. The ratios calculated using the four methods were translated into a percentage representing the amount of ulnar head dislocation outside the sigmoid notch. Using the Epicenter method, which had the best interobserver agreement, normal values of ulnar translation varied from 35% volar dislocation to 6% dorsal dislocation in pronation and from 11% volar dislocation to 19% dorsal dislocation in supination. Mino described, using the Radioulnar line method, the position of the ulnar head within the lines through the dorsal and volar border in every rotational position.[11,18] This resulted in a narrow window for normal values, which is smaller then what was found based on our data. Using Mino's criteria would easily lead to high numbers of patients with uninjured wrist function who are considered to have an abnormal DRUJ and DRUJ instability (false-positive findings). On the other hand Park et al.[21] reported normal values in uninjured wrists varying from 27% volar to 35% dorsal dislocation; a wider range then what we found. Based on Parks wide normal range one may judge an actual unstable DRUJ as normal on CT scan, leading to a false negative outcome. These findings correspond with the results of Kim and colleagues[25], who found a poor correlation between CT-findings and clinical DRUJ assessment. We therefore recommend to interpret normal values with caution when determining DRUJ instability on CT-scans. To avoid false positive and negative findings, we suggest, in accordance to Nakamura and colleagues,[14] to compare the healthy and the injured wrist of a patient expected to have DRUJ instability. The uninjured wrist will reflect the normal laxity of the DRUJ in both pro- and supination. However, no studies on this theory for any of the four scoring methods have been published.[14] For patients with injuries of both wrists, normal values as presented by Park, Mino and our data, are the best available reference.

One of the limitations of this study is that only the reliability of CT-scans for determination of clinical DRUJ instability could be evaluated. Since no reliable and objective test is available for diagnosing DRUJ instability, we were not able to evaluate the validity of CT-scans for determination of clinical DRUJ instability. Nevertheless, these results are valuable given the lack of reliable data on the evaluation of methods for diagnosing radiological DRUJ instability using CT in injured wrists.

CONCLUSION

Measurements for DRUJ instability on CT in pro- and supination can be reliably performed in both normal and posttraumatic wrists. The Epicenter method is the method of choice. There is large normal variation in DRUJ movement. Scanning of both wrists prevents the radiological overdiagnosis of instability.

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