Carpal Alignment: A New Method for Assessment

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Abstract

Background Carpal alignment may be used as a tool to evaluate fracture reduction in patients with distal radius fractures. However, there is little consensus on how to measure and quantify carpal alignment.

Purpose The aim of this study was to compare the inter- and intraobserver variability of a new perpendicular method with the existing method in fractured and unfractured wrists. Additionally, the normal distribution of carpal alignment in unfractured wrists was investigated.

Patients and Methods Carpal alignment was assessed on lateral plain radiographs using two different methods, one described by Ng and McQueen and another newly proposed method, the perpendicular method. Using the perpendicular method, the observer draws one line along the inner rim of the volar cortex of the radius and one perpendicular line to the center of the capitate. The carpus is aligned when the line along the inner rim transects the center of the capitate. Three examiners measured the carpal alignment in 50 patients with nonfractured and 50 patients with fractured distal radius. Intra- and interobserver variability for both methods were determined.

Results The interobserver coefficient for the perpendicular method was 0.98 and that for the Ng method was 0.86. The intraobserver coefficients for three examiners were 0.89, 0.62, and 0.63, respectively, for the Ng method. For the perpendicular method, the intraobserver variability was 0.96, 0.89, and 0.72, respectively. In patients with unfractured wrists, the mean perpendicular to the center of the capitate was 0.25 mm dorsally.

Conclusion The new proposed method is a reproducible method for measuring carpal alignment with a high inter- and intraclass coefficient.

Clinical Relevance This method of measurement allows for a reproducible technique for measuring carpal alignment.

Keywords

- carpal alignment
- measurements
- distal radius fracture

Conventional radiological parameters such as radial inclination, radial length, ulnar variance, and dorsal or volar angulation have been described to correlate with functional outcome in patients with distal radius fractures.^{1–4} However, there are also numerous studies that show no or only a weak correlation

between these same parameters and functional outcome.^{3,5,6} Previous studies have shown the clinical importance of carpal alignment. The incidence of carpal malalignment is correlated with poor functional outcome.⁷ McQueen et al noted that carpal alignment was the main predictor of functional outcome.⁸

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Carpal alignment is not commonly used, maybe because the doctors are unsure about how to measure and quantify this parameter.^{9,10} Carpal alignment entails that the hand should be in line with the forearm.^{4,11} Carpal malalignment has been described as early as in 1919 as the “dorsal luxation of the capitate.”¹² In malunited distal radius, fractures compensatory movement at the midcarpal or radiocarpal level takes place to realign the hand. This mechanism may correlate with poor functional outcome.^{4,8,13,14} Therefore, carpal alignment may be used as a tool to predict patient-related outcome in patients with distal radius fractures. Ng and McQueen defined carpal alignment as a line along the long axis of the capitate and a line along the long axis of the radius. If these lines intersect within the carpus, the carpus and the radius are aligned.

Several radiographic additional indices have been described to assess carpal alignment. The effective radiolunate flexion measures the relationship between the axes of the displaced distal radius and the lunate and classifies carpal alignment into two patterns: midcarpal and radiocarpal alignment.^{9,10} Despite these methods, there is still no gold standard to measure carpal alignment radiographically. Moreover, none of these methods is able to quantify carpal alignment and discriminate between volar and dorsal translation of the carpus. We proposed a new and simple method, the perpendicular method, to assess and to quantify carpal alignment.

The aim of this study was to compare the inter- and intraobserver variability for the new perpendicular method with the standard Ng method in fractured and unfractured wrists and to determine the normal distribution of carpal alignment in unfractured wrists. Additionally, the agreement between the two methods was analyzed.

Patients and Methods

Patient Selection

Between 2011 and 2014, a prospective database was established for patients with wrist trauma in an academic hospital. All patients had a protocolized physical examination and a radiographic measurement of the wrist.¹⁵ This database contains information about patients with and without fractures of the distal radius. For this retrospective observational study, consecutive adult patients with nonoperatively treated distal radius fractures (AO [Arbeitsgemeinschaft für Osteosynthesefragen] classification type A and C) and with unfractured wrists were included. Radiographs were available at presentation and at 6 weeks follow-up. Patients with pathological fractures, and a previous distal radius fracture in the same arm, were excluded.

Sample Size Calculation

To express the degree of inter- and intraobserver agreement, the intraclass correlation coefficient (ICC) was used. To be able to detect a difference between an ICC of an excellent correlation (0.8) and a good correlation (0.7) with an $\alpha = 0.05$ and a power of 0.80, a total 100 patients were needed to be assessed. The calculations were performed with Power Analysis and Sample Size Software (PASS, NCSS Statistical Software, Kaysville, UT).

Radiographic Measurements

In the unfractured wrists, the lateral radiographic parameters at presentation were measured. In the fractured wrists, the lateral radiographic parameters at presentation and at 6 weeks follow-up were measured. Carpal alignment was measured using two different methods. The Ng method uses a line along the long axis of the capitate and a line along the long axis of the radius. Carpal alignment was defined as when both lines intersected within the carpus. Consequently, malalignment was defined as displacement of the longitudinal axis of the capitate either dorsal or volar to the longitudinal axis of the radius on a lateral view (**Fig. 1A**).¹⁶

However, this method only provides a dichotomous variable: aligned versus nonaligned. Therefore, we proposed a new method, the perpendicular method. This method uses one line along the inner rim of the volar cortex of the radius, also known as the line of Lewis, and one perpendicular line to the center of the capitate.¹⁷ The carpus was defined as aligned when the line along the inner rim transected the center of the capitate. The center of the capitate is at the center of a circle drawn around the base of the capitate. The carpus was defined as aligned when the line along the inner rim transected the center of the capitate. By measuring the perpendicular distance to the center of the capitate, the degree of carpal malalignment and direction volar versus dorsal can be quantified (**Fig. 1B**).

These radiographic parameters were measured independently by three authors (C. A. S., L. R., and N. W. L. S.) on all radiographs using a digital radiographic system (IMPAX). A calibration session was performed prior to the measurements were performed. The inter- and intraobserver variability as determined for carpal alignment and perpendicular line measurement was determined. To determine the intraobserver variability, the measurements were reassessed by the same researchers with a 1-month increment. With three observers performing measurements twice on 100 patients, a total of 600 measurements were performed. Additionally, the correlation between the two methods was analyzed. Moreover, the normal distribution of carpal alignment in unfractured wrists was determined for both methods.

Statistical Analysis

Descriptive analyses were performed to assess baseline characteristics. For continuous data, mean (standard error of the mean) and standard deviation (SD) (parametric data) or medians and percentiles (nonparametric data) were calculated. For categorical data, frequencies and percentages were calculated.

The ICC for inter- and intraobserver agreement was calculated for each study parameter. Based on its value, the ICC is summarized, according to Hallgren,¹⁸ as an excellent correlation (0.75),³ a good correlation (0.6–0.74), a fair correlation (0.4–0.59), and a poor correlation (<0.4). For this study, an ICC of 0.6 or above was considered acceptable.

Normality was determined by using the Shapiro–Wilk test and a visual check by plotting the data distribution on a histogram. Data analysis was performed with the Statistical Package for Social Sciences (SPSS version 24, SPSS Inc., Chicago, IL).

Fig. 1 (A) Carpal alignment measured using the Ng method. (B) Carpal alignment measured using the perpendicular method.

Results

Patient Demographics

This study comprised 100 patients, 50 with unfractured distal radius and 50 with displaced distal radius fractures. Patient demographics are shown in ►Table 1.

Intraclass Correlation Coefficient

The interobserver agreement to determine carpal alignment was 0.95 (95% confidence interval [CI]: 0.93–0.96) for the perpendicular method and 0.86 (95% CI: 0.82–0.90) for the Ng method. The intraobserver variability for measuring carpal alignment according to the Ng method and the perpendicular method is depicted in ►Table 2.

Perpendicular line measurement to the center of the capitate (measured in millimeters) had an interobserver agreement of 0.98 (95% CI: 0.976–0.987).

Agreement between the Two Methods

Carpal alignment was identified with the Ng method in 356 of the total 600 measurements. In 53% of these measurements ($n = 187$), the carpus was aligned using the perpendicular method ($r_s = 0.03$; $p = 0.4$). When both methods found the carpus to be aligned, the mean translation of the center of the capitate was 0.75 mm (SD: 1.9) dorsally. In the other 47% of the measurements in which the carpus was found malaligned according to the perpendicular method, the mean translation of the capitate was 2.9 mm (SD: 3.2) dorsally, with a range of –12 to 7 mm.

Table 1 Patient demographics

	Unfractured, N (%)	Fractured, N (%)
Gender		
Male	21 (42)	14 (28)
Female	29 (58)	36 (72)
Age, median [IQR]	32 [23–54]	63 [56–75]

Abbreviation: IQR, interquartile range.

Table 2 Intraobserver variability for the Ng and perpendicular methods

	Intraclass coefficient (95% CI)		
	Observer 1	Observer 2	Observer 3
Ng method	0.89 (0.83–0.93)	0.62 (0.44–0.75)	0.62 (0.46–0.75)
Perpendicular method	0.96 (0.84–0.97)	0.88 (0.82–0.92)	0.72 (0.58–0.81)

Abbreviation: CI, confidence interval.

Fig. 2 Distribution of the perpendicular distance from the line of Lewis to the capitate in unfractured wrists.

Carpal Alignment in Unfractured Wrists

In the unfractured wrists, the mean of the perpendicular line along the line of Lewis to the center of the capitate was 0.25 mm dorsally (SD: 2.52; 95% CI -0.53 to 0.41). **Fig. 2** depicts the distribution of the length of the perpendicular for unfractured wrists.

There was carpal alignment in 79% (236/300) of the unfractured wrists when using the perpendicular method compared with 59% (177/300) carpal alignment in the unfractured wrists using the Ng method. For the considered malaligned unfractured wrists ($n = 66$), the median perpendicular to the center of the capitate was -2.4 (interquartile range: -4.5 to 1.1).

Discussion

The perpendicular method is a reproducible method to determine carpal alignment with a high inter- and intraobserver variability. Furthermore, it is possible to quantify carpal malalignment, with an intraobserver variability for the perpendicular line measurement to the center of the capitate of 0.98. In

79% of unfractured wrists, the carpus was found to be aligned using the perpendicular method, whereas, in only 59% of these wrists, carpal alignment was identified using the Ng method.

In only 53% of measurements using the Ng method, we correspondingly found carpal alignment using the perpendicular method. There was a mean translation of the capitate of 3 mm dorsally when the Ng method defined the carpus to be aligned and the perpendicular method did not. Moreover, the measurements ranged up to -12 mm, indicating that the center of the capitate was more than 1 cm dorsal to the line of Lewis, clearly demonstrating malalignment. Consequently, when using the Ng method, carpal malalignment may not always be recognized. **Fig. 3** illustrates a case in which, according to the Ng method, the carpus is aligned, but where both optically and with the perpendicular method a noteworthy malalignment is measured. The clinical implications of this finding are a field for further research.

An additional feature of the perpendicular method compared with the Ng method is the quantification of the amount of translation by measuring the distance of the perpendicular. This makes it possible to quantify the amount and direction of carpal malalignment. An evident learning curve was observed in measuring carpal alignment. This was more apparent when the Ng method was used. The least experienced member of the team had a lower intraobserver agreement compared with the more experienced member.

A noteworthy, but contradictory, result in our study is that in 20% of unfractured wrists, the carpus seems maligned using the perpendicular method, and using the Ng method, this is 40%. This may indicate that in some patients, the carpus is physiologically not aligned with the radius. The distribution of carpal alignment in the general population has not yet been investigated. These variations in alignment in unfractured wrists may be an area for future research. Measurements were performed with no margin, and perhaps an acceptable range of distance from the perpendicular to the center of the capitate should be accepted. Based on the CI of -0.53 to 0.41, we would argue that a margin of 0.5 cm of dorsal and 0.5 cm of volar displacement would be within the range of aligned. This would need to be validated in further studies.

Fig. 3 Discrepancy between the two methods: alignment with the Ng method (white) but malalignment with the perpendicular method (black).

Fig. 4 (A) Carpal alignment measured using the perpendicular method in the same wrist in different rotational positions: -10, 0, and 10 degrees. (B) Carpal alignment measured using the perpendicular method in the same wrist in flexed and extended positions.

Limitations of this study should be addressed. Wrist positioning on radiographs may influence the carpal alignment indices.¹⁹ Although radiographs of the wrist are taken according to protocols, there remains variability in wrist positioning leading to off-axis films. When using the perpendicular method, alignment might be less influenced by wrist position due to the line along the inner cortex of the volar rim being in proportion to the capitate. ► **Fig. 4** depicts a wrist in various rotational positions (A) and in extended and flexed positions (B), but the carpal alignment remains. This is consistent with clinical practice but may limit the precision of our measurements. Furthermore, the line of Lewis may not always be obvious, especially in pathological cases such as Paget's disease. A reasonable length of radial shaft needs to be visible on the radiograph to be accurate. Moreover, the distribution of normal carpal alignment was determined in a significantly younger population than those with fractured wrists. Midcarpal instability could, for example, play a role in the distribution of carpal alignment in unfractured wrists. Patients may have experienced a previous distal radius fracture. In these patients, two forms of malalignment may have occurred: "adaptive" midcarpal malalignment and pathological radiocarpal malalignment.¹⁶ "Adaptive" midcarpal malalignment is the adaptation to the malunion at the midcarpal level. Pathological radiocarpal malalignment causes a radiocarpal dorsal imbalance, resulting in dorsal subluxation of the radiolunate joint. These changes in alignment are more often the result of biomechanical

changes than of ligament injury.²⁰ Last, there is no gold standard for carpal alignment, making it impossible to calculate the sensitivity and specificity of our new method.

The newly proposed method, the perpendicular method, is a reproducible method for measuring carpal alignment with a high inter- and intraclass coefficient. The amount of translation can be reliably measured, allowing quantification of carpal malalignment rather than a binary outcome (alignment or malalignment). A considerable carpal malalignment may be missed when using the Ng method. Now that we have this method for measuring carpal alignment, future validation studies should be performed. Moreover, the effect of this radiological parameter on the functional outcome is still to be determined.

Note

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Funding

None.

Conflict of Interest

None declared.

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