Morphological Associations between the Distal Radioulnar Joint and the Lunate

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Abstract

Background Variations in morphology of the carpal bones have been described. Their implication in wrist disease and specific kinematic features has been recognized, and a better knowledge of these variations is essential.

Questions/Purpose To radiographically determine any association between the morphological variations of the distal radioulnar joint (DRUJ) and the lunate bone.

Materials and Methods Radiographs of 100 wrists of patients presenting to the emergency department with wrist pain and referred to our outpatient clinic were retrospectively reviewed for DRUJ inclination, ulnar variance, and radiocarpal and midcarpal morphology of the lunate.

Results There were 51 females and 49 males, mean age 51.2 years (range: 21–94). There was a statistically significant association between the DRUJ inclination and the morphology of the radiocarpal side of the lunate ($p < 0.001$). The mean values of ulnar variance changed according to DRUJ inclination and the radiocarpal side of the lunate ($p < 0.001$) but not according to the midcarpal side of the lunate. There was no significant association between the morphology of the DRUJ and the midcarpal side of the lunate or between the midcarpal and the radiocarpal morphology of the lunate.

Conclusion This study demonstrated a statistically significant association at the radiocarpal level between the DRUJ inclination, ulnar variance, and the morphology of the lunate. No association was found with the morphology of the midcarpal side of the lunate. Accordingly, a classification of these carpal associations is proposed, highlighting seven main wrist configurations.

Clinical Relevance These associations can guide future studies of wrist kinematics.

Keywords

- carpal anatomy
- morphology variations
- distal radioulnar joint
- lunate

Variations in morphology of the wrist have implications in wrist diseases^{1–4} and specific kinematic features.^{5–7} A better knowledge of these morphological variations is essential to better understand physiological and pathological kinematics and kinetics of the wrist.

The geometry of the lunate and the radius/lunate complex are key elements in the mechanism of the carpal joint and wrist kinematics.^{7–12} Furthermore, it is involved in many common pathologies of the wrist, such as osteoarthritis, rheumatoid

diseases, and Kienböck's disease, whose management remains challenging.¹³

In 1928, Hulten published a radiographic study comparing distal radioulnar relationships of normal wrists and those of patients with Kienböck's disease.¹⁴ He described the relative length of the ulna compared with that of the radius and introduced the concept of negative ulnar variance, positive ulnar variance, and neutral ulnar variance.

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In a 1966 doctoral thesis on Kienböck's disease, Zapico¹⁵ recognized three different shapes of the lunate on its radiocarpal side. He also described a relationship between these types of lunate and the ulnar variance.

In 1990, Burgess¹⁶ and Viegas¹⁷ described two types of lunate, based on its midcarpal morphology. Type I has a single midcarpal surface articulating with the capitate. Type II has two midcarpal articulating facets, one articulating with the capitate and the other with the hamate.

Förstner¹⁸ and Tolat et al¹⁹ described three types of distal radioulnar joints (DRUJs) based on the orientation of the articular surface. Their studies showed a relationship between the orientation of the DRUJ and the ulnar variance.

The aims of this study were to evaluate the associations between the ulnar variance, the DRUJ, and the midcarpal and radiocarpal morphology of the lunate bone.

Materials and Methods

Study Design and Patient Selection

Following approval by our institution's ethics committee, 100 standard anteroposterior wrist radiographs of patients, previously treated in the outpatient clinic at our institution, were selected for this retrospective study. The patients had initially been screened in the emergency department for wrist pain or injury and were then referred to our outpatient clinic. The diagnoses of the selected patients are summarized in ►Table 1. Inclusion criterion was adults older than 18 years. Exclusion criteria were a history of radius or ulna fracture, fracture of the carpal bones, and malformations. Age and gender were recorded. Radiographs of the affected wrist were taken using a standardized method,^{20,21} with abduction of the shoulder, elbow flexed 90 degrees, and neutral pronosup-

ination of the forearm. The measurements were calculated on digitalized pictures, using a DICOM viewer (OsiriX MD v.2.6 64-bit).

Statistics

Statistical analysis was performed using SPSS release 17.0 (SPSS Inc., Chicago, IL). Continuous variables were expressed in millimeters as median (interquartile range). Categorical variables were expressed as frequency with percentage. Cross tabs 2 × 2 were constructed, and a Pearson chi-square test was performed. Statistical significance was set at $p < 0.05$. Ulnar variance was compared with other variables using an analysis of variance (ANOVA).

Variable Measurements

The long axis of the radius was defined as a line drawn through two points located in the middle of the diaphysis of the radius, at distances of 3 and 6 cm proximal to the lunate articular facet of the radius.^{22,23}

The ulnar variance was measured according to the method of perpendiculars.^{24–26} This method is relatively easy to use and has a high level of interobserver and intraobserver reliability²⁵ (►Fig. 1A–C).

The type of DRUJ was determined as described by Tolat,¹⁹ i.e., by measuring the angle between a line parallel to the long axis of the ulna and a line passing between the apposing joint surfaces (►Fig. 1D–F). Type 1 or “vertical” has an angle equal to infinity; type 2 or “oblique” has an angle closing distal to the DRUJ; and type 3 or “reverse oblique” has an angle closing proximal to the DRUJ.^{18,19,27–29}

Three types of morphologies were recorded for the radiocarpal side of the lunate as described by Zapico.¹⁵ Type 1 has a proximal and medial aspect converging in a prominent proximal apex, with an angle between the radial and proximal sides of the lunate of approximately 135 degrees (►Fig. 1G). Type 2 shows a flat proximal aspect, more parallel to the midcarpal border of the lunate, with an angle between the radial and proximal sides of the lunate of approximately 100 degrees (►Fig. 1H). Type 3 has a V-shaped proximal aspect (►Fig. 1I).

The midcarpal morphology of the lunate was recorded as two types according to Viegas.^{2,17,30} Type I has only one distal articular surface (with the capitate), and type II has an additional distal articular facet for the hamate. Nakamura et al³¹ showed that the shortest distance between the capitate and triquetrum (C–T distance) on a radiograph increases as the width of the hamate facet of the lunate increases, and they described a method of determining the lunate type according to the C–T distance. Some authors have demonstrated that some type II lunates with a small hamate facet may have incorrectly been included in the type I group.^{2,6} To minimize this error, we used the method described by Galley et al,⁶ which consists of determining the lunate type according to the C–T distance (i.e., type I lunate has a C–T distance ≤ 2 mm, and type II lunate has a C–T distance ≥ 4 mm) and creating a third, intermediate group, “type III” (i.e., $2.0 \text{ mm} < \text{C–T distance} < 4.0 \text{ mm}$), which contains both type II lunates with a small hamate facet and type I lunates (►Fig. 1J–L).

Table 1 Diagnosis of patients presenting with wrist pain or injury to the emergency department and referred to our outpatient clinic

Diagnosis	Patients (n = 100)
Nonspecific carpal bruise	32
Carpal sprain	13
Carpal tunnel syndrome	2
Fifth metacarpal fracture	1
First metacarpal fracture	2
Ganglion cyst	3
Scaphotrapeziotrapezoid arthritis	1
Soft tissue lesion or infection	4
Thumb carpometacarpal arthritis	34
Thumb metacarpophalangeal arthritis	1
Thumb metacarpophalangeal sprain	1
Triangular fibrocartilage complex sprain	3
Ulnar nerve compression	1
Ulnocarpal impingement	2

Fig. 1 Radiographic examples of wrist morphologies. Ulnar variance according to the method of perpendiculars: (A) negative, (B) neutral, and (C) positive. Distal radioulnar joint: (D) Type 1 vertical or parallel, (E) Type 2 oblique, and (F) Type 3 reverse. Radiocarpal morphology of the lunate: (G) type 1, (H) type 2, and (I) type 3. Midcarpal morphology of the lunate: (J) type I, (K) type II with an additional distal articular facet for the hamate, and (L) the capitotriquetral (C-T) distance.

Results

► **Table 2** summarizes the demographic data and the variable measurements. All associations concerning the midcarpal aspect of the lunate were determined excluding the 47 lunates classified as intermediate type III according to the method of Galley et al.⁶

Specific Associations

Ulnar Variance

Associations with the mean values of ulnar variance are shown in ► **Table 3**. The mean ulnar variance varied significantly

according to the type of DRUJ ($p < 0.001$), where a more positive ulnar variance was associated with type 3 (reverse) DRUJ. More neutral variance was associated with type 1 (vertical) DRUJ, and smaller mean values (although not necessarily negative ulnar variance) were associated with type 2 (oblique) DRUJ (► **Fig. 2**).

Another statistically significant association was observed between the radiocarpal morphology of the lunate according to Zapico¹⁵ and the mean values of the ulnar variance ($p < 0.001$). Type 1 lunate was associated with more negative mean values of ulnar variance, type 2 lunate with more neutral values, and type 3 (V-shaped) with more positive mean values of ulnar variance (► **Fig. 3**).

Table 2 Demographic data and variable measurements

Variables	Categories (types)	Total, <i>n</i>	Total without intermediate type III lunate, <i>n</i> (%)
DRUJ according to Tolat et al ¹⁹	1	29	15 (28.3)
	2	65	36 (67.9)
	3	6	2 (3.8)
Midcarpal morphology of the lunate according to Viegas, ² Nakamura ³¹ and Galley ⁶	I	8	8 (15.1)
	II	45	45 (84.9)
	III (intermediate)	47	–
Radiocarpal morphology of the lunate according to Zapico ¹⁵	1	43	25 (47.2)
	2	23	10 (18.9)
	3	34	18 (34.0)
Gender	Males	49	35 (66.0)
	Females	51	18 (34.0)
	Range	Mean (SD)	Mean (SD)
Ulnar variance	–3.7–4.5	0.94 (1.68)	0.90 (1.65)
Age	21–94	51.2 (17.0)	49.9 (17.8)

Abbreviation: DRUJ, distal radioulnar joint.

Table 3 Mean ulnar variance

Variables	Type of variation	Mean ulnar variance (SD)	<i>p</i> -Value
DRUJ according to Tolat et al ¹⁹	1	1.73 (1.39)	<0.001
	2	0.40 (1.61)	
	3	2.88 (1.28)	
Midcarpal morphology of the lunate according to Viegas, ² Nakamura ³¹ and Galley ⁶	I	0.50 (1.37)	0.75
	II	0.97 (1.70)	
	III	0.98 (1.73)	
Radiocarpal morphology of the lunate according to Zapico ¹⁵	1	0.25 (1.75)	<0.001
	2	0.90 (1.22)	
	3	1.84 (1.46)	

Abbreviation: DRUJ, distal radioulnar joint; SD, standard deviation.

Fig. 2 (A) Positive UV associated with type 3 (reverse) DRUJ. (B) Neutral UV associated with type 1 (vertical) DRUJ. (C) Smaller mean values associated with type 2 (oblique) DRUJ. DRUJ, distal radioulnar joint; UV, ulnar variance.

Fig. 3 (A) Type 1 lunate associated with negative ulnar variance. (B) Type 2 lunate with neutral ulnar variance, and (C) Type 3 (V-shaped) lunate with more positive ulnar variance.

Fig. 4 (A) Lunate type 1 associated with a DRUJ type 2. (B) Lunate type 3 associated with a DRUJ type 3.

No significant association could be found between the midcarpal morphology of the lunate and the ulnar variance ($p = 0.75$).

Radiocarpal Morphology of the Lunate

The analysis demonstrated a statistically significant association between the radiocarpal morphology of the lunate (Zapico¹⁵), DRUJ, and ulnar variance. There was also a significant association between the radiocarpal morphology of the lunate and DRUJ type according to Tolat ($p < 0.001$). Type 1 lunate was associated with type 2 DRUJ. All patients (six cases) with type 3 DRUJ had a type 3 lunate. Among the 23 wrists with a type 2 lunate, 10 had a type 1 DRUJ, and 13 had a type 2 DRUJ (►Fig. 4).

Midcarpal Morphology of the Lunate

No association could be found between the midcarpal morphology of the lunate and the other variables (i.e., radiocarpal morphology of the lunate, DRUJ, and ulnar variance).

Discussion

Normal anatomy of the wrist has been extensively described in the literature over the past three decades.^{1,30,32–37} More recently, variations in morphology, and their implication in diseases of the wrist^{1–3,16} and specific kinematic features^{5–7} have been emphasized. The distal radius/lunate complex is a key component in wrist kinematics^{7–12} and is subject to morphological variations. This study has some limitations. First, only standard radiographs were included; computed tomography (CT) scans or magnetic resonance imaging (MRI) could have added anatomical information. Standard radiographs are the routine diagnostic examination for patients with wrist pain. Furthermore, the majority of publications concerning morphological bone variations of the wrist are based on radiographs and thereby offer more data for comparison. The variations assessed in this study are described in the literature primarily using radiographic criteria and only rarely using CT or MRI.^{26,38} Another potential limitation of this study is the ethnicity of the investigated population, which is a mixed one, from a single urban, university hospital.

Ulnar Variance

Overall, the mean ulnar variance was positive, similar to that reported by Nakamura et al³⁹ and Schuurman et al⁴⁰ (►Fig. 5). A negative ulnar variance was the least represented group,

Fig. 5 Summary of UV across studies. UV, ulnar variance.

consistent with other studies.^{28,39,40} Discrepancies in the proportions of each group within the studies may be due to the technique used to determine the ulnar variance.²⁵ In this study, as in the study by Nakamura et al,³⁹ positive variance was set at values > 1 mm, whereas Schuurman et al⁴⁰ set it at values > 0 mm. Furthermore, factors such as age, gender, and geography might have influenced these results.^{39,41}

Distal radioulnar joint: The results of this study are compared with those of the literature^{19,27–29} in ►Fig. 6. A type 3 reverse oblique DRUJ was always the least represented group, whereas type 2 oblique was the most represented type in the present study, as well as in the studies by de Smet and Fabry²⁹ and Tolat et al.¹⁹

Radiocarpal morphology of the lunate: Our results are compared with published data^{15,40,42} in ►Fig. 7. The results for type 1 and type 2 were heterogeneous in these four studies, but type 3 was never the predominant group. These irregular results might have been due to the lack of well-defined criteria for determining the shape of the proximal surface of the lunate. Zapico¹⁵ classified type 1 as having an angle between the proximal and lateral surface of the lunate of approximately 135 degrees; in type 2, this angle was approximately 100 degrees; type 3 presented two proximal articular facets, forming a V-shaped surface. These criteria were challenging to apply precisely. It was particularly difficult to distinguish between a type 1 and a type 2 lunate, as the angle between the proximal and lateral surface of the lunate often had a value between 100 and 135 degrees. The interobserver reliability using Zapico's criteria¹⁵ was

Fig. 6 Summary of DRUJ morphology across studies. DRUJ, distal radioulnar joint.

Fig. 7 Summary of radiocarpal morphology of the lunate across studies.

Fig. 8 Summary of midcarpal morphology of the lunate across studies.

Table 4 Distribution of the three morphological variations together

DRUJ					D1 (30)				
Lunate		L1 (6)			L2 (10)			L3 (14)	
UV	N (2)	+ (4)	– (0)	N (4)	+ (6)	– (0)	N (1)	+ (13)	– (0)
DRUJ					D2 (64)				
Lunate		L1 (37)			L2 (13)			L3 (14)	
UV	N (12)	+ (13)	– (12)	N (6)	+ (6)	– (1)	N (6)	+ (6)	– (2)
DRUJ					D3 (6)				
Lunate		L1 (0)			L2 (0)			L3 (6)	
UV	N (0)	+ (0)	– (0)	N (0)	+ (0)	– (0)	N (0)	+ (6)	– (0)

Abbreviations: DRUJ, distal radioulnar joint; N, neutral; UV, ulnar variance; + positive ulnar variance; – negative ulnar variance.

Note: DRUJ with D1 for vertical or parallel type, D2 oblique, and D3 reverse type.

The lunate types according to Zapico¹⁵ are L1 for the type 1 showing a proximal and medial aspect converging in a prominent proximal apex, L2 for type 2 with a flat proximal aspect, more parallel to the midcarpal border of the lunate, and L3 for type 3 with a V-shaped proximal aspect.

probably low, and a clearer, objective and reproducible method for determining lunate morphology is needed.

Midcarpal morphology of the lunate: With the exception of the study by Burgess,¹⁶ most published studies^{2,3,17,30,43–45} demonstrated similar proportions of the two types of lunate (– Fig. 8). This study and the study by Galley et al⁶ reported smaller proportions of type I lunates. This may be explained by the methodology used; both studies determined the type of lunate according to the C–T distance method, which included an intermediate (“type III”) group, to avoid erroneously designating type II lunates with a small hamate facet as type I.^{2,6}

Ulnar variance versus radiocarpal morphology of the lunate: In 1991, Obermann⁴² described correlations between the ulnar variance and the shape of the lunate according to Zapico’s classification¹⁵ in 68 patients. No statistical analysis was done, but type 3 was predominant in the positive variance group. Type 2 was found less often in the negative ulnar variance group, and no correlation was found for type 1. Schuurman et al⁴⁰ did not find any statistical relationship between the ulnar variance and the radiocarpal morphology of the lunate, but a precise description of the method used to determine the type of lunate was lacking. In this study, a type 1 lunate was associated with negative ulnar variance, type 2 lunate with neutral values, and type 3 with positive ulnar variance, consistent with Obermann’s results.⁴²

Ulnar variance versus DRUJ: Förstner,¹⁸ Tolat et al,²⁷ Hollevoet et al,²⁸ and this study found the same statistically significant association between the angulation of the DRUJ and the ulnar variance. A vertical DRUJ (type 1) was associated with a neutral variance, an oblique DRUJ (type 2) was associated with negative variance, and reverse type DRUJ (type 3) was associated with positive ulnar variance.

Midcarpal morphology of the lunate: Viegas et al² found no correlation between the midcarpal morphology of the lunate and the ulnar variance. To our knowledge, no other published study to date has evaluated possible associations between the midcarpal morphology of the lunate and the ulnar

Fig. 9 The seven main configurations of morphological associations. DRUJ with D1 for vertical or parallel type, D2 for oblique type, and D3 for reverse type. The lunate types according to Zapico¹⁵ are L1 for type 1 showing a proximal and medial aspect converging in a prominent proximal apex, L2 for type 2 with a flat proximal aspect, more parallel to the midcarpal border of the lunate, and L3 for type 3 with a V-shaped proximal aspect. DRUJ, distal radioulnar joint; N, neutral; UV, ulnar variance; +, positive; -, negative.

variance or the DRUJ orientation. This study found no association between the midcarpal morphology of the lunate and the other variables.

This study demonstrated a clear association between the mean values of the ulnar variance, DRUJ orientation, and radiocarpal morphology of the lunate. The anatomical variations of the midcarpal side of the lunate seem to be excluded from the radiocarpal level. Previous publications described these variables separately or in association with one other morphological variable. However, these have never been compared all together to find any possible associations. While the published data are sometimes heterogeneous, most of our results confirmed these data and supported a plausible and logical reasoning. Combining all three morphological associations produced 27 theoretical combinations. We organized and classified these combinations in **Table 4** and have shown the distribution of the three morphological variations together among the 100 wrist radiographs. The seven main configurations are shown in **Fig. 9**. Interestingly, all six cases of type 3 DRUJ were type 3 DRUJ–type 3 lunate configuration, i.e., with a V-shaped lunate and a positive ulnar variance. Having determined these anatomical (i.e., static) associations, this study can guide the conduct of kinematic studies of the wrist, with the hope of adding new knowledge to the treatment of some common pathologies of the wrist.

Conflict of Interest
None.

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