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Association of Lunate Morphology With Carpal Instability in Scapholunate Ligament Injury

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Abstract

Background: We examined the relationship between lunate morphology (type I without a medial facet; type II with a medial facet) and dorsal intercalated segmental instability (DISI) in patients with scapholunate ligament injuries. We tested the primary null hypothesis that there is no relationship between lunate morphology and development of DISI. Secondary analysis compared the agreement of classifying lunate morphology based on the presence of a medial lunate facet, capitate-to-triquetrum (CT) distance, and magnetic resonance imaging (MRI). **Methods:** We performed a retrospective chart review of patients with known scapholunate ligament injuries from 2001 to 2016. Posterior-anterior radiographs and MRI, when available, were evaluated. CT distances were measured as a secondary classification method. DISI and scapholunate instability were determined as radiolunate angle >15° and scapholunate angle >60°, respectively. Differences between groups were determined using chi-square analysis with significance set at $P < .05$. Agreement between plain radiographs, MRI, and CT distance was calculated using the kappa statistic. **Results:** Our search found 58 of 417 patients who met inclusion criteria; 41 of 58 had type II and 17 of 58 had type I lunates. There was no significant difference between groups in regard to DISI or scapholunate instability. Subanalysis using MRI alone or correcting any discrepancy between plain film and MRI classification, using MRI as the standard, found no difference between groups in regard to DISI or scapholunate instability. **Conclusions:** In patients with scapholunate ligament injuries, there are no differences in the development of DISI or scapholunate instability between patients with type I and type II lunates.

Keywords: lunate morphology, type II lunate, carpal kinematics, DISI, carpal instability

Introduction

Multiple factors, including carpal morphology and laxity, have been suggested to influence carpal kinematics and kinetics in the normal and unstable wrists.[1,4,5,8,14,15,18,20] The presence of a medial facet, termed a type II lunate, is reported between 27% and 73%[8,10,12,18,20,21] and has been suggested to impact dissociative carpal instability.[8,18] For example, patients with type II lunates have been shown to develop arthritic changes at the proximal hamate pole, suggesting an articulation between the lunate and the hamate which may alter carpal kinematics.[15,19,20]

Rhee et al previously demonstrated that more patients with type I lunates developed dorsal intercalated segmental instability (DISI) patterns compared with type II lunates in patients with known scapholunate ligament tears. They theorized that the articulation between the lunate and the hamate lends increased stability against the typical extension deformity seen when the scaphoid and lunate articulation is uncoupled.[18] Increased stability due to this medial facet is also theorized in other studies where patients with type II lunates presented with less severe progression of Kienbock disease and less severe scaphoid flexion deformity without coronal lunate fracture.[17] Another study suggests that patients with scaphoid nonunions have a lower incidence of DISI deformity.[8]

Traditionally, the different lunate morphologies are classified radiographically by the presence, or absence, of a medial lunate facet that articulates with the hamate.[20] Subsequently, Sagerman et al compared the accuracy of radiographic assessment of lunate morphology with anatomic findings on gross dissection. They found 64% to 72% of lunates were

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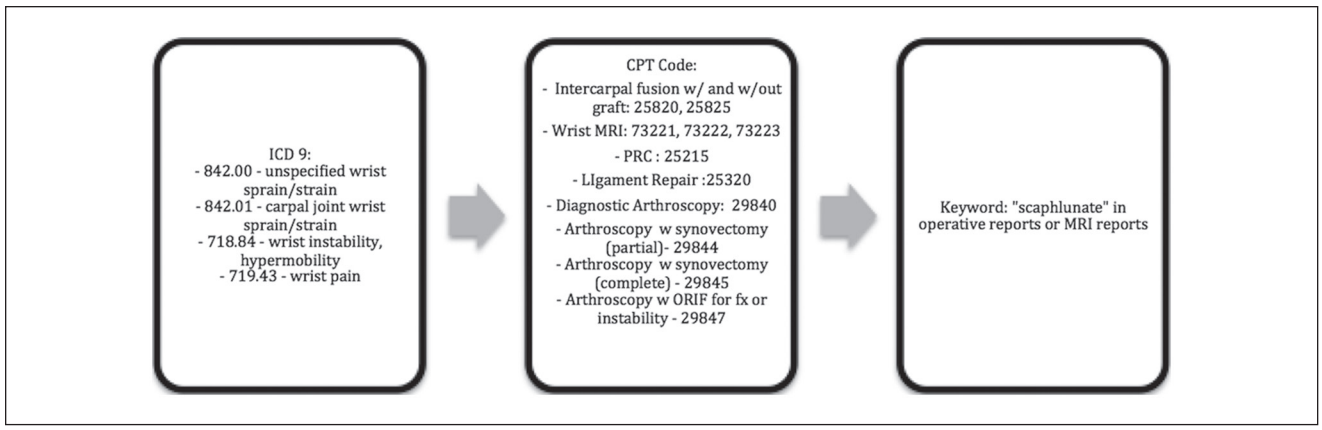

Figure 1. Search protocol. We queried the Center for Clinical Informatics Cohort Finder and Chart Review programs using the above algorithm to create our cohort of patients. Charts were then manually reviewed for inclusion eligibility.
Note. MRI = magnetic resonance imaging; ICD 9 = International Classification of Disease 9; CPT = Current Procedural Terminology; PRC = Proximal Row Carpectomy; ORIF = Open Reduction Internal Fixation.

correctly identified on plain posterior-anterior (PA) radiographs depending on the evaluator.[19] In 2007, Galley et al measured the shortest capitate-to-triquetrum (CT) distance to identify the presence of a medial facet. Their method is based on the theory that the presence of a medial facet will increase the CT distance.[4] Rhee et al compared traditional identification of a medial facet on PA radiograph with the CT distance for identification and reported fair interobserver relationship ($\kappa = 0.394$).[18] Finally, advanced imaging techniques including magnetic resonance imaging (MRI) have been used to assess lunate morphology as well, demonstrating 100% accuracy.[10,11] Direct visualization of carpal morphology remains the most accurate form of evaluation; however, it remains impractical in most clinical cases.

Prior studies demonstrate altered wrist kinematics in the setting of type I versus type II lunate morphology, but the clinical implications continue to be studied.[1,14] Studies examining differences in DISI deformity in various injury and disease states primarily use radiographs to identify the lunate morphology which demonstrates only 64% to 72% accuracy.[8,17-19] The variable accuracy of classifying lunate morphology brings into question the validity of the relationships proposed between lunate morphology and instability patterns.

Our study aims to validate the findings of the prior study in determining whether there is a relationship between lunate morphology and carpal instability patterns. We performed a retrospective chart review from 2001 to 2016 of patients with known complete scapholunate ligament tears to test the primary null hypothesis that there is no relationship between lunate morphology and development of DISI. Secondary analysis compared the agreement of classifying lunate morphology based on radiographic presence of a medial lunate facet or CT distance, and MRI evaluation.

Materials and Methods

Institutional review board approval was obtained for this retrospective chart review. We used the Center for Clinical Informatics Cohort Finder and Chart Review programs to identify eligible patients. Figure 1 illustrates the search criteria used to identify patients with potential scapholunate ligament injuries. Subsequently, operative reports were reviewed to confirm complete scapholunate ligament injuries. Inclusion criteria for the study were similar to the previous report, including patients with operative reports describing a confirmed complete scapholunate injury or patients with scapholunate advanced collapse patterns. Patients were excluded from the study if they had a concurrent history of a multiligamentous wrist injury, previous wrist surgery, history of carpal or distal radius fracture, inflammatory arthritis, congenital wrist abnormalities, or inadequate imaging. Inadequate imaging was defined as a lack of perioperative radiographs or radiographs that did not have proper alignment defined as lateral radiographs with radius-to-long finger metacarpal angle >20° or inadequate scaphopisocapitate overlap.[16,22] We powered our study based on the findings of the prior published report.[18] To reach a sample size similar to that of the prior published report, charts were reviewed from 2001 to 2016.

Patients who met all of the above criteria had standard PA and lateral hand/wrist radiographs, as well as MRI if present, evaluated independently by 2 senior orthopedic surgery residents. All measurements were taken as the average between the 2 observers. Lunate type was classified radiographically in 2 different methods. The first method was based on the presence (type II) or absence (type I) of a medial lunate facet.[20] If there was a discrepancy between observers regarding lunate type based on this method, a third observer was used to determine the lunate type. The second method was

by measuring the CT distance as described by Galley et al.[4] Wrists were classified as type I for a distance of 0 to 2 mm, indeterminate for a distance of 2.1 to 3.9 mm, and type II for a distance >4.0 mm. The CT distance was measured by both observers, and the average measurement was used to determine the lunate type.

The radiolunate angle was used to determine DISI deformity, and scapholunate angle was used to determine dissociative carpal instability of the proximal row. The axes of the lunate, scaphoid, and radius were used to measure radiolunate and scapholunate angles as described by Larsen et al.[9] DISI was defined as a radiolunate angle >15°, and scapholunate instability was defined as scapholunate angle >60°.[7]

Chi-square analysis was used to compare groups with significance set at $P < .05$. Agreement between plain radiographs, MRI, and CT distance for assessing lunate morphology was calculated using the kappa statistic. The kappa statistic agreement was interpreted as slight (0-0.20), fair (0.21-0.40), moderate (0.41-0.60), substantial (0.61-0.80), and almost perfect (0.81-0.99).[18]

Results

We searched records from 2001 to 2016 yielding 417 charts of which 109 wrists met our inclusion criteria. Fifty-one wrists were excluded due to concurrent history of a multiligamentous wrist injury, previous wrist surgery, history of carpal or distal radius fracture, inflammatory arthritis, congenital wrist abnormalities, or inadequate imaging. Of the remaining patients, 58 wrists were included in the study. Demographics of our cohorts are shown in Table 1.

Radiographic Assessment of Medial Facet

Based on radiograph assessment of a medial facet, 41 of 58 (71%) were classified as type II and 17 of 58 (29%) were classified as type I. We did not find a statistically significant difference between the type I and type II groups in regard to DISI ($P = .33$) or scapholunate instability ($P = .11$) (Table 2). Observers had a kappa statistic of 0.6459 using this technique, indicating substantial agreement.

Radiographic Assessment by Galley Method

We also compared PA radiographs with the Galley method for identification of lunate morphology (Table 3). Observers had a kappa statistic of 0.251 using this technique, indicating fair agreement. Due to the minimal agreement, we chose to use the results of the medial facet method of lunate classification for our analysis, as used by Rhee et al in a prior study.[18]

MRI Assessment

MRI studies were available for 26 patients. Assuming 100% accuracy in identifying lunate type using MRI, we found 18 of 26 (69%) to be type II and 8 of 26 (31%) to be type I.[11] Agreement between MRI and medial facet radiographic assessment had almost perfect agreement, with a kappa statistic of 0.831. In this group, we did not find a statistically significant difference between the type I and type II groups in regard to DISI ($P = .15$) or scapholunate instability ($P = .53$). Of note, when radiographic identification was corrected using MRI as the gold standard for diagnosis, only 2 patients crossed over from the type I group to the type II group. This did not change statistical relationships (Table 4).

Carpal Instability Patterns

Finally, we assessed for any relationship between DISI and scapholunate instability. There were 14 of 41 patients with

Table 1. Comparison of Demographic Data Between Type I and Type II Lunate Groups.

	Type I (n = 17)	Type II (n = 41)	*P* value
Hand dominance			
R	16	38	.84
L	1	3	
Hand affected			
R	11	26	.92
L	6	15	
Sex			
M	10	31	.20
F	7	10	
Age (years)	45	54	.63

Table 2. DISI (RL >15°) and Scapholunate Instability (SL >60°) Based on Lunate Type Using Radiographic Medial Facet Method.

	Type I (n = 17)	Type II (n = 41)	*P* value
RL <15°	4	15	.33
RL >15°	13	26	
SL <60°	3	2	.11
SL >60°	14	39	

Note. DISI = dorsal intercalated segmental instability; RL = radiolunate angle; SL = scapholunate angle.

Table 3. Classification of Lunate Type Based on Capitate-to-Triquetrum Distance (Galley Method) Versus PA Radiographic Assessment Using Medial Facet Method.

	PA radiographic assessment			
Galley method	Type I	Intermediate	Type II	Total
Type I	2	0	0	2
Intermediate	12	0	10	22
Type II	3	0	31	34
Total	17	0	41	58

Note. PA = posteroanterior.

Table 4. DISI (RL >15°) and Scapholunate Instability (SL >60°) Based on Lunate Type When Radiographic Lunate Morphology Identification Is Corrected With MRI Assessment.

	Type I (n = 15)	Type II (n = 43)	*P* value
RL <15°	4	15	.56
RL >15°	11	28	
SL <60°	3	2	.07
SL >60°	12	41	

Note. DISI = dorsal intercalated segmental instability; RL = radiolunate angle; SL = scapholunate angle; MRI = magnetic resonance imaging.

type II lunates and 2 of 17 patients with type I lunates that had normal radiolunate angles (<15°) and high scapholunate angles (>60°). This did not represent a significant difference between groups ($P = .08$). Overall, there was slight agreement (kappa = 0.110) between the incidence of scapholunate instability and DISI.

Discussion

Our study was motivated by limited supporting evidence of any correlation of lunate type and instability in the setting of scapholunate ligament injuries.[18] This lack of published evidence is compounded with the use of relatively unreliable identification methods. We sought to validate the findings of a prior study with the addition of the use of MRI when available. In our cohort, we did not find a difference between lunate type and incidence of DISI or scapholunate instability using plain radiographs or MRI. We modeled our study after the work by Rhee et al including the patient selection criteria, sample size, and radiographic parameters used for analysis with the addition of MRI analysis. In our cohort, however, we were not able to reproduce their findings. Our results suggest that lunate type may not be protective against DISI deformity in scapholunate injuries. Of note, the average age of our cohort was older (type 1: 45 vs 41 years old and type II: 54 vs 38 years old) and had more males (70% vs 50%). It is possible that the difference in age or sex distribution could contribute to greater ligamentous laxity of the intrinsic and extrinsic ligaments that would influence carpal instability.

The incidence of type II lunates in our cohort (71%) is consistent with previous reports.[8,10,18,20,21] Prior studies examining the effects of lunate type on wrist mechanics in vivo have used plain radiographs.[8,18] Sagerman et al demonstrated 64% to 72% accuracy of identifying type II lunates using PA radiographs compared with direct examination in a cadaver-based study.[19] It is proposed that very small cartilaginous medial facets <3 mm in width can be missed on radiographs and may lead to misclassification of type II lunates as type I.[3,20,21] As such, the gold standard of identifying lunate type remains direct visualization. McLean et al, however, proposed that MRI is the most accurate method of identifying lunate type with 100% accuracy in their sample of 13 lunates.[11]

In our study, 26 patients with MRI data were available, allowing analysis based on accurate classification of lunate type. Subgroup analysis of these patients also showed no correlation between lunate type and incidence of DISI deformity. Furthermore, 24 of 26 (92%) were correctly identified by radiographs which is highly accurate when compared with MRI assessment and represents almost perfect agreement. Although our sample size is small in this analysis, our findings are consistent with previous reports of the high accuracy of radiographs for identification of lunate morphology.[11] These findings support our radiographic results. There was slight agreement between the incidence of scapholunate instability and DISI. We were unable to draw any conclusions as to the influence of lunate type in this subgroup; however, future studies evaluating the potential correlation of lunate type in this group are needed. Although ligamentous laxity has been suggested to influence carpal stability, we were unable to evaluate its potential effects due to the retrospective nature of this study.[6]

Our study questions the contribution of lunate morphology on the kinematics of the wrist in the setting of complete scapholunate ligament injuries. When drawing conclusions regarding the influence of lunate morphology, it is critical that we are able to identify the correct morphology. Although our study is in disagreement with previous reports, it is possible that there is a critical area of articulation between the hamate and the lunate that may lend increased stability rather than simply the presence or absence of a medial lunate facet. Further studies are needed to better evaluate whether any relationship truly exists.

We recognize there are limitations to our study. We used plain radiographs to assess lunate morphology as in previous studies, despite its questionable accuracy. We used MRI evaluation in a subset of patients to corroborate our radiographic results, however. Future studies that draw conclusions on wrist kinematics may benefit from MRI-based lunate classification. We also used static radiographic measurements to assess stability which may have missed dynamic instability.

Wrist kinematics are dependent on multiple ligamentous attachments, and in scapholunate ligament injury, for example, the remaining ligaments contribute to maintaining the normal relationships between the carpal bones.[2,13] It is possible that lunate morphology may play a role in stabilizing the wrist; however, wrist kinematics are complex and attributing changes in kinematics to a single articulation may be an oversimplification. Further studies on the effects of lunate morphology on carpal kinematics may benefit from more accurate imaging techniques such as MRI or direct visualization.

Ethical Approval

This study was approved by our institutional review board.

Statement of Human and Animal Rights

No animal data were utilized in this study. Waiver of consent and Health Insurance Portability and Accountability Act authorization were obtained and approved by our institutional review board.

Statement of Informed Consent

The data for this project were obtained via chart review, and a waiver of consent was obtained and approved by our institutional review board.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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