RESEARCH ARTICLE

A Slightly Dorsally Tilted Lunate on MRI can be Considered Normal

Anne-Carolin Döring, MD; Celeste L. Overbeek, MD; Teun Teunis, MD; Stéphanie J.E. Becker, MD; David Ring, MD, PhD

Research performed at Orthopaedic Hand and Upper Extremity Service, Massachusetts General Hospital, Boston, MA 02114, USA

Received: 6 September 2014 *Accepted: 8 December 2015*

Abstract

Background: Abnormal angulation of the lunate can be an indication of intercarpal pathology. On magnetic resonance images (MRIs) the lunate often looks dorsally angulated, even in healthy wrists. The tilt on individual slices can also be different and might be misinterpreted as pathological, contributing to inaccurate diagnoses and unnecessary surgery. The primary aim of this study was to determine the average radiolunate angle on sagittal wrist MRI images as well as the radiolunate angle in the most radial, central and most ulnar part of the lunate; also the interobserver reliability was determined.

Methods: 140 MRIs from adult, non-pregnant patients presenting to the outpatient hand and upper extremity service between 2010 and 2013 with wrist pain were used for this retrospective study. One author measured the radiolunate and capitolunate angle (i.e., tangential and axial method) in all MRIs. Additionally, two authors measured the same angles independently in 46 MRIs to analyze interobserver reliability.

Results: The average radiolunate angle was 8.7 degrees dorsal. There were no significant differences in the radiolunate angles between the different parts of the lunate. A very good interrater agreement was measured considering the radiolunate angle and capitolunate angle (tangential and axial method).

Conclusions: Our study showed that the lunate appears slightly dorsally angulated on an MRI of a healthy wrist. Regarding the radiolunate angle, 10 to 15 degrees of dorsal tilt can be considered normal. This study provides reference information of normal anatomy for carpal axial alignment that may facilitate diagnoses of wrist pathology.

Keywords: Capitolunate angle, Lunate bone, MRI, Radiolunate angle

Introduction

Abnormal angulation of the lunate on radiographs can be an indication of intercarpal pathology (1-3). On standard, lateral radiographs, the normal capitolunate angle averages 20˚ volar (range: 10˚-30˚) and the normal radiolunate angle is about neutral, with a range from 15˚ dorsal to 15˚ volar (4-7). In other words, regarding these broad ranges, angles that are often considered pathological can be observed in healthy wrists. In addition, small differences caused by rotation of the wrist might lead to misinterpretation of the angles.

The situation may be even more complex with magnetic resonance imaging (MRI). We have noticed that the lunate often looks dorsally angulated on sagittal plane MRI images of a healthy wrist, more so on some slices than others. While radiographs give a "composite" angle, it may be that there is an apparent tilt if one looks at individual slices of the wrist that might be misinterpreted as pathological (8).

If dorsal tilt of the lunate on normal sagittal MRI images depends on the part of the lunate that is imaged, then it becomes difficult for radiologists, surgeons, and patients to interpret the position of the lunate; potential misinterpretation contributes to inaccurate diagnoses and unnecessary surgery. The primary aim of this study was to determine the average radiolunate angle on sagittal wrist MRI images. In secondary analyses we determined the radiolunate angle in the most radial,

Corresponding Author: David Ring, Department of Surgery and Perioperative Care, Dell Medical School, The University of Texas at Austin, Austin, Texas, USA
E-mail: dring@mgh.harvard.edu

AB&JS THE ONLINE VERSION OF THIS ARTICLE ABJS.MUMS.AC.IR

central and most ulnar part of the lunate; the average capitolunate angle using two methods of measurement; differences in radiolunate and capitolunate angles by age and sex; and the interobserver reliability of the measurements.

Materials and Methods

Subjects

In this Institutional Review Board approved retrospective study, we obtained 209 wrist MRIs from adult, non-pregnant patients presenting to the outpatient hand and upper extremity service between 2010 and 2013 with wrist pain. Inadequate MRIs (i.e., measurement of the angles was impossible due to absent landmarks or bad quality) were excluded. Additionally, MRIs of patients with a diagnosis related to the lunate or adjacent structures were excluded [Table 1]. One hundred and forty patients satisfied the eligibility criteria. There were 68 (49%) men and 72 (51%) women with a mean age of 41 years (standard deviation 13 years; range, 18-76 years).

MRI assessment

One author measured the radiolunate and capitolunate (i.e., tangential and axial method) angle in 140 MRIs using ONIS 2.5 (DigitalCore, Co.Ltd, Tokyo, Japan). Additionally, two authors measured the same angles independently in 46 MRIs to analyze interobserver reliability. All assessors recorded in which slice they performed their first measure, so that angles were compared in the same slice. The 3 measurers were blinded to each other's assessment until the MRIs of all patients were reviewed.

Table 1. Excluded MRIs (n=69)

General criteria	
Age (<18 years)	9
Pregnancy	0
Technical criteria	
Bad quality, no visible landmarks	14
No wrist MRI	3
Double MRI	1
Disease specific criteria	
Kienböck disease	2
Scapholunate ligament (SLL) tear	8
Degenerative cartilage changes	11
SLL tear + degenerative changes	8
Rheumatoid arthritis	1
Fracture	
Scaphoid	7
Scaphoid, hamate, capitate, trapezium	1
Distal radius	1
Triquetrum	1
Distal first metacarpal	2

The following angles were measured on the sagittal MRI slices: 1) The radiolunate angle, measured between the axis of the lunate and the axis of the radius. The axis of the lunate is a line perpendicular to the tangent of the two distal poles. The axis of the radius is a line through the center of the medullary canal at 2 and 5 centimeter proximal to the radiocarpal joint; 2) The capitolunate angle (tangential method), measured as the angle between the tangent of the proximal and distal dorsal margins of the capitate and lunate axis as described; 3) The capitolunate angle (axial method), measured between the capitate axis (from the center of the proximal and distal poles) and the lunate axis [Figure 1] (9).

Volar angulation of the distal articular surface of the lunate with respect to the capitate or radial axis was recorded as positive and dorsal tilt as negative (6).

Statistical analysis

A power analysis based on radiolunate angle measurements from the first 50 MRIs determined that a sample size of 126 subjects was needed to detect a 6.5° minimal recognizable difference (MRD) as shown by Larsen et al. of an abnormal radiolunate angle of ≤ -15° or >15° with a 95% confidence interval within 5% of the true prevalence (10% width of confidence intervals)(7, 9).

Data is presented as frequencies and percentages for categorical variables and as means with 95% confidence intervals (CI) for continuous variables.

To determine whether the tilt of the lunate depends on the part of the lunate that is imaged, we evaluated the radiolunate angle in the most radial, central and most ulnar part of the lunate on sequential sagittal MRI slices. In case there were four slices where the radiolunate angle could be measured, the average of the second and third measurement was taken as the

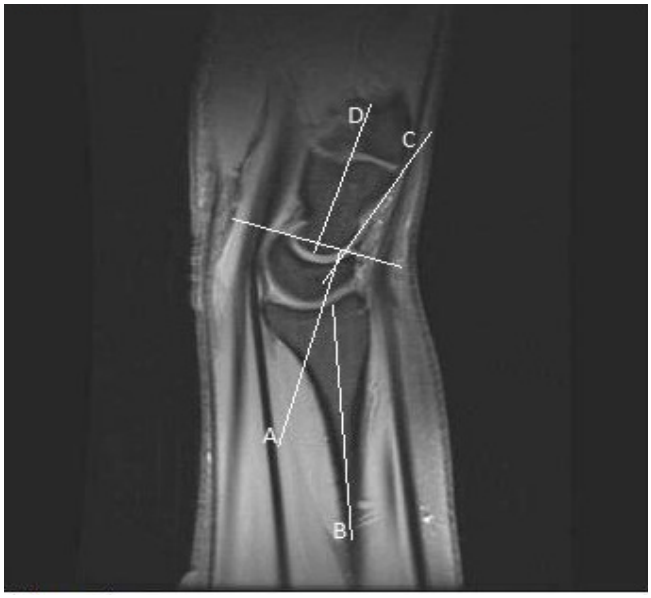

Figure 1. A: lunate axis, B: radius axis, C: tangent of the proximal and distal dorsal margins of the capitate, D: capitate axis.

central part measurement. In case there were only two measurements (because of insufficient visibility of landmarks that were needed to be able to make the measurements) no measurement of the central part was noted. The difference in radiolunate angle between the most radial, central and most ulnar part of the lunate was evaluated by use of the Student t-test in case of normally distributed data and the Mann-Whitney-U test in case the data was not normally distributed.

Associations between the response variables (radiolunate, tangential capitolunate and axial capitolunate angle) and sex were assessed with either the Students t-test or Mann-Whitney-U test depending on the normality of the data. The associations between the response variables and age were assessed by means of the Pearson correlation for normally and Spearman rank correlation for non-normally distributed data. *P* value less than 0.05 was considered significant.

Intraclass correlations for two-way mixed-effects models were estimated to test the absolute agreement between the three assessors (interobserver reliability) concerning the angle measurements. Absolute agreement in an intraclass correlation indicates how much each measurement performed per observer differs from the other observer.

Table 2. MRI findings (n=140)

	Mean	SD	Range	
Slices with visible lunate (no.)	4.4	0.78	2.0	6.0
Average slice thickness	3.0	0.40	1.0	8.0
Radiolunate angle	Mean	SE	95% CI	
Slice 1 (n=125)	-7.9	0.99	-9.9	-6.0
Slice 2 (n=140)	-9.2	0.86	-11	-7.5
Slice 3 (n=120)	-9.3	0.95	-11	-7.4
Slice 4 (n=48)	-12	1.3	-15	-9.9
Slice 5 (n=3)	-8.2	3.7	-24	7.9
Capitolunate angle - Tangential				
Slice 1 (n=125)	13	1.2	11	15
Slice 2 (n=140)	14	0.99	12	16
Slice 3 (n=123)	15	1.1	12	17
Slice 4 (n=48)	14	1.6	11	17
Slice 5 (n=3)	17	2.6	5.8	28
Capitolunate angle - Axial				
Slice 1 (n=125)	1.3	1.1	-0.78	3.4
Slice 2 (n=140)	1.8	0.99	-0.18	3.7
Slice 3 (n=123)	4.1	1.0	2.1	6.0
Slice 4 (n=49)	3.3	1.3	0.71	5.9
Slice 5 (n=3)	6.5	2.5	-4.4	17
Average angles				
Radiolunate	-8.7	0.85	-10	-7.0
Capitolunate - Tangential	14	1.0	12	16
Capitolunate - Axial	2.5	0.94	0.68	4.4
Difference between tangential and axial method	Mean	SD	Range	
Slice 1 (n=125)	12	4.8	-17	29
Slice 2 (n=140)	12	3.9	-11	20
Slice 3 (n=123)	11	4.3	-1.5	20
Slice 4 (n=48)	11	5.0	0.77	28
Slice 5 (n=3)	10	3.6	6.7	14

Results

The average radiolunate angle was 8.7 degrees dorsal (95% CI -10 to -7.0) [Table 2]. There were no significant differences in the radiolunate angles between the most radial, central, and most ulnar part of the lunate [Table 3].

The average capitolunate angle, measured by the tangential method, was 14 degrees volar (95% CI 12 to16). The average capitolunate angle, measured by the axial method, was 2.5 degrees volar (95% CI 0.68 to 4.4) [Table 2].

Bivariate analyses showed no significant differences in radiolunate and capitolunate angles (both measurement methods) by age and sex [Table 4].

We found an intraclass correlation coefficient of 0.87 (95% CI 0.79 to 0.92, *P*<0.001) between the three observers regarding the radiolunate angle. The intraclass correlation coefficient of the tangential capitolunate measurement was 0.93 (95% CI 0.86 to 0.96, *P*<0.001) and for the axial method 0.90 (95% CI 0.81 to 0.95, *P*<0.001) [Table 5].

Discussion

Angulation of the lunate on a lateral radiograph of the wrist can be used to assess intercarpal pathology. The range of normal radiolunate angles on radiographs of healthy wrists includes angles that are sometimes considered pathological (1-3). It was our impression

Table 3. Radiolunate angle in radial, middle and ulnar part of lunate

Measure	Mean	95% CI	
Radiolunate radial part (n=140)	-7.8	-9.6	-6.0
Radiolunate middle part (n=112)	-10	-12	-8.2
Radiolunate ulnar part (n=140)	-8.9	-11	-7.2
Difference between:			
Radial and middle part	2.2	*P*=0.09	
Radial and ulnar part	1.1	*P*=0.38	
Middle and ulnar part	1.1	*P*=0.39	

Table 4. Bivariate analyses (n=140)

Variables	Radiolunate Angle	*P*	Capitolunate angle - Tangential	*P*	Capitolunate angle - Axial	*P*
Sex (Mean ± standard deviation)						
Men	-9.3 (9.8)	0.51	2.8 (11)	0.77	14 (12)	0.76
Women	8.2 (10)		2.3 (11)		14 (12)	
Age (Pearson's r)	0.043	0.62	0.092	0.28	0.11	0.21

Table 5. Interobserver reliability (n=46)

Measure	Rater	Intraclass correlation coefficient	*P*	95% CI	
Radiolunate Angle	1				
	2	0.87	<0.001	0.79	0.92
	3				
Capitolunate Angle - Tangential	1				
	2	0.93	<0.001	0.86	0.96
	3				
Capitolunate Angle - Axial	1				
	2	0.90	<0.001	0.81	0.95
	3				

that this may be more pronounced on MRI images. Our study of MRI images confirmed our impression: there was an average radiolunate angle of 8.7 degrees dorsal (range, 7 to 10 degrees dorsal) with minor differences between measurements of the radial, central or ulnar part of the lunate and no influence of age and sex.

The results of this study should be interpreted in light of its shortcomings. The MRIs we used were obtained for diagnostic purposes in patients with wrist complaints and may be different from the general population. However, to correct for this potential shortcoming, we used strict exclusion criteria. Additionally, neutral alignment of the carpal bones is necessary to measure lunate tilt precisely. Although standard protocol MRIs were used for this study, we expect some variation in wrist position. Given the large number of scans evaluated, these variations might be expected to average out. The wrist may be extended and it's not always possible to see the third metacarpal bone to determine wrist position Lastly, one observer did all of the measurements, but we established that the measurement technique is reliable.

Our findings on MRI are consistent with studies of radiographs: 10 to 15 degrees of dorsal tilt (radiolunate angle) can be normal. The average radiolunate angle was about 9 degrees dorsal and the average capitolunate angle was about 14 degrees volar, meaning that the lunate appears slightly dorsally angulated on an MRI of a healthy wrist (4, 5). These results are comparable with the normal capitolunate angle on radiographs (i.e., 20˚ volar, range: 10˚-30˚), but with a smaller range (95% CI 12 to16). With this range, a better distinction can be made between normal and pathological angles (6).

As observed in radiographs, an apparent dorsal tilt of the lunate on MRI may not be pathological. Misinterpretation of the radio- and capitolunate angle might increase the risk of unhelpful diagnoses and unnecessary invasive treatments.

Acknowledgements

CLO is supported by Dutch research grants from Anna Foundation|NOREF, the Netherlands, for scientific research.

TT is supported by Dutch research grants from Kuitse Fonds – Prins Bernhard Cultuurfonds, and Stichting Fundatie van de Vrijvrouwe van Renswoude te 's-Gravenhage, the Netherlands, for scientific research.

SJEB is supported by Dutch research grants from Anna Foundation NOREF, Genootschap Noorthey, Stichting Fonds Doctor Catharine van Tussenbroek, and Stichting Vreedefonds, the Netherlands, for scientific research.

Anne-Carolin Döring MD
Celeste L. Overbeek MD
Teun Teunis MD
Orthopaedic Hand and Upper Extremity Service, Yawkey Center, Suite 2100, Massachusetts General Hospital, Boston, MA, USA

Stéphanie J.E. Becker MD
Orthopaedic Hand and Upper Extremity Service, Yawkey Center, Suite 2100, Massachusetts General Hospital, Boston, MA, USA

David Ring MD, PhD
Department of Surgery and Perioperative Care, Dell Medical School, The University of Texas at Austin, Austin, Texas, USA

References

1. Nakamura R, Hori M, Imamura T, Horii E, Miura T. Method for measurement and evaluation of carpal bone angles. J Hand Surg Am. 1989;14(2 Pt 2):412-6.
2. Smith DK, Gilula LA, Amadio PC. Dorsal lunate tilt (DISI configuration): sign of scaphoid fracture displacement. Radiology. 1990;176(2):497-9.
3. Timins ME, Jahnke JP, Krah SF, Erickson SJ, Carrera GF. MR imaging of the major carpal stabilizing ligaments: normal anatomy and clinical examples. Radiographics. 1995;15(3):575-87.
4. Wolfe SW, Pederson WC, Hotchkiss RN, Kozin SH, Cohen MS. Green's Operative Hand Surgery. 6th ed. Elsevier; 2011.
5. Rhee PC, Moran SL, Shin AY. Association between lunate morphology and carpal collapse in cases of scapholunate dissociation. J Hand Surg Am. 2009;34(9):1633-9.
6. Yang Z, Mann FA, Gilula LA, Haerr C, Larsen CF. Scaphopisocapitate alignment: criterion to establish a neutral lateral view of the wrist. Radiology. 1997;205(3):865-9.
7. Larsen CF, Mathiesen FK, Lindequist S. Measurements of carpal bone angles on lateral wrist radiographs. J Hand Surg Am. 1991;16(5):888-93.
8. Maizlin ZV, Vos PM. How to measure scapholunate and Cobb's angles on MRI and CT. J Digit Imaging.25(4):558-61.
9. Larsen CF, Stigsby B, Lindequist S, Bellstrom T, Mathiesen FK, Ipsen T. Observer variability in measurements of carpal bone angles on lateral wrist radiographs. J Hand Surg Am. 1991;16(5):893-8.