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The hamatolunate facet: characterization and association with cartilage lesions – magnetic resonance arthrography and anatomic correlation in cadaveric wrists

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Abstract The objective of this study was to characterize the appearance of the hamatolunate facet using high-resolution magnetic resonance (MR) arthrography in cadavers and to correlate the presence of this anatomic variant with the presence of osteoarthritis in the wrist. High-resolution MR images of 22 cadaveric wrist specimens were obtained after tricompartmental arthrography. Two readers in consensus analyzed the MR images and recoded the presence or absence of a hamatolunate facet. Geometric characteristics and cartilage and ligament integrity were analyzed. A third reader, who was blinded to the purpose of the study, recorded cartilage lesions of all the bones of the proximal and distal carpal rows. A hamatolunate facet was present in 11 of 22 wrists (50%). The mean coronal size of the lunate facet at the lunate (type II lunate) was 4.5 mm (range, 2–6 mm). The highest frequencies of cartilage lesions were seen in the scapho-trapezio-trapezoid joint (45.5%) and at the proximal pole of the hamate (54.4% and 40.9% for consensus reading/blinded reading, respectively). In cases with a hamatolunate facet, the frequency of cartilage lesions in the proximal pole of the hamate was 81.8% and 63.6% versus 27.3% and 18.2% without such a facet (chi-squared, P=0.01/P=0.03). No correlation of the presence of a hamatolunate facet with interosseous ligament tears or lesions of the triangular fibrocartilage was seen. In conclusion, the hamatolunate facet is a very common anatomic variant. The presence of a hamatolunate facet is associated with cartilage damage in the proximal pole of the hamate.

Keywords Magnetic resonance imaging · Arthrography · Wrist Anatomy · Cartilage

Introduction

The hamatolunate facet is an anatomic variant of the midcarpal joint of the wrist consisting of an additional articulation between the hamate and lunate bones [1]. Usually only one distal articular facet, articulating with the capitate bone, is present in the lunate bone. In cases with a hamatolunate facet, a second facet in the ulnar side of the lunate bone articulates with the proximal pole of the hamate. A lunate with this additional facet has been termed a type II lunate, while a type I lunate does not have this additional facet [2, 3, 4]. The reported frequency of a hamatolunate facet has varied between 44% [3] and 73% [1]. This facet has received a great deal of attention by hand surgeons because of its strong association with marked cartilage lesions in the proximal pole of the hamate and with ulnar-sided wrist pain [1, 2, 3, 4, 5, 6]. Cadaveric dissection studies have demonstrated that the proximal pole of the hamate is the most frequent site of cartilaginous lesions in the wrist overall [1]. Reports investigating the imaging characteristics of this anatomic variant are sparse [7]. The diagnosis of a hamatolunate facet is not reliable using conventional radiographs [8]. Moreover, in studies assessing the frequent sites of degenerative articular diseases of the wrist using conventional radiographs, the proximal pole of the hamate usually is not depicted [9]. Several reports indicate that a reliable diagnosis of this anatomic variant and, more importantly, the associated chondral lesions requires midcarpal arthroscopy [4, 8, 10]. Reports regarding therapeutic surgical management of pain related to the associated cartilage damage have recently been published [8, 11].

The purpose of our study was to characterize the appearance of the hamatolunate facet and the so-called type II lunate using high-resolution magnetic resonance (MR) arthrography in cadavers and to correlate the presence of this anatomic variant with the presence of osteoarthritis.

Materials and methods

Specimens and image acquisition

Twenty-two wrists were harvested from non-embalmed cadavers (mean age at death, 75 years; age range at death, 45–90 years). The specimens were derived from arms cut through the midportion of the radius and ulna. The specimens were immediately deep-frozen at –40°C (Forma Bio-Freezer, Forma Scientific, Marietta, OH) and then were allowed to thaw for 24 h at room temperature prior to MR imaging. Before imaging, the radiocarpal, midcarpal, and the distal radioulnar joints were injected with a solution of 1 ml gadolinium dimeglumine (Magnevist, Schering, Berlin, Germany) diluted in 250 ml of saline mixed with an equal amount of iodinated contrast agent (Omnipaque 350; Nycomed Amersham, Princeton, NJ).

MR images were acquired with a 1.5-T MR scanner (Signa; GE Medical Systems, Milwaukee, WI) using a dedicated receive-only wrist coil. The wrists were placed palm down parallel to the gantry table in a neutral position. Coronal, T_2-weighted (TR: 4000 ms, TE: 125 ms) and proton density (PD) images (TR: 4000 ms, TE: 25 ms) images were obtained with fat saturation (slice thickness: 2 mm; interspace gap: 0.5 mm; matrix size: 512×256 pixels; field of view, FOV: 8 cm×8 cm; two acquisitions). Coronal, T_1-weighted spin echo (TR: 500 ms, TE: 12 ms; slice thickness: 2 mm; interspace gap: 0.5 mm; matrix size: 512×256 pixels; FOV: 6 cm×6 cm; two acquisitions), sagittal fat-saturated T_1-weighted spin echo (TR: 500 ms, TE: 12 ms; slice thickness: 2.5 mm; interspace gap: 0.5 mm; FOV: 8 cm×8 cm; matrix size: 512×256 pixels; two acquisitions) and axial T_1-weighted (TR: 500 ms, TE: 12 ms; slice thickness: 2.5 mm; interspace gap: 0.5 mm; FOV: 6 cm×6 cm; matrix size: 512×256 pixels; two acquisitions) spin echo MR images were also obtained.

After imaging, all cadaveric specimens were immediately positioned with the wrist in a neutral position, frozen at –40°C for at least 24 h, and subsequently sectioned with a band saw into 2-mm-thick sections corresponding to the imaging planes used for MR arthrography. Photographs of each section were obtained with the specimen thawed.

Image analysis

First, the coronal T_2-weighted and PD fat-saturated MR images were analyzed by two musculoskeletal radiologists in consensus. To prevent a possible bias, the proximal and distal carpal row were analyzed separately for the presence of a hamatolunate facet, the geometric characteristics of the hamatolunate facet, and the integrity of the cartilage surfaces.

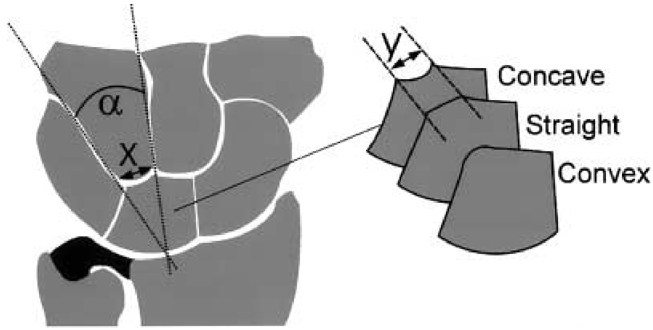


Fig. 1 Measurements performed on the basis of coronal images: The angle (α) between the radial and ulnar sides of the hamate and the measurement (x), the size of the hamate, are noted. An additional facet at the lunate (type II lunate) was considered only when a concave or straight additional joint surface was present that could be differentiated from the main joint surface. A convex surface was considered a negative finding. The size of the facet was measured as displayed (distance *y*)

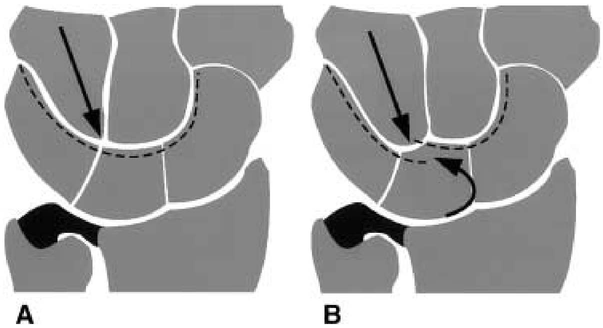


Fig. 2A, B Coronal section of a wrist without (**A**) and with (**B**) a hamatolunate facet. The proximal pole of the hamate (*arrow*) is tapered in wrists without a facet and round in wrists with a facet. The second carpal arc (*dotted line*) is interrupted in cases with a hamatolunate facet (curved arrow)

In this first assessment, the bones of the distal carpal row were masked on all images, and the lunate bone was analyzed for the presence of a hamatolunate facet. This facet was defined as an additional midcarpal joint surface at the distal surface of the lunate bone that was clearly distinguishable from the main distal joint surface with either a concave or straight surface and was visible on at least two continuous slices (Fig. 1). A convex surface was not considered to be a distinct facet [7] (Fig. 1). The maximum coronal size of the facet of the lunate was measured (Fig. 1). A potential disruption of the second carpal arc was noted [12] (Fig. 2). The cartilage surface of the hamatolunate facet was graded according to the following classification: grade 0, normal cartilage surface; grade 1, irregular surface of the cartilage but no defects; grade 2, defects in the articular cartilage that did not reach the subchondral bone; grade 3, cartilage defects that reached the subchondral bone; grade 4, cartilage defects that reached the subchondral bone and were associated with signal changes in the bone (hyperintensity on fluid-sensitive sequences, sclerosis, or cyst formation).

Thereafter, the images were intermingled and the proximal carpal row was masked. The geometric characteristics of the proximal pole of the hamate were analyzed as shown in Fig. 1. The shape of the proximal pole was rated as round or tapered by in-

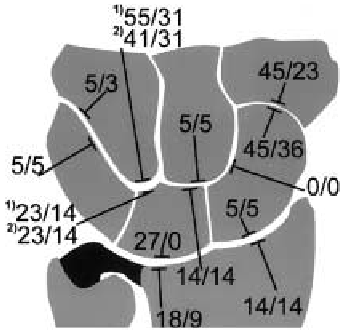


Fig. 3 Distribution of cartilaginous lesions in different wrist locations. The first number represents the percentage of cartilage surfaces in which a lesion (grade 1–4) was found; the second number represents the percentage in which a severe lesion (grade 3–4) was found. 1)Blinded reading, 2)masked reading

spection; the width of the pole and the angle between the ulnar and radial joint surfaces was measured (Fig. 1). The integrity of the articular cartilage of the proximal pole of the hamate was graded as previously described. A third musculoskeletal radiologist, blinded to the purpose of the study, was asked to grade the integrity of the articular cartilage of all joint surfaces of the bones of the wrist (Fig. 3). All sequences were available simultaneously for this reading.

The presence of the hamatolunate facet, the integrity of the interosseous ligaments of the carpus (scapholunate ligament, SLL; lunotriquetral ligament, LTL) and the integrity of the triangular fibrocartilage (TFC) were analyzed on the anatomic sections and correlated to the MR scans.

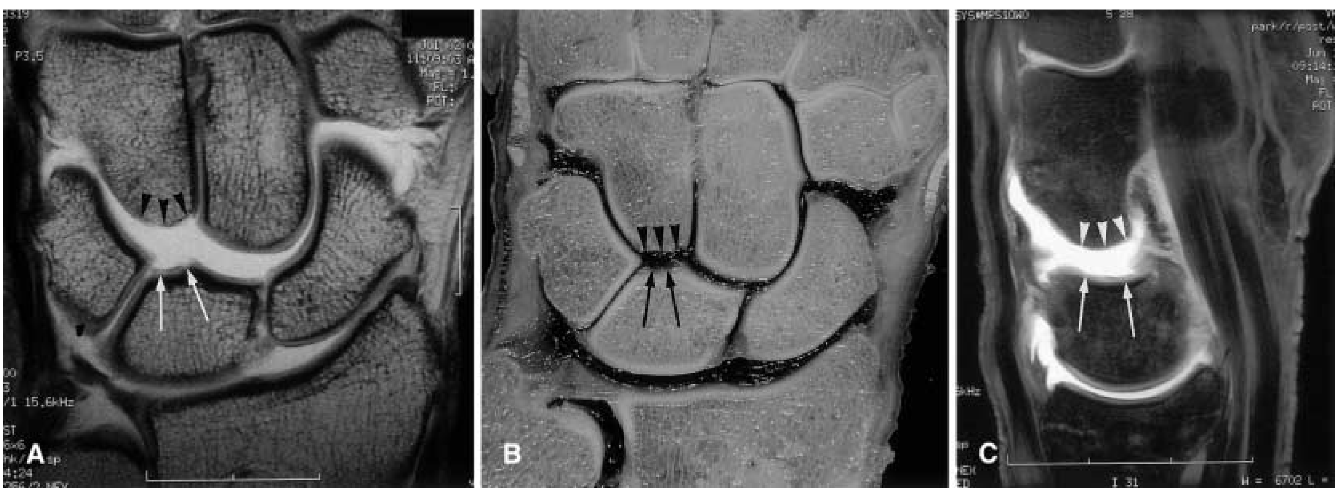
The association of a hamatolunate facet and the presence of cartilage lesions in the proximal pole of the hamate and other lesions (such as ligament disruption and TFC perforations) were determined using a chi-squared test. All measurements were tested for their association with the presence of a hamatolunate facet using the Mann-Whitney-U test. Significance was set at $P<0.05$.

Results

A hamatolunate facet was present in 11 of 22 wrists (50%). The mean coronal size of the facet in the lunate was 4.5 mm (range, 2–6 mm). The size of the facet was usually not uniform throughout all the consecutive coronal sections, and the facet was often larger at the dorsal aspect of the wrist than at the more palmar aspect (six of 11 cases). In three cases, the facet was visible only on the dorsal sections; no facet was visible on the ventral scans. In almost all cases with a hamatolunate facet (nine of 11 cases, 81.8%), the proximal pole of the hamate was round. In wrists without a facet, the proximal pole of the hamate was tapered (ten of 11 cases, 90.9%, $P=0.001$). The proximal pole of the hamate was significantly larger in wrists with a facet compared to those wrists without a facet (mean, 5.3 mm, SD 1.9 mm vs. mean, 2.4 mm, SD 0.7 mm, $P=0.001$). The angle between the ulnar and radial margins of the hamate was smaller in those hamates with a facet (mean, 42.6 mm, SD 9.6 mm) compared to hamate bones without a facet (mean, 51.1 mm, SD 5.5 mm). However, this difference was not significant ($P=0.086$). In all cases with a second facet, a step appearance in the alignment of the distal joint surface of the proximal carpal row (second carpal arc) was noted (Fig. 2). This was absent in all cases without a second facet of the lunate.

The distribution of cartilaginous lesions in all wrists is displayed in Fig. 3. The highest frequencies of such lesions were seen in the scapho-trapezio-trapezoid joint (45.5%, ten of 22 cases) and in the proximal pole of the

Fig. 4A–C A 62-year-old male cadaveric wrist specimen with a large hamatolunate facet. **A** T_1-weighted (TR: 500 ms, TE: 12 ms) coronal arthrographic image of the wrist. **B** Corresponding anatomic section showing a large hamatolunate facet (*arrows*). Note the marked erosion with complete absence of cartilage in the proximal pole of the hamate (*arrowheads*). The second facet of the lunate shows more moderate cartilage defects (*arrows*). **C** Corresponding T_1-weighted fat saturated (TR: 500 ms, TE: 12 ms) sagittal magnetic resonance (MR) arthrographic image of the wrist at the level of the proximal pole of the hamate showing the cartilage loss in the proximal pole of the hamate (*arrowheads*). The cartilage in the lunate side is irregular but mainly preserved (*arrow*)



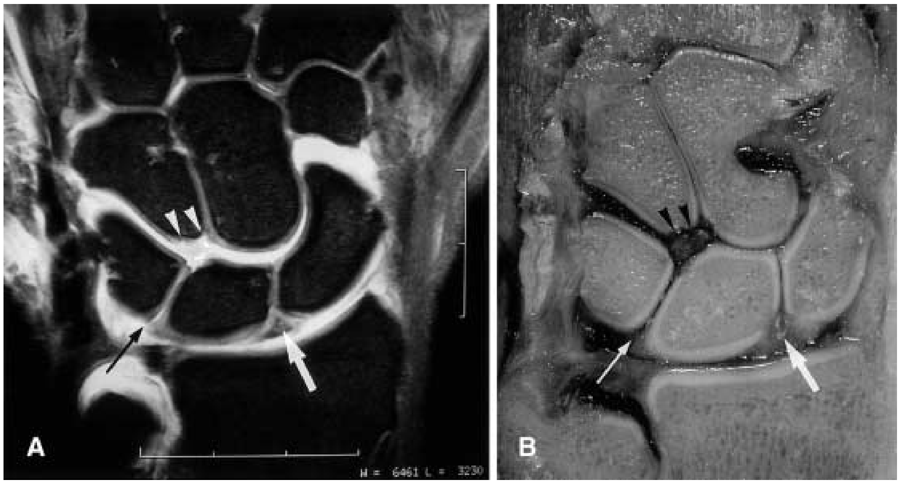


Fig. 5A, B A 75-year-old female cadaveric wrist specimen with a small hamatolunate facet. **A** Proton density fat-saturated (TR: 4000 ms, TE: 25 ms) coronal arthrographic image of the wrist. **B** Corresponding anatomic section with a small hamatolunate facet. There is a deep erosion of the cartilage in the proximal pole of the hamate (*arrowheads*). The cartilage of the second facet of the lunate also shows defects. Note the tear in the lunotriquetral ligament (*small arrow*) and calcification of the scapholunate ligament (*large arrow*)

hamate (54.4%, 12 cases or 40.9%, nine cases; consensus reading/blinded reading). In cases with a hamatolunate facet, the frequency of cartilage lesions in the proximal pole of the hamate was 81.8% (nine of 11 cases) or 63.6% (seven of 11 cases) versus 27.3% (three of 11 cases) or 18.2% (two of 11 cases) without such a facet (chi-squared, P=0.01 vs. P=0.03). Advanced cartilage damage (i.e., grades 3–4 lesions) in the proximal pole of the hamate occurred only in cases with a hamatolunate facet (seven of 12 cases for both readings) (Fig. 4).

A tear in the LTL was seen in ten cases (45%). In cases with a hamatolunate facet, this ligament was torn in seven cases (63.6%), and in cases without a facet, the ligament was torn in three cases (27.3%). The SLL ligament was torn in only three cases (13.6%). TFC lesions were found in nine wrists (40.9%). Six lesions (54.5%) were found in wrists with a hamatolunate facet, and three (27.3%) in wrists without such a facet. No significant association was seen with ligament tears or lesions of the TFC and the presence of a hamatolunate facet.

Discussion

Chronic wrist pain, especially in the ulnar side, presents a true diagnostic challenge. Ulnar-sided pain has been termed the “low back pain” of the wrist. Forty-four separate entities have been considered as causes for such pain [13]. The high frequency of asymptomatic lesions of the interosseous ligaments and the TFC increase the diagnostic dilemma [14, 15, 16]. With the development and routine use of midcarpal arthroscopy, the midcarpal compartment has been recognized as a frequent site of cartilaginous lesions [5, 8]. In a series of 68 wrist arthroscopies performed in patients with chronic wrist pain of unknown cause, chondral lesions in the midcarpal joint were identified as the cause of pain in 21 cases, followed in frequency by peripheral tears of the TFC in 15 cases [17].

In studies using dissections of cadaveric wrists, the proximal pole of the hamate has been recognized as one of the most frequent sites of cartilaginous damage [1]. This damage has been found to have a significant association with the presence of a hamatolunate facet [1, 2, 18]. The same association was documented in our small series, using MR arthrography as a diagnostic tool. It is unclear, however, why the cartilaginous damage is usually more pronounced in the hamate than in the lunate (Fig. 5). These cartilaginous abnormalities in the proximal pole of the hamate are not usually recognizable on conventional radiographs [19].

Fifty percent of our specimens revealed a hamatolunate facet. In the literature, the frequency of this anatomic variant has varied between 44% [3] and 73% [1]. In a large series of wrist dissections in cadavers, Viegas and colleagues [22] found 73% of type II lunates. However, 23% of the hamatolunate facets in this last series measured 1 mm or less. We used a rather strict definition of a hamatolunate facet, and the frequency of this facet in our series was therefore considerably lower, but similar to the frequency found by other investigators [2, 7, 8].

In a study in which results of conventional radiographs of 81 cadaveric wrists were compared to findings obtained upon subsequent dissection, the accuracy for determining lunate morphology ranged between only 64% and 72% [8]. We noticed that the size of the hamatolunate facet is not uniform throughout consecutive coronal images. The facet is often larger dorsally and may be completely absent in the most volar images. This geometric characteristic may explain why the hamatolunate facet is not detected more frequently.

In all of our specimens with a hamatolunate facet, the second carpal arc was disrupted with discontinuity of a line drawn from the midcarpal articular surface of the triquetrum to the lunate surface more distally (Figs. 2A, 4A, 5A). This discontinuity was not present in specimens without a facet (Fig. 2B). This observation is in accordance with the work of Peh and coworkers [12]. It has been emphasized that the hamate jumps over this step at the lunate facet during forced ulnar deviation of the wrist and leads to an increased load in the proximal pole of the hamate [1]. In the report by Thurston and coworkers, pain was provoked by forceful ulnar deviation of the wrist [11]. During daily activities, such as holding objects, the wrist is more ulnarly deviated and extended and the main load is applied through the lunate and less through the scaphoid [20]. In this wrist position, the hamatolunate facet may further increase the load guided through the lunate, resulting in overuse of the cartilage in the proximal pole of the hamate [21].

An investigation using midcarpal arthroscopy in 78 patients confirmed the association of chondral lesions in the proximal pole of the hamate and the presence of a hamatolunate facet. In this series, chondral lesions also were frequently (22.8%) found in the proximal pole of the hamate without a hamatolunate facet. In these cases, however, the chondral lesions were uniformly associated with other ligamentous or osteochondral lesions, or both, whereas isolated cartilaginous lesions in the proximal pole of the hamate were found only with type II lunates. In our series, chondral lesions in the proximal pole of the hamate without a hamatolunate facet were rare and always mild to moderate in extent. The frequency of tears of the LTL and lesions of the TFC was twice as high than in cases without a hamatolunate facet (Fig. 5A). However, due to the small sample size, these differences were not significant.

Recently, Thurston and coworkers reported successful surgical treatment of patients with chronic ulnar-sided wrist pain that was intensified with forced ulnar abduction in a small series of patients [11]. They performed either an open or arthroscopic resection of the proximal pole of the hamate, and a cartilaginous defect was confirmed in all patients. All responded favorably to this procedure. Other authors have recommended arthroscopic debridement of cartilaginous erosions in the hamate [10].

Despite the sometimes dramatic chondral erosions seen in the proximal pole of the hamate in association with a hamatolunate facet, and despite initial reports of successful treatment of these erosions, the clinical significance of this lesion is unknown. Approximately half of all wrists have such a facet, and most of these have or will develop a chondral defect at this site [22]. However, many of these lesions are probably clinically silent, as are many other structural lesions in the wrist [14, 15, 16].

A diagnostic challenge relates to the differentiation of symptomatic and asymptomatic lesions. In the series reported by Malik and coworkers, nine of 107 wrists with a type II lunate showed subchondral marrow edema in the proximal pole of the hamate on MR imaging [7]. Although no correlation with specific clinical data was provided, subchondral marrow edema may indicate a symptomatic lesion that is invisible arthoscopically.

There are several study limitations to be considered. First, as noted in the previous paragraph, the clinical significance of the hamatolunate facet is unknown, and the limited available clinical data prevent us from commenting on this issue. Second, our sample size is small. Third, the natural course of the chondral defect in the proximal pole of the hamate is not known. Whether this defect is acquired or developmental is not clear either, and the importance of developmental factors is supported by the low frequency of cartilaginous lesions in the apposing articular surface of the lunate.

In conclusion, the hamatolunate facet is a very common anatomic variant. The presence of a hamatolunate facet is associated with severe chondral damage in the proximal pole of the hamate.

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