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SCIENTIFIC ARTICLE

MRI appearance of the anomalous volar radiotriquetral ligament in true Madelung deformity

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Abstract

Objective To characterize the MRI appearance of the anomalous volar radiotriquetral ligament in cases of classic Madelung deformity.

Materials and methods With institutional review board approval, a search of the radiology information system was performed to identify cases of potential Madelung deformity using variations of the criteria "Madelung deformity." Cases of classic Madelung deformity were included based on the following criteria: dorsal subluxation of the ulnar head, volar tilt of the distal radius, increased radial inclination of greater than 25°, triangulation of the carpus, and presence of Vickers ligament defined as an anomalous volar radiolunate ligament. Patients with a history of wrist trauma or severe degenerative change distorting anatomy were excluded. The resulting cases were reviewed to characterize the anomalous radiotriquetral ligament.

Results Eight cases of classic Madelung deformity in 6 patients were identified. All 8 cases were characterized by the presence of an anomalous radiotriquetral ligament, which was more conspicuous than Vickers ligament. None of the excluded pseudo-Madelung deformity cases displayed a Vickers ligament or radiotriquetral ligament.

Conclusion The radiotriquetral ligament is an anomalous ligament that is a constant and distinguishing finding in classic Madelung deformity in this study. Awareness of the radiotriquetral ligament and distinguishing it from Vickers ligament on imaging studies and at surgery may have clinical implications that need to be further investigated.

Keywords Madelung · Ligaments · MRI

Introduction

Madelung deformity is a disorder affecting the wrist secondary to abnormal growth of the distal radius physis. The classic Madelung deformity is distinguished from other Madelung-like deformities of the distal radius by the presence of an anomalous thick volar ligament tethering the lunate to the radius. This volar ligament tethers the development of the volar ulnar radius, resulting in proximal and volar subsidence of the lunate. The anomalous radiolunate ligament was first described by Vickers in 1992 and has been referred to as Vickers ligament [1]. Radiographic criteria for classic Madelung deformity include dorsal subluxation of the ulnar head, volar tilt of the distal radius, increased radial inclination of greater than 25°, triangulation of the carpus, and the presence of Vickers ligament [2]. Subsequent studies have shown an additional anomalous volar ligament described as the radiotriquetral ligament (RTL) [2–4]. These reports describe the magnetic resonance imaging (MRI) course of the RTL and its relationship to Vickers ligament. The purpose of this study was to examine the anatomical MRI characteristics of the RTL in cases of classic Madelung deformity and to detail the differences from Vickers ligament.

Materials and methods

After Institutional Review Board approval, a retrospective review of the radiology database was undertaken to identify patients with Madelung deformity from 1 January 2000 to 1 September 2017. Specifically, the radiology information system was searched for MRI reports using variations of the

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criteria "Madelung deformity." Two musculoskeletal fellowship trained radiologists with 11 and 20 years of experience evaluated the radiographic and MRI examinations to determine by consensus if each case met criteria for classic Madelung deformity. The criteria of classic Madelung deformity included:

1. Dorsal subluxation of the ulnar head
2. Volar tilt of the distal radius
3. Increased radial inclination of greater than 25°
4. Triangulation of the carpus
5. Presence of Vickers ligament defined as an anomalous volar radiolunate ligament [2]

Patients with a history of wrist trauma or severe degenerative change distorting the anatomy were excluded. The cases of classic Madelung deformity were also reviewed by consensus to further characterize the anomalous RTL, specifically its relationship with Vickers ligament, the size and conspicuity of the RTL relative to Vickers ligament, an intermediate or hyperintense signal cleft distinguishing the RTL from Vickers ligament, and the distal insertions of the RTL.

A 3.0-T or 1.5-T MRI unit (GE Healthcare HDxt, Waukesha, WI, USA) with a dedicated birdcage extremity coil was used for all cases. All wrists were scanned using our standard MRI wrist protocol that covered the wrist from the radius metaphysis to the base of the metacarpals. A 10-cm field of view with a matrix size of 384 × 256 and a NEX of 2 was employed. Axial, coronal, and sagittal T1-weighted (3 T 2 mm, TR/TE 700–900/10; 1.5 T 2 mm, TR/TE 400–600/10) and T2-weighted fat-suppressed (3 T 2 mm, TR/TE 3,000–6,000/45; 1.5 T 2 mm, TR/TE 3,000–5,000/45) sequences were obtained. The patients were positioned prone and head first within the scanner with the arm above the head and the coil as close to the isocenter as possible.

Results

The radiology information system search returned a total of 19 cases. After application of the exclusion and inclusion criteria, 8 cases of classic Madelung deformity were identified.

The 8 cases included 5 left wrists and 3 right wrists in 6 patients. All patients were female with a mean age of 24.7 ± 14.6 years (range 12–50). The MRI examinations were performed between November 2002 and August 2017. Five cases were performed at 3.0 T and 3 were performed at 1.5 T. There was no appreciable difference in the evaluation of the RTL between studies performed at 3.0 T and 1.5 T.

All 8 cases demonstrated an anomalous RTL and in all 8 cases, it was more conspicuous than Vickers ligament. The RTL was a constant in both skeletally mature and immature patients and was present in 5 skeletally immature wrists and 3 skeletally mature wrists. The proximal attachment of the RTL was from the radial notch and slightly ulnar and dorsal in position in relation to Vickers ligament (Fig. 1). The RTL was present one or two slices dorsal to Vickers ligament in the coronal plane in all cases (Fig. 2). The RTL and Vickers ligament were separated by an intermediate signal cleft in 6 out of 8 cases. The RTL divided distally with a constant attachment to the palmar triquetrum (Fig. 3a) and a constant attachment to the triangular fibrocartilage disc (Fig. 3b). The RTL variably attached to the palmar band of the lunotriquetral ligament, volar radioulnar ligament, and ulnotriquetral ligament.

Of the 11 excluded cases, 2 cases were removed based on a history of previous trauma to the wrist, but otherwise met the inclusion criteria for classic Madelung deformity. One case was a reverse Madelung deformity, but did have a Vickers ligament and RTL. Seven cases were pseudo-Madelung deformities with no Vickers ligament or RTL. One case was in an 81-year-old woman with advanced degenerative changes of the wrist resulting in severely distorted anatomy, limiting evaluation.

Discussion

The anatomical MRI characteristics of the anomalous RTL in cases of classic Madelung deformity have not been adequately characterized. Of the 8 cases of classic Madelung deformity identified in this series, all were female and all demonstrated an anomalous RTL that was more conspicuous than Vickers ligament on all imaging sequences and planes. None of the

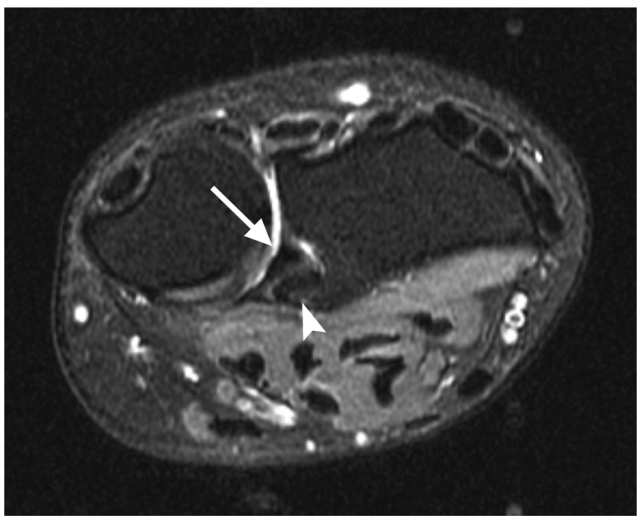

Fig. 1 A 23-year-old woman with Madelung deformity. Axial T2-weighted fat-suppressed (T2FS) image of the wrist at the level of the radial notch. The proximal attachment of the radiotriquetral ligament (RTL; *arrow*) from the radial notch is located immediately ulnar and dorsal to Vickers ligament (*arrowhead*). The ligaments are separated by an intermediate signal cleft

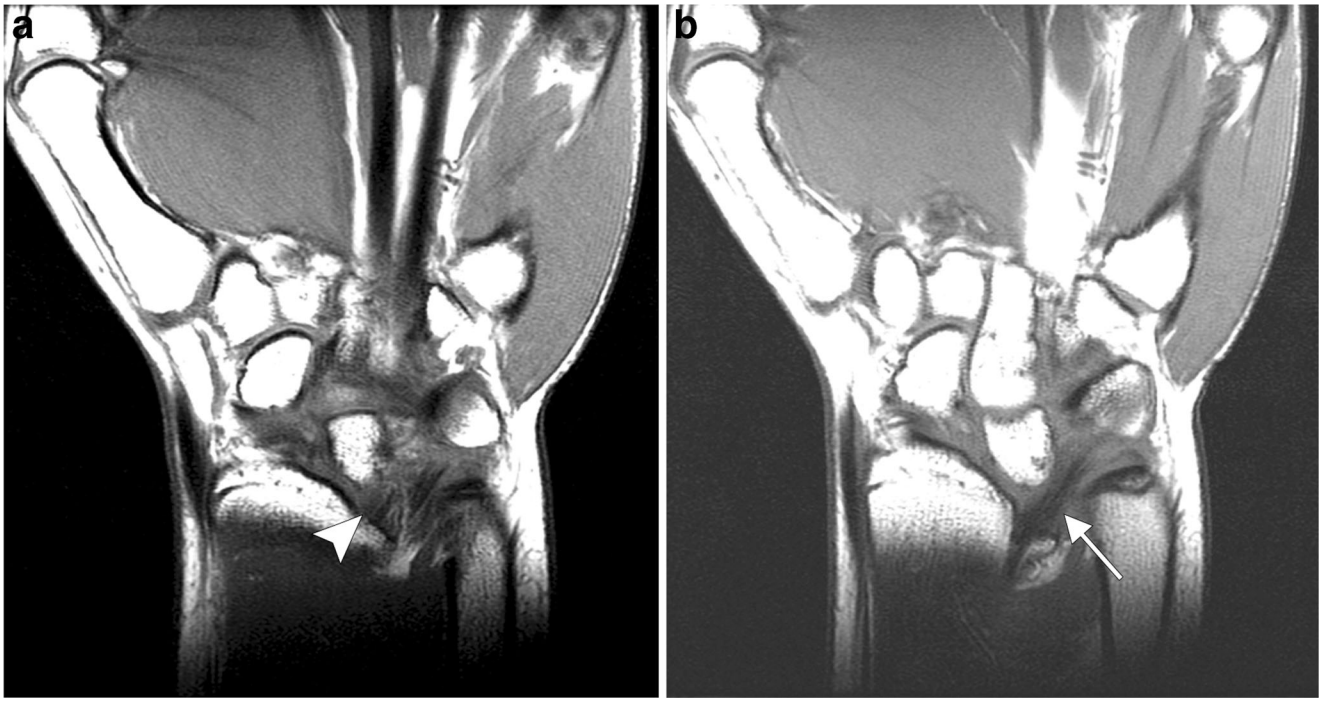

Fig. 2 A 16-year-old girl with Madelung deformity. **a** Coronal T1-weighted image (T1WI) of the wrist. The Vickers ligament (*arrowhead*) extends from the radial notch to the volar lunate. **b** The RTL (*arrow*) arises from the radial notch one slice dorsal to Vickers ligament in the coronal plane

excluded pseudo-Madelung deformity cases displayed a Vickers ligament or RTL. The RTL was best assessed in the coronal plane and was constantly located immediately dorsal to Vickers ligament. The proximal attachment of the RTL was best assessed in the axial plane at the radial notch and was located immediately ulnar and dorsal to Vickers ligament. The

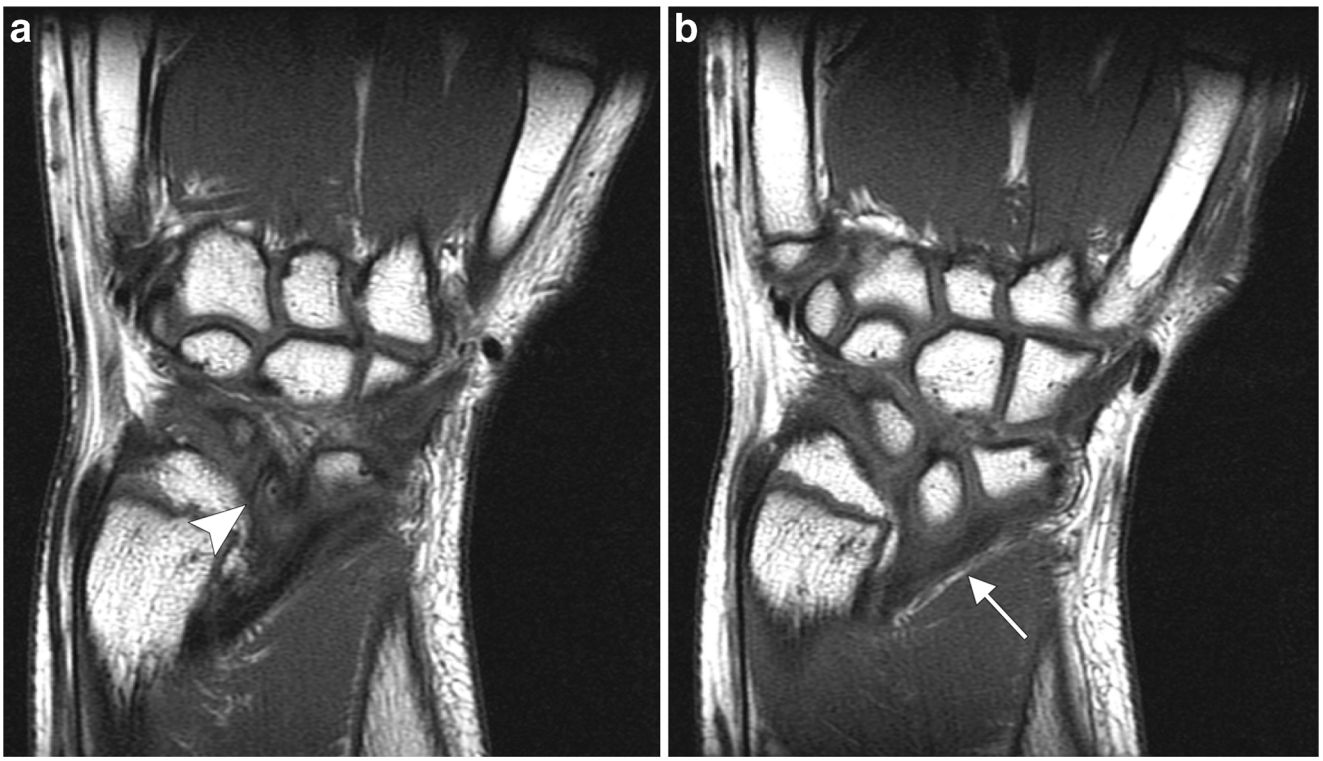

Fig. 3 A 12-year-old girl with Madelung deformity. Coronal T1WI of the wrist. **a** The Vickers ligament (*arrowhead*) extends from the radial notch to the volar lunate. **b** The RTL (*arrow*) arises from the radial notch two slices dorsal to Vickers ligament in the coronal plane

distal attachment of the RTL was variable upon the volar ulnar-sided osseous and ligamentous structures.

Surgical release of Vickers ligament off the distal radius has been advocated early in the course of treatment to potentially prevent the deformity from progressing [5]. As the RTL is not universally recognized or distinguished from Vickers ligament at surgery, release of the "volar ligament" from the distal radius at the level of the physis releases both Vickers ligament (radiolunate) and the RTL given the current surgical technique. The clinical implications of the release of Vickers ligament and the RTL are not well understood, with Vickers ligament inconsistently reported in the surgical literature [6].

We recognize the limitations of this study. The foremost limitations are its retrospective nature and small sample size. Not all patients underwent surgery and of those who did, there was no mention of the RTL at the time of surgery. There are no studies within the surgical literature confirming the presence of the RTL.

In conclusion, the RTL ligament was present in 100% of the cases of classic Madelung deformity and was more conspicuous than Vickers ligament, which is a defining trait of Madelung deformity. None of the excluded pseudo-Madelung deformity cases displayed a Vickers ligament or RTL. The RTL is not universally recognized, except by experts familiar with the condition and treatment. Awareness of RTL and distinguishing it from Vickers ligament on imaging studies and at the time of surgery may have potential clinical implications in the management of Madelung deformity that need to be evaluated in future studies.

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Compliance with ethical standards

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Conflicts of interest The authors have no conflicts of interest to disclose.

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