Imaging Key Wrist Ligaments: What the Surgeon Needs the Radiologist to Know

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OBJECTIVE. Although much attention is paid to the scapholunate ligament, lunotriquetral ligament, and the triangular fibrocartilage complex, additional intrinsic and extrinsic ligaments in the wrist play an important part in carpal stability. With improved MRI techniques, the radiologist can increasingly visualize these ligaments.

CONCLUSION. The anatomy, MRI appearance, and clinical significance of the scapholunate ligament, lunotriquetral ligament, triangular fibrocartilage complex, carpal metacarpal ligaments, and volar and dorsal extrinsic ligaments are reviewed.

Many radiologists who interpret MRI examinations of the wrist for evaluating ligamentous integrity often focus on three ligamentous complexes—the scapholunate ligament, lunotriquetral ligament, and triangular fibrocartilage complex. Although these ligaments are the most clinically significant ligaments of the wrist, other intrinsic and extrinsic ligaments provide important stability to the carpal bones. We consulted with our orthopedic colleagues and we will emphasize the ligaments we think to be of greatest clinical and surgical importance.

In this article, we will review not only the three ligamentous complexes on which most radiologists focus, but also other important ligaments that should be evaluated. Although this article is not an exhaustive review of all ligaments of the wrist, it will highlight ligaments that ought to receive special attention. After having talked with our orthopedic colleagues, we will discuss our experience in visualization and assessment of the integrity of these ligaments. We will also address pathologic conditions and consequences of injury to these respective ligaments.

We have divided our discussion of pertinent ligaments of the wrist into several broad categories: the intrinsic ligaments, the volar extrinsic ligaments, the dorsal extrinsic ligaments, and the ligaments of the thumb. Intrinsic ligaments of the wrist are ligaments that attach solely to the carpal bones in the wrist, whereas extrinsic ligaments have additional attachments to the forearm, retinacula, or tendon sheaths. We will address the following intrinsic ligaments: the scapholunate ligament, lunotriquetral ligament, and scaphotrapeziotrapezoid ligament. The volar extrinsic ligaments we will discuss include the volar radioscaphocapitate, volar radiotriquetral, volar ulnolunate, volar ulnotriquetral, and volar radioulnar. The dorsal extrinsic ligaments we will describe include the dorsal intercarpal ligament, dorsal radiotriquetral, and dorsal radioulnar. For the thumb, we will discuss the superficial anterior oblique ligament, deep anterior oblique ligament, and dorsoradial ligament.

Intrinsic Ligaments of the Wrist

Radiologists and clinicians typically focus on the "big three" intrinsic ligamentous complexes—the scapholunate ligament, lunotriquetral ligament, and triangular fibrocartilage complex. Multiple anatomic research studies have shown that it is not injury solely to these ligaments that can lead to carpal instability, but that each of them has intimate relationships with other extrinsic ligaments that we will discuss further.

The scapholunate ligament has three components—volar, dorsal, and interosseous. The dorsal and volar represent true ligaments, whereas the interosseous component is fibrocartilage. A volar radioscapholunate ligament joins the volar scapholunate ligament and also separates the large interosseous component and the volar component [1]. Given their interrelationship, it is not surprising that injury to one may be associated with injury to the other. The volar aspect of the scapholunate ligament typically is obliquely oriented and measures,

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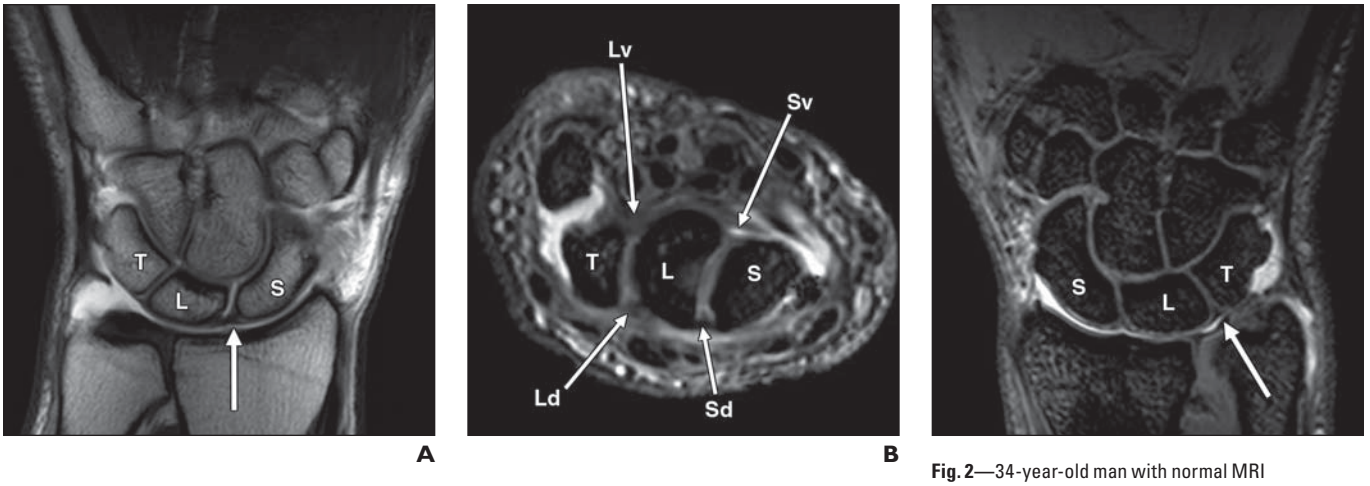

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Fig. 1—21-year-old man with normal MRI appearance of scapholunate ligament.
A, Normal scapholunate ligament (*arrow*) is seen on coronal T1-weighted MR arthrogram of wrist. L = lunate, S = scaphoid, T = triquetrum.
B, Normal scapholunate ligament (Sd = dorsal band of scapholunate ligament, Sv = volar band) and lunotriquetral ligament (Ld = dorsal band of lunotriquetral ligament, Lv = volar band) are seen on axial 3D gradient-recalled echo sequence from MR arthrogram of wrist.

Fig. 2—34-year-old man with normal MRI appearance of lunotriquetral ligament. Normal lunotriquetral ligament (*arrow*) is seen on coronal 3D gradient-recalled echo MR arthrogram of wrist. L = lunate, S = scaphoid, T = triquetrum.

on average, 1 mm in thickness [1]. Although the volar component is the weakest, the dorsal is the most critical in preserving the relationship between the scaphoid and lunate.

The thick dorsal component is oriented transversely to the lunate and scaphoid, is associated with the joint capsule, and measures, on average, 3 mm in thickness. In symptomatic individuals, it is the dorsal component that most often has a complete defect, whereas the most commonly seen defect among asymptomatic individuals is within the interosseous portion. In addition, when a ligamentous defect is present, it is typically seen at the scaphoid attachment and rarely at the lunate attachment [2].

Although scapholunate defects may be detectable on nonarthrographic sequences, we think that arthrographic sequences best depict anatomy and abnormalities because of its superb contrast resolution. Although others have found examinations conducted on 3-T MRI scanners to reveal superior signal-to-noise ratio and improved reader confidence, we think that 1.5-T examinations are sufficient to assess the scapholunate ligament [3]. In particular, axial and coronal 3D gradient-recalled echo (GRE) sequences can reveal all three components of the scapholunate ligament (Fig. 1).

The lunotriquetral ligament, like the scapholunate ligament, has three components—volar, dorsal, and proximal. Although some have divided the appearance of the ligament to either having a triangular or linear appearance, there is evidence that the ligament typically appears as both—the proximal zone typically has a triangular appearance, whereas the volar zone often has a linear shape [4]. Note, however, that the volar zone is quite small (approximately 1 mm) and can be quite subtle [5]. The triangular shape of the proximal zone has an apex pointed distally, whereas the volar zone has a linear shape that runs parallel in the interspace between the lunate and triquetrum, extending distally.

The dorsal component is the most important in carpal stability and resistance to rotation, with complete tears potentially leading to volar intercalated segment instability. Although varying additional ligaments have also been implicated in the development of volar intercalated segment instability, Viegas et al. [6] have found an associated abnormality involving the dorsal joint capsule and the dorsal radiotriquetral ligament. The lunotriquetral ligament is also less flexible than the scapholunate ligament, which results in less potential for motion between the lunate and triquetrum, and the ligament consequently limits the dorsiflexion tendency of these two.

Partial tears of the lunotriquetral ligament can be quite subtle. Of the three primary intrinsic ligamentous complexes, abnormalities of the lunotriquetral ligament are often the most challenging to detect. MRI can be helpful, because ligamentous tears may not be seen on arthroscopy unless there is dissociation [5]. We find that both axial and coronal sequences are complementary, although intrinsic signal abnormality within the lunotriquetral ligament that may indicate a partial tear can be best depicted on coronal sequences, in particular 3D GRE sequences (Fig. 2).

The triangular fibrocartilage complex is composed of the triangular fibrocartilage disk, volar and dorsal radioulnar ligaments, volar ulnolunate and volar ulnotriquetral ligaments, meniscal homolog, ulnar collateral ligament, and extensor carpi ulnaris tendon sheath. Although much attention is paid to the triangular fibrocartilage disk component and attachments on the radius and ulna, in our discussion of the extrinsic ligaments, we will address the remaining components that can be of clinical significance.

One other intrinsic carpal ligament that may be of interest to the referring physician is the scaphotrapeziotrapezoid ligament. This ligament has fibers on the volar and dorsal aspects of the distal pole of the scaphoid, with some fibers extending to the trapezium and other fibers extending to the trapezoid (Fig. 3) [7]. Some fibers of the volar radioscaphocapitate ligament blend with the volar fibers of this ligament.

Injury to the scaphotrapeziotrapezoid ligament can be quite challenging to detect. Unfortunately, the ligament itself can be difficult to visualize. If the scaphocapitate ligament is intact, the interval between these three carpal bones may be normal, even in the presence of underlying ligamentous injury. Ligamentous rupture is best seen on arthrography by abnormal extension of contrast into the flexor carpi radialis tendon sheath [8].

Volar Extrinsic Ligaments of the Wrist

We have found the volar radioscaphocapitate ligament to be one of the most easily identified extrinsic ligaments. The volar radioscapho-

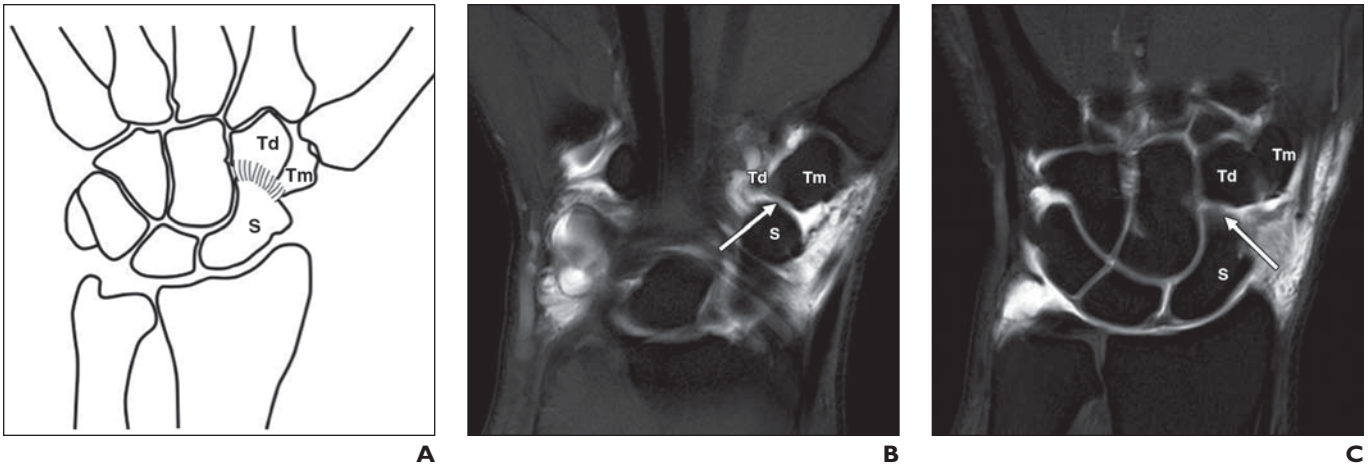

Fig. 3—Normal scaphotrapeziotrapezoid ligament.
A, Drawing depicts normal anatomy of scaphotrapeziotrapezoid ligament. S = scaphoid, Td = trapezoid, Tm = trapezium. (Drawing by Richardson ML)
B, 32-year-old man with normal appearance of scaphotrapeziotrapezoid ligament (*arrow*) seen on coronal T1-weighted fat-saturated MR arthrogram of volar wrist.
C, 32-year-old man with normal appearance of scaphotrapeziotrapezoid ligament (*arrow*) seen on coronal T1-weighted fat-saturated arthrogram of volar wrist.

capitate ligament originates at the distal aspect of the radial styloid. The fibers then extend distally and medially (in an obliquely oriented ulnar direction) to the capitate. There is debate concerning the ligament's attachment on the scaphoid, though some authors have found that some of the fibers do attach here [9]. The most conspicuous fibers on MRI are seen on coronal images extending to the scaphoid waist (Fig. 4). Other fibers pass by the proximal pole of the scaphoid and subsequently attach on the proximal capitate. A few fibers also blend with the volar scaphotrapeziotrapezoid ligament. However, there is no focal division among the fibers such that they can easily be separated into unique entities; rather, the ligament has several differing terminations [9].

The entirety of the volar radioscaphocapitate ligament is usually best seen on a few coronal 3D GRE images performed at a 1-mm slice thickness. Recent preliminary research has found inconsistent assessment of the volar radioscaphocapitate and volar radiolunate ligaments in MRI evaluation when MRI is used as the reference standard [10]. However, further research will need to be conducted. Arthroscopically, this ligament is quite easily seen, although the radial styloid attachment may be suboptimally evaluated [11].

Because the volar radioscaphocapitate ligament attaches at the radial styloid, fractures or osteotomies at this site may lead to an alteration in the carpal biomechanics. Given its extension across (and attachment to) the scaphoid, this ligament is involved in the stability of the scaphoid. Although one commonly thinks of injury to the scapholunate ligament in scapholunate dissociation, underlying injury to the

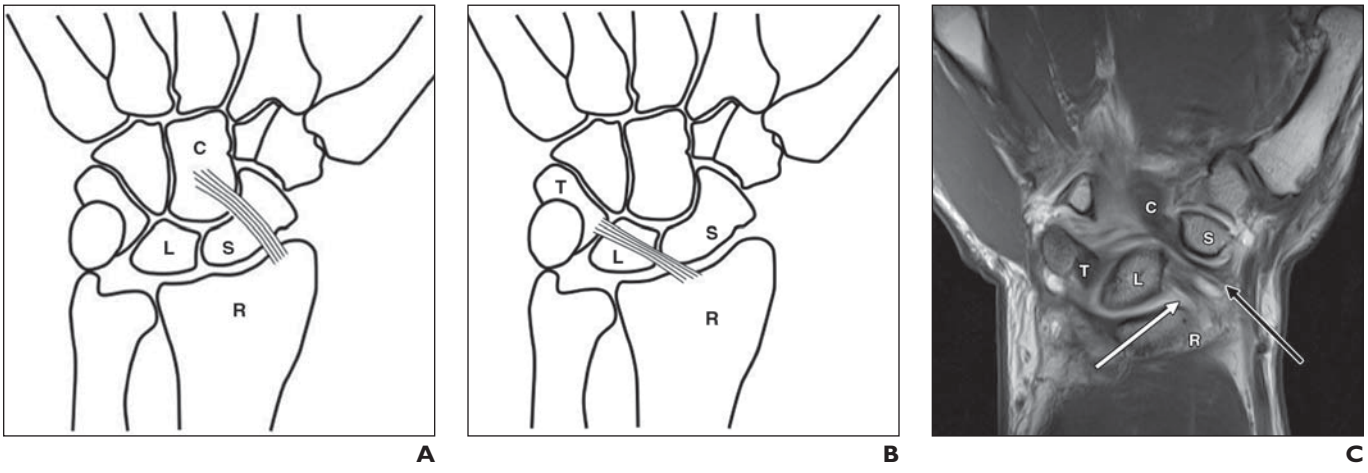

Fig. 4—Normal appearance of volar radioscaphocapitate and volar radiolunate ligaments.
A, Drawing depicts normal anatomy of volar radioscaphocapitate ligament. Fibers are seen extending from volar distal radius at radial styloid across scaphoid (S) to capitate (C). L = lunate, R = radius. (Drawing by Richardson ML)
B, Drawing depicts normal anatomy of volar radiolunate ligament, with fibers extending from distal radius to lunate and subsequently to triquetrum (T) as fibers blend with lunotriquetral ligament. (Drawing by Richardson ML)
C, 51-year-old man with normal volar radioscaphocapitate ligament (*black arrow*) and volar radiolunate ligament (*white arrow*) seen on coronal T1-weighted MR arthrogram from volar aspect of wrist. Fluid within radiocarpal joint from arthrogram is seen intervening between volar radioscaphocapitate ligament and volar radiolunate ligament, allowing delineation between two.

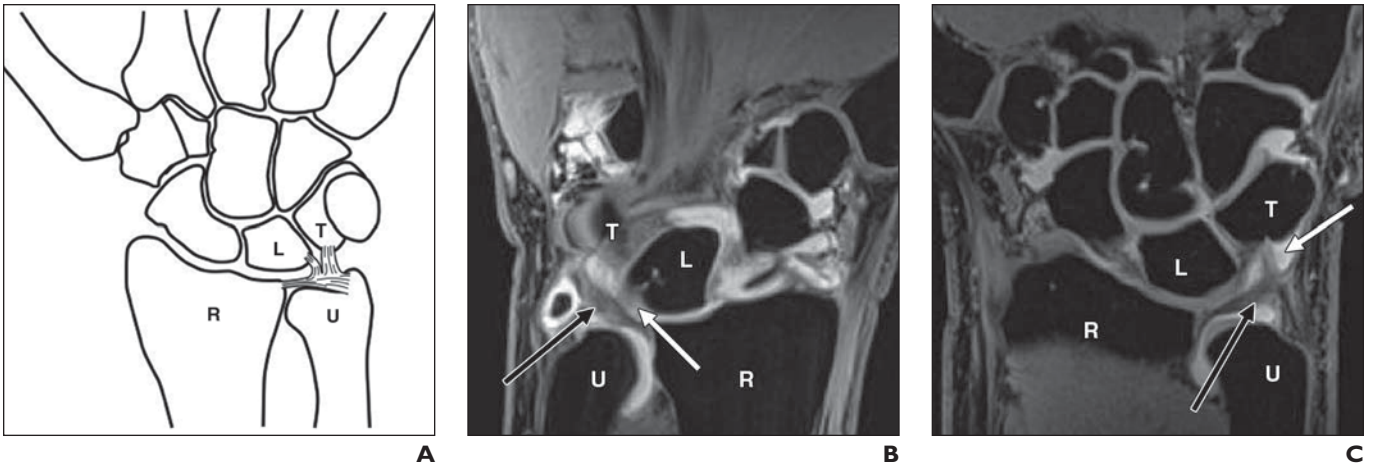

Fig. 5—Normal appearance of volar ulnolunate and volar ulnotriquetral ligaments.
A, Drawing shows normal anatomy of volar ulnolunate and volar ulnotriquetral ligaments. Volar ulnolunate ligament extends from volar radioulnar ligament (volar band contiguous with disk of triangular fibrocartilage) to lunate (L). Volar ulnotriquetral ligament extends from volar radioulnar ligament to triquetrum (T). R = radius, U = ulna. (Drawing by Richardson ML)
B, 29-year-old man with normal volar ulnolunate ligament (*white arrow*) seen on coronal 3D gradient-recalled echo (GRE) MR arthrogram image of wrist. Ligament extends from volar radioulnar ligament (*black arrow*) to lunate.
C, 25-year-old man with normal volar ulnotriquetral ligament (*white arrow*) seen on coronal 3D GRE MR arthrogram image of wrist. Ligament extends from volar radioulnar ligament (*black arrow*) to triquetrum.

volar radioscaphocapitate or volar radiolunate ligament is also typically present [12].

The volar radiolunate ligament is often called by many names, including the radiolunotriquetral or long radiolunate ligament. We will refer to it as the volar radiolunate ligament. The volar radiolunate ligament also originates at the radial styloid, abutting the origin of the radioscaphocapitate ligament at its medial aspect. The volar radiolunate ligament is just proximal to the radioscaphocapitate ligament and extends in a fairly parallel fashion, extending obliquely to attach on the lunate. The superficial fibers of this ligament then blend with the lunotriquetral interosseous ligament, attaching to the triquetrum [9]. Because the volar radiolunate ligament nearly parallels the volar radioscaphocapitate ligament, it is best visualized on MRI in a similar fashion; coronal and sagittal sequences can nicely depict both ligaments simultaneously (Fig. 4). A sulcus lies between the volar radioscaphocapitate and volar radiolunate ligaments, allowing delineation between these two by intervening joint fluid. Abnormalities of the volar radiolunate ligament have been seen in individuals with a Madelung deformity [13].

The volar ulnolunate, volar ulnotriquetral, and volar distal radioulnar ligaments are components of the triangular fibrocartilage complex. The volar radioulnar ligament represents a thickened peripheral margin of the disk of the triangular fibrocartilage complex. The volar radioulnar ligament originates at the radius and, because it is associated with the disk, attaches on the ulna at the styloid and fovea.

The volar ulnolunate ligament originates proximally at the volar radioulnar ligament. The volar ulnolunate ligament then extends distally to the lunate, in a fairly parallel fashion to the long axis of the wrist and forearm. At the lunate, some fibers join the lunotriquetral ligament. The volar ulnotriquetral ligament also originates proximally at the volar radioulnar ligament, but is just ulnar (medial) to the volar ulnolunate ligament. This ligament then fans out, attaching broadly on the triquetrum.

The volar ulnolunate and volar ulnotriquetral ligaments can be best evaluated on coronal images (Fig. 5). Here, the small amount of joint fluid between the two can allow the low signal of the ligaments to be more conspicuous when set against the bright signal of joint fluid or arthrographic contrast. The volar radioulnar ligament can easily be seen in all three imaging planes, although axial images allow visualization of the volar and dorsal ligaments and the disk of the triangular fibrocartilage (Fig. 6).

The volar radioulnar ligament is important in stability at the wrist with supination when seen in conjunction with injury to the interosseous membrane [14]. Tears of the ligament itself without involvement of the triangular fibrocartilage disk are uncommon. However, recognition is important, because the peripheral zone is vascularized and has a greater potential for healing. Tears may also blunt the cushioning response of the triangular fibrocartilage complex, predisposing to osteoarthritis of the radiocarpal or distal radioulnar joint [15]. Because the volar ulnolunate and volar ulnotriquetral ligaments attach on the volar radioulnar ligament (the periphery of the triangular fibrocartilage complex) and not on the ulna, injury to the volar ulnolunate and volar ulnotriquetral ligaments can occur with peripheral triangular fibrocartilage complex injuries. These traumatic injuries that involve detachment of the articular disk can lead to instability at the wrist [17]. The volar ulnolunate and volar ulnotriquetral ligaments help stabilize the interaction between the radius and ulna with pronation and supination. The volar ulnolunate and volar ulnotriquetral ligaments also help in preventing the carpal bones from being displaced toward the ulna. Injury to the ulnotriquetral ligament can often be detected clinically. On physical examination, if there is tenderness volarly at the ulnar fovea that reproduces the patient's pain, this has a very high sensitivity for distal volar radioulnar or volar ulnotriquetral ligament injury [18].

MRI can play a complementary role in the assessment of the volar ulnolunate and volar ulnotriquetral ligaments, giving confirmation before potential arthroscopy. A few small studies have found conflicting results on the sensitivity of MRI in depicting tears of the volar ulnolunate and volar ulnotriquetral ligaments [18]. One might expect that, with continued experience and exposure and with improved imaging techniques, imaging sensitivity will improve.

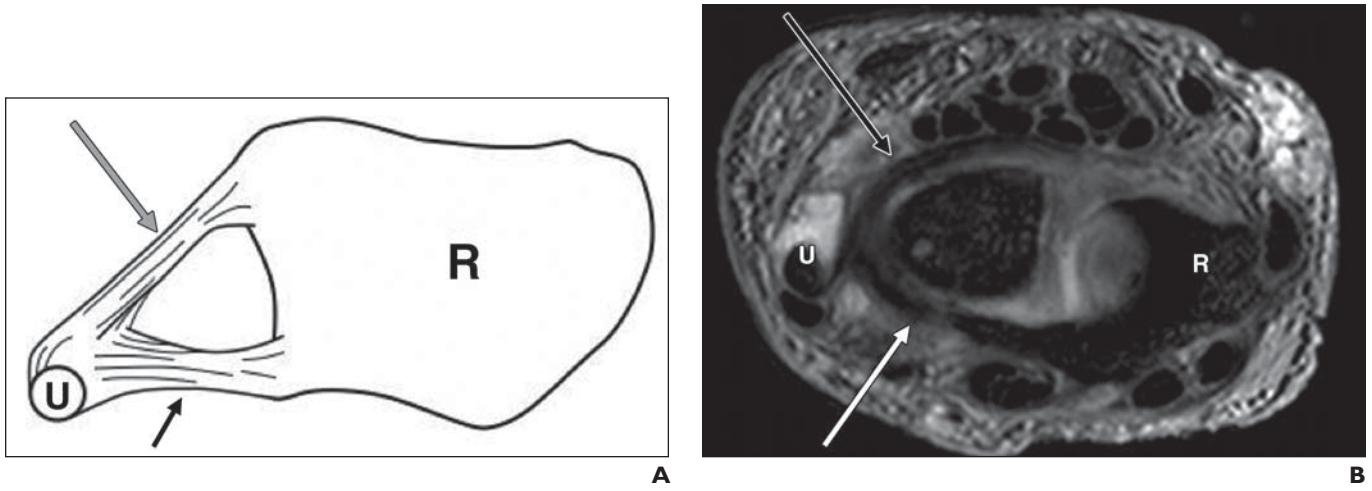

Fig. 6—Normal appearance of volar and dorsal radioulnar ligaments.
A, Drawing depicts normal appearance of volar (*gray arrow*) and dorsal (*black arrow*) radioulnar ligaments. R = radius, U = ulna. (Drawing by Richardson ML)
B, 73-year-old woman with normal volar radioulnar ligament (*black arrow*) and dorsal radioulnar ligament (*white arrow*) seen on axial 3D gradient-recalled echo MR arthrogram.

Dorsal Extrinsic Ligaments of the Wrist

Three main dorsal extrinsic ligaments have great functional significance—the dorsal intercarpal, dorsal radiotriquetral, and dorsal radioulnar ligaments. The dorsal radiotriquetral ligament stretches from the dorsal radial styloid to the dorsal tubercle of the triquetrum. It stretches in an oblique fashion just distally and ulnarly (medially), with the fibers also attaching and crossing the ulnar aspect of the lunate. The dorsal intercarpal ligament extends from the dorsal tubercle of the triquetrum to the dorsal groove of the scaphoid. Typically, the dorsal intercarpal ligament also attaches to the dorsal aspect of the lunate and, in one half of individuals, also attaches to the dorsal proximal trapezium [19]. The dorsal intercarpal ligament attaches to both the scapholunate and lunotriquetral ligaments.

The dorsal radiotriquetral and dorsal intercarpal ligaments together have a zig-zag configuration, which others refer to as a V shape (Fig. 7). The dorsal intercarpal ligament and dorsal radiotriquetral ligament function as a radioscaphoid stabilizer on the dorsal side. Because the dorsal intercarpal ligament attaches on the scaphoid and lunate, it has a key function in allowing controlled movement of the scaphoid and in prohibiting scapholunate dissociation. In particular, sectioning of the dorsal intercarpal ligament leads to alteration in positioning of the lunate [20]. As already mentioned, the volar radioscaphocapitate ligament has a function in rotation of the scaphoid and also is involved in scapholunate dissociation.

The dorsal radioulnar ligament, like the volar radioulnar ligament, represents a thickened peripheral margin of the disk of the triangular fibrocartilage. As mentioned already, although the volar radioulnar ligament is important in wrist stability with supination, the dorsal radioulnar ligament is important in wrist stability with pronation when the interosseous membrane is also injured [14].

Coronal images, whether with thin-section 3D GRE sequences or with T1- or T2-weighted sequences, best reveal the dorsal radiotriquetral and dorsal intercarpal ligaments in their entirety. Although arthrographic sequences show these ligaments to better advantage, these ligaments can still be seen quite easily on nonarthrographic sequences. As with the volar radioulnar ligament, the dorsal radioulnar ligament in conjunction with the disk of the triangular fibrocartilage can be best seen on axial sequences (Fig. 6).

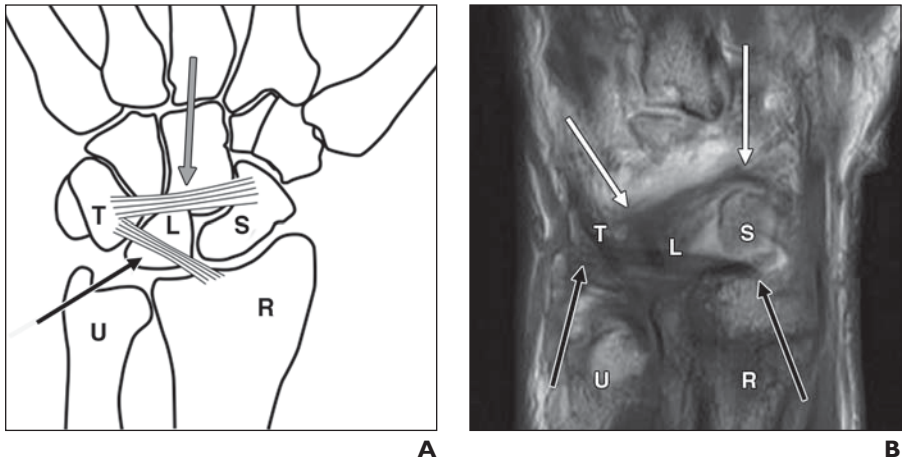

Fig. 7—Normal appearance of dorsal radiotriquetral ligament and dorsal intercarpal ligament.
A, Drawing depicts normal anatomy of dorsal intercarpal ligament (*gray arrow*) and dorsal radiotriquetral ligament (*black arrow*). Dorsal intercarpal ligament extends from dorsal tubercle of triquetrum (T) to dorsal groove of scaphoid (S). Dorsal radiotriquetral ligament extends from dorsal radial styloid to dorsal tubercle of triquetrum. L = lunate, R = radius, U = ulna. (Drawing by Richardson ML)
B, 51-year-old man with normal dorsal radiotriquetral ligament (*black arrows*, sites of attachment on dorsal radial styloid and dorsal tubercle of triquetrum) and dorsal intercarpal ligament (*white arrows*, attachment sites on scaphoid and triquetrum) on coronal T1-weighted MR arthrogram.

Ligaments of the Thumb

Although MRI examinations of the wrist are constructed to evaluate the wrist, several ligaments at the carpal metacarpal joint and metacarpal phalangeal joint may be included in the

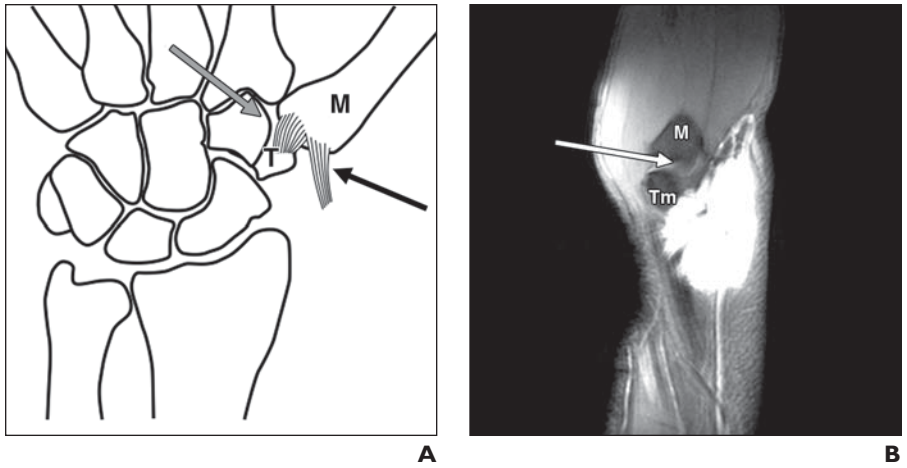

Fig. 8—Normal appearance of dorsoradial ligament of first carpal metacarpal joint.
A, Drawing from dorsal aspect of wrist depicts dorsoradial ligament (*gray arrow*) and its relationship with abductor pollicis longus tendon (*black arrow*). Dorsoradial ligament extends from dorsal radial tubercle of trapezium (Tm) to dorsal aspect of first metacarpal (M). Abductor pollicis longus tendon inserts on radial side of proximal first metacarpal. Abductor pollicis longus tendon is located superficial to dorsoradial ligament and has been reflected off its more proximal course on this drawing. (Drawing by Richardson ML)
B, 33-year-old man with normal dorsoradial ligament (*arrow*) seen extending from dorsal radial tubercle of trapezium to dorsal aspect of first metacarpal on sagittal T2-weighted fat-saturated MRI.

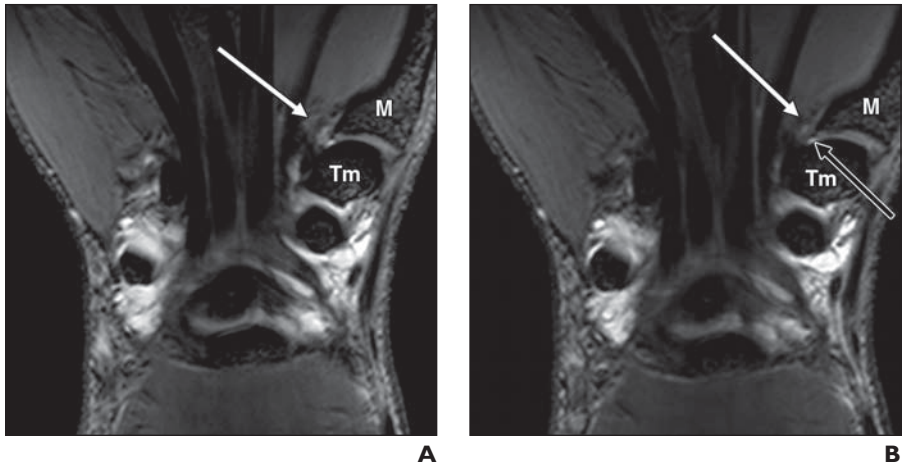

Fig. 9—32-year-old man with normal appearance of superficial and deep anterior oblique ligaments of first carpal metacarpal joint.
A, Normal superficial anterior oblique ligament (*arrow*) of first carpal metacarpal joint (M) is seen on coronal 3D gradient-recalled echo (GRE) MRI. Tm = trapezium.
B, Normal deep (*black arrow*) and superficial (*white arrow*) anterior oblique ligaments of first carpal metacarpal joint are seen on coronal 3D GRE MRI.

FOV. The ulnar collateral and radial collateral ligaments of the first interphalangeal joint may or may not be included. These ligaments would be best viewed with dedicated imaging, but when seen, should be assessed. Although there are numerous ligaments at the first carpal metacarpal joint, the dorsoradial ligament and superficial and deep portions of the anterior oblique ligament can in particular be quite important in first carpal metacarpal stability.

The dorsoradial ligament extends from the dorsal radial tubercle of the trapezium to the base of the first metacarpal. The ligament is adjacent to the dorsal aspect of the abductor pollicis longus tendon. The dorsoradial ligament is typically best seen on sagittal sequences on one or two images obtained at 3-mm slice thickness (Fig. 8). The dorsoradial ligament is the strongest of the ligaments at the first carpal metacarpal joint, and thus key in joint stability [21].

The superficial anterior oblique ligament attaches from the volar trapezium, just proximal to its articular surface, to the first metacarpal just distal to its articular surface. The deep anterior oblique ligament, also known as the beak ligament, attaches at the articular margins of the trapezium and first metacarpal. As implied by its namesake, the deep anterior oblique ligament lies on the volar side of the first carpal metacarpal joint, is intraarticular, and runs in an oblique fashion. The ligament is shorter than the superficial anterior oblique ligament and, therefore, becomes taut earlier in extreme ranges of motion. The ligament is also slightly less bulky in overall size than its superficial counterpart. The deep and superficial anterior oblique ligaments prevent volar subluxation of the first metacarpal [22].

The deep and superficial anterior oblique ligaments can be best delineated on dedicated arthrographic sequences. Assessment can be challenging, because nonvisualization of the deep anterior oblique ligament does not necessarily imply ligament disruption; it is not found in 30% of individuals [7, 22]. We think that, in most instances, coronal sequences provide the best assessment, because many practices focus more on axial and coronal planes for wrist MRI examinations. Thin-section (1-mm thick) 3D GRE coronal sequences can best reveal the oblique ligaments on two or three images (Fig. 9). The ligaments will be visualized running obliquely from the trapezium to the first metacarpal.

Conclusion

The scapholunate ligament, lunotriquetral ligament, and triangular fibrocartilage complex are typically given the greatest attention when assessing the ligaments of the wrist. Although these ligaments are important in carpal stability, additional extrinsic and intrinsic ligaments of the wrist have an impact on carpal stability. The volar radioscaphocapitate and dorsal intercarpal ligaments can be involved in scapholunate dissociation. The volar and dorsal radioulnar ligaments, volar ulnolunate ligament, and volar ulnotriquetral ligaments represent lesser-known segments of the triangular fibrocartilage complex. The dorsoradial and superficial and deep anterior oblique ligaments of the first carpal metacarpal joint are important in stability at this joint. With continued improvements in MRI techniques, radiologists should attempt to assess these ligaments.

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