LUNOTRIQUETRAL INJURIES

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Lunotriquetral injury is an important consideration in the evaluation of ulnar-sided wrist pain. An understanding of the anatomy, kinematics, and pathomechanics of this injury assists in elucidating the diagnosis through history and physical examination. The use of appropriate radiographic imaging may provide additional support for the diagnosis. Arthroscopy has emerged as not only the gold standard for diagnosis of this injury, but also as an effective means of treatment. Treatment decisions must be based on both the degree of severity and acuity of the injury. Although the majority of patients will do well with nonoperative management, the indications for surgery and the varied outcomes of surgical management are discussed.

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Carpal instabilities result from a spectrum of injuries involving both osseous and ligamentous structures. Early literature on carpal instabilities focused on the scaphoid and the radial side of the wrist; however, as advances in technology and surgical techniques have developed and a better understanding of wrist biomechanics has become available, there has been an increased understanding of ulnar carpal instabilities.

As a group, ulnar carpal injuries are about one-sixth as common as their radial counterparts.¹ They are categorized into triquetromidcarpal, or midcarpal, instability and lunotriquetral instability. Lunotriquetral injury is an unusual cause of ulnar-sided wrist pain. It results from both traumatic and degenerative etiologies. This article discusses the anatomy, kinematics, pathomechanics, clinical presentation, and management of lunotriquetral injuries.

TERMINOLOGY

Carpal instabilities have been classified as static (visible deformity on radiographs), dynamic (visible deformity on stress radiographs or fluoroscopic stress tests), or predynamic (ligamentous injury without radiographic deformity). In the case of lunotriquetral injuries, the term dissociation has been used clinically to describe static instability and the term sprain has been used clinically to describe predynamic and dynamic instabilities.² To avoid confusion, we often refer to these injuries as unstable (equivalent of static), dynamically unstable (equivalent of dynamic), and stable (equivalent of predynamic). We have titled the article as lunotriquetral injuries rather than instabilities to emphasize that not all injuries are unstable.

WRIST ANATOMY AND KINEMATICS

To achieve a functional range of motion and yet still maintain stability, the wrist requires a complex articular configuration that does not readily lend
itself to anatomic description and interpretation. In addition to guiding motion of the hand in space, the many intercarpal linkages serve as shock absorbers to diffuse and redirect force transmitted from the hand to the forearm. Aside from the insertion of the flexor carpi ulnaris on the pisiform and hook of the hamate, the carpal bones have no tendinous insertion; therefore, these functions depend mostly on bony structures and soft-tissue constraints.

The ligamentous anatomy of the wrist has been well described. Most of the ligaments are thickenings of the joint capsule with longitudinally oriented groups of collagen fibers. They are categorized as extrinsic (insertions on both the carpal bones and on structures external to the carpal bones) and intrinsic (insertions exclusively within the carpal bones). These ligaments are further divided into dorsal and palmar groups. The ligaments pertinent to our discussion are shown in Figures 1, 2, and 3.

The intrinsic ligaments, interosseous and scaphotriquetral (Fig 3), tightly constrain the proximal row. The interosseous ligament covers the palmar, proximal, and dorsal surfaces of the bones, leaving the distal aspect of the joint in open communication with the midcarpal joint. The 3 regions are distinct. The dorsal and palmar interosseous ligaments are true ligaments, but the proximal ligament is actually a fibrocartilaginous membrane and provides little stability. The palmar ligament is the thickest and strongest, and it is the most important in resisting palmar translation. The dorsal ligament is the most important for rotational resistance. They are equally responsible for resisting dorsal translation. The scaphotriquetral ligament passes along the distal margins of the dorsal surfaces of the scaphoid, lunate, and triquetrum and is considered a distal extension of the interosseous ligaments.

The proximal carpal row moves passively in response to compressive and tensile forces generated by bony structures and soft-tissue constraints. In the normally constrained wrist, the reactive forces across the midcarpal joint are balanced. In flexion and extension, the proximal carpal row moves in synchrony with the distal carpal row and the metacarpals; however, with ulnar and radial deviation, the dynamics become more complex. With radial deviation, compressive forces across the scaphoid-trapezoid-trapezium ligaments are increased.

FIGURE 1. Palmar ligaments.

FIGURE 2. Dorsal ligaments.
Multiple cadaveric studies have helped to elucidate the mechanisms of lunotriquetral injury and to identify relevant anatomic structures. In 1980, Mayfiled et al. presented a classic study on perilunate instability. They showed that loading in maximal extension, ulnar deviation, and intercarpal supination causes progressive injury (Fig 4). They defined a lesser arc, purely ligamentous, and a greater arc, involving carpal bones, around which injury progresses. This may produce combinations of bone and ligament injuries. Note that via this mechanism, lunotriquetral injury does not occur until stage III, and would thus have multiple associated injuries.

Pin et al. showed in cadavers that carpal ligament injury forms a spectrum: from elastic elongation to permanent elongation to tear. He showed that extrinsic ligaments have more capacity for stretch than intrinsics, such that the intrinsic ligaments can be completely disrupted whereas the extrinsic ligaments are only partially injured. He suggested this as the mechanism of the forme fruste injury (lunotriquetral instability as the only clinical manifestation of stage III perilunate injury) proposed by Lichtman et al.

Reagan et al. described isolated lunotriquetral sprains after wrist trauma. They suggested that hypothenar loading from a fall on an outstretched hand in maximal extension and radial deviation would result in the reverse order of injury proposed by Mayfiled et al. The first stage of this mechanism allows for isolated lunotriquetral sprain. This group also classified lunotriquetral injuries, based on the integrity of the interosseous ligaments, into the broad categories of sprains and dissociations.

Alexander and Lichtman have postulated that isolated lunotriquetral injuries also may occur with the wrist palmar flexed. A dorsally applied force then causes the interosseous fibers to fail but spares the palmar radiolunotriquetral ligament.

Palmer and Werner identified that ulnar positive variance causes increased ulnar loading and degenerative injuries on the ulnar side of the wrist. It is conceivable that not only does ulnar positive variance result in degenerative changes, but also predisposes to lunotriquetral injury with axial loading.
Cadaver studies also have identified the ligaments that are important for lunotriquetral stability. Sectioning of the lunotriquetral interosseous ligaments does not result in radiographically detectable static or dynamic instability, but has been observed to allow slightly abnormal intercarpal motions. Additional sectioning of the palmar lunotriquetral ligaments resulted in dynamic volar intercalated segment instability (VISI), thus these ligaments were determined to be important for proper rotation of the carpal bones on radial or ulnar deviation. Still further sectioning of the dorsal radiocarpal ligaments (dorsal radiotriquetral and dorsal scaphotriquetral) resulted in static VISI.

In applying the ring concept of carpal kinematics, Lichtman postulated that there is a potential flexion moment at the STT link and an extension moment at the triquetrohamate link, and that these moments are balanced in the intact wrist. With a break at the lunotriquetral joint, compressive forces at the STT cause the scaphoid to flex. Simultaneously, the head of the capitate moves proximally into the lunotriquetral gap and causes the triquetrum to move ulnarward on the hamate, effectively creating an extension thrust on the triquetrum via movement on the helical slope. Because the lunate is still attached to the scaphoid, it will follow the scaphoid into flexion and create a VISI deformity. The extent of the deformity often correlates with the extent of ligament damage.

In summary, the stability of the carpal complex is derived from a combination of precisely opposed, multifaceted articular surfaces with both intrinsic and extrinsic ligamentous restraints. Damage to the interosseous ligaments results in micromotion instability that can cause synovitis or arthritis; however, interosseous ligament rupture is not sufficient to allow VISI because the extrinsic ligaments (dorsal radiocarpal and palmar carpal ligaments) provide important secondary restraints. With damage to these secondary constraints, the opposing moments on the proximal row cause unbalanced movement into the predictable pattern of VISI. This imbalance will be manifested by either dynamic or static instability depending on the extent of ligamentous damage.

**FIGURE 4.** (A) Perilunate injury. (B) Four stages of progressive perilunar instability.

**CLINICAL PRESENTATION AND EXAMINATION**

The history and physical examination are important elements in correctly identifying lunotriquetral injury. The typical patient will give a history of a specific injury, usually a fall on an outstretched hand; however, twisting, pulling, pushing, catching, and
striking also have been reported as inciting events.\textsuperscript{2} There is a high incidence of associated carpal bone, carpal ligament, and triangular fibrocartilage complex injuries.\textsuperscript{14}

Patients often present several weeks, or even months, after the acute injury. Ulnar-sided wrist pain is a common chief complaint. The patients often describe their pain as persistent with increased intensity after heavy use. Patients may provide additional history of clicking with ulnar deviation, grip weakness, and/or a sense of wrist instability.\textsuperscript{10}

Physical examination should involve the entire wrist and hand to rule out other causes of ulnar-sided wrist pain (Table 1). Unless the injury has occurred quite recently, there likely will be no swelling. The wrist may have some limitation of motion, and there is nearly always tenderness over the lunotriquetral joint.

There are several diagnostic adjuvants that aid in correctly identifying lunotriquetral pathology. The ulnar snuffbox test\textsuperscript{15} is performed by applying lateral pressure to the triquetrum between the flexor carpi ulnaris and the extensor carpi ulnaris tendons. Pain is considered a positive test result. The ballottement test\textsuperscript{2} is performed by grasping the triquetrum and pisiform between the thumb and index finger of one hand and the lunate between the thumb and index finger of the other. The triquetrum is then rocked back and forth on the stabilized lunate. Again, pain is considered a positive test result. The shear test\textsuperscript{15} is performed by the examiner using one thumb to apply a dorsal force to the pisiform/triquetrum and his other thumb to apply a volar force to the lunate. Laxity compared with the other hand or reproduction of the patient’s symptoms is considered positive. A click with neutral to ulnar deviation with the wrist pronated and under axial compression has been reported to be a predictable finding in patients with dynamic lunotriquetral injury.\textsuperscript{3} Injection of the midcarpal joint with local anesthetic can be a useful diagnostic tool.\textsuperscript{10} Resolution of pain and increased grip strength after injection are sensitive, but not specific, indicators of lunotriquetral injury.

### TABLE 1

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<thead>
<tr>
<th>Differential Diagnosis of Ulnar-Sided Wrist Pain</th>
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<tr>
<td>Entrapment of the dorsal branch of the ulnar nerve</td>
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<tr>
<td>Triangular fibrocartilage tear</td>
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<tr>
<td>Ulnocarpal arthrosis</td>
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<tr>
<td>Midcarpal instability</td>
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<tr>
<td>Kienböck's disease</td>
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<td>Extensor carpi ulnaris subluxation</td>
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<td>Extensor carpi ulnaris or flexor carpi ulnaris tendonitis</td>
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<tr>
<td>Distal radioulnar joint subluxation</td>
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<tr>
<td>Pisotriquetral arthrosis</td>
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<td>Fracture of the hook of the hamate, ulnar styloid, or triquetrum</td>
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<tr>
<td>Ulnocarpal impingement</td>
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<td>Chondromalacia of lunate or distal ulna</td>
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<td>Lunocarpal instability</td>
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<td>Lunotriquetral synostosis</td>
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<td>Lunotriquetral injuries</td>
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### Radiographic Studies

Standard posteroanterior and lateral radiographs of both wrists in neutral rotation allow for measurement of static carpal alignment\textsuperscript{16} and for assessment of ulnar variance.\textsuperscript{17} The posteroanterior view should be inspected for carpal integrity and for the smooth arcs that are formed by the proximal and distal joint surfaces of the proximal carpal row (Gilula’s arcs 1 and 2) and the proximal joint surface of the capitate and hamate (Gilula’s arc 3) (Fig 5). Disruption of these arcs indicates ligament damage allowing subluxation or dislocation. Overlapping of normally parallel articular surfaces is also an indicator of ligament damage. The lateral view should be evaluated for intercalated collapse deformities. The most direct method of
doing this is to compare the longitudinal axis of the lunate with the longitudinal axis of the capitate and radius. They should be reasonably collinear. Another method involves determining the longitudinal axis of the triquetrum and the longitudinal axis of the lunate. The longitudinal axis of the triquetrum is defined as a line passing through the distal triquetral angle and bisecting the proximal articular surface. The longitudinal axis of the lunate is defined as a line bisecting the distal and proximal surfaces of the lunate at right angles to a line across the palmar and dorsal distal poles. The average normal lunotriquetral angle measures positive 14° (range, −3° to 31°), and the average angle in wrists with lunotriquetral dissociation is −16° (range, −50° to −3°).

The radiographic appearance of wrists with isolated intrinsic ligament tears are typically normal; however, posteroanterior clenched fist (stress) views and posteroanterior views in ulnar and radial deviation may reveal dynamic instability. Because Gilula’s lines are not accurate indicators of lunotriquetral instability in radial or ulnar deviation views, comparison with the other side must be performed to detect abnormalities accurately.

Arthrography has been used extensively in diagnosing lunotriquetral injuries. Leakage of dye from the midcarpal joint into the radiocarpal joint or vice versa is considered a positive test. The triple injection arthrogram in combination with cinearthrography increases sensitivity and specificity; however, the procedure is time consuming and has a high incidence of false positives owing to increased numbers of asymptomatic degenerative perforations that develop with increasing age. In light of the advantages of arthroscopy in the diagnosis and management of these injuries, we do not routinely use arthrography in the work-up of these lesions.

A recent study showed that computed tomography of the wrist after dye injection of the radiocarpal and midcarpal joints has similar sensitivity and specificity as compared with arthrography in the diagnosis of carpal ligament injuries. This modality has the added advantage of identifying the precise location of the lesion. We do not have experience with this technique.

Although magnetic resonance imaging (MRI) has not reliably diagnosed lunotriquetral ligament tears in published studies, it allows visualization of bone and soft-tissue lesions that may mimic symptoms of lunotriquetral injury (eg, Kienbock’s disease, ulnar abutment syndrome). As newer imaging techniques emerge, and advances in technology improve resolution, MRI may play an increasingly valuable role as a diagnostic tool in the future.

Other useful imaging techniques have been proposed. Movements that recreate the patient’s symptoms viewed under fluoroscopy may reveal dynamic instability. A bone scan may be used to identify the presence or absence of inflammation if patient malingering is suspected.

**Arthroscopy**

Arthroscopy is the most definitive modality for the evaluation of lunotriquetral injuries and has become the gold standard for diagnosis. It allows for definitive treatment of many soft-tissue injuries and permits evaluation of ligament tears before undertaking open surgical treatment. This provides better preoperative planning and facilitates an informed discussion regarding treatment options with the patient.

A systematic examination of the wrist is performed to identify all injuries. The degree of instability between the lunate and triquetrum can only be assessed by evaluating both the midcarpal and radiocarpal joints. Examination of the radiocarpal joint allows assessment of the synovium, the proximal carpal articular surface, the radial and ulnar articular surfaces, the scapholunate interval, the volar radiocarpal ligaments, the lunotriquetral interosseous ligament, and the triangular fibrocartilage complex. Because the interosseous ligament does not extend distally, examination of the midcarpal joint allows a good look into the lunotriquetral interval. Injuries can be classified based on the integrity of the interosseous membrane as observed from the radiocarpal space and the congruity of the joint surface from both the midcarpal and the radiocarpal space (Table 2).

**Treatment**

Several factors must be considered when deciding on the optimal treatment plan for a patient. Degree of stability, time elapsed since injury, associated injuries, ulnar positive variance, and demands of the patient will all affect treatment choice.
Initial treatment of stable injuries, both acute and chronic, consists of immobilization. Either a carefully molded cast with a supporting pad under the pisiform or a wrist splint with a lateral supracondylar extension to prevent pronation\textsuperscript{24} will help to maintain optimal alignment as ligament healing progresses and inflammation subsides. Nonsteroidal anti-inflammatory medications and cortisone injections also may be necessary, especially in injuries that present more than 3 to 4 weeks after the inciting event. The injury may require 3 to 6 months of treatment for complete resolution of symptoms.\textsuperscript{24} This will be curative in the majority of patients; however, if symptoms do not significantly improve within 6 weeks, arthroscopy is warranted to further assess the injury and allow for definitive treatment.\textsuperscript{25,26}

Arthroscopy allows direct visualization and repair of articular pathology. In stable injuries, the fibrocartilaginous portion of the interosseous membrane is often the only lunotriquetral structure damaged. This portion of the interosseous membrane heals poorly and is associated with ulnar-sided synovitis. Simple motorized shaver debride-ment provides symptomatic relief in the majority of patients.\textsuperscript{25,26} It is important to debride only the fibrocartilaginous portion of the ligament to avoid producing iatrogenic instability.

Dynamically unstable injuries, whether acute or chronic, may be managed initially with immobi-

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\hline
\textbf{Geissler Classification} \\
\hline
Attenuation or hemorrhage of interosseous ligament as viewed from the radiocarpal joint \\
No incongruency of carpal alignment as viewed from the midcarpal space \\
Attenuation or hemorrhage of interosseous ligament as viewed from the radiocarpal joint \\
Step-off of carpal alignment as viewed from the midcarpal space, probe is unable to pass into the gap \\
Incongruency or step-off of carpal alignment as seen from both radiocarpal and midcarpal spaces, probe may be passed between carpal bones \\
Incongruency or step-off of carpal alignment as seen from both radiocarpal and midcarpal spaces, gross instability with manipulation, 2.7-mm arthroscope may be passed through the gap between the bones \\
\hline
\end{tabular}
\caption{Geissler Classification}
\end{table}

zation; however, if the injury is chronic, this is less likely to be curative. A large portion of patients with dynamically unstable injuries will obtain relief of symptoms after shaver debridement\textsuperscript{25}; however, one study\textsuperscript{1} revealed poor results with debride-ment alone. Therefore, recent investigators have recommended that arthroscopic reduction and pin-ning also be performed.\textsuperscript{27} The heads of the pins are buried subcutaneously and the wrist is splinted for 8 weeks. This provides very good results in most of these patients.

For unstable lesions, as well as dynamically un-stable lesions not amenable to arthroscopic treat-ment, open surgical repair is indicated. The goals of surgical intervention are the realignment of the lunocapitate axis, the reestablishment of the rotational integrity of the proximal row, and the reduction of excessive intercarpal motion. Direct ligament repair, ligament reconstruction, and arthrodesis all have been proposed as open surgical methods for the unstable injury.

Direct ligament repair\textsuperscript{2} is most appropriate in the acute setting, before the torn ends of the ligament atrophy. Multiple strand repair using bone tunnels or suture anchor implants is required in addition to K-wire fixation. The repair is protected for at least 6 weeks, but may be continued longer if pain persists. The aim of repair is to restore carpal kinematics. Although Ritt et al\textsuperscript{13} showed in cadavers that liga-
tment repair does not reproduce normal carpal kinematics, clinical results\textsuperscript{2,28} suggest that the procedure effectively relieves symptoms. Primary ligament re-

repair is less efficacious when performed after the acute inflammatory response or when performed in patients demanding high use.\textsuperscript{28}

In patients with chronic injuries, ligament recon-

struction should be weighed against lunotriquetral fusion. Reconstruction is performed by using the radial half of the extensor carpi ulnaris tendon, leaving its distal attachment intact.\textsuperscript{15} The ligament is passed through bone tunnels in the lunate and triquetrum to form a loop. The dorsal radiocarpal ligament is advanced and tacked onto the repair. K-wires are used to stabilize the repair, and it is protected for at least 6 weeks. The argument in favor of reconstruction is that it restores normal kinematics; however, the surgery is technically demanding and has a high learning curve.
Additionally, it is supported by only one published outcome study at the present time.28

Our own experience has been that arthrodesis is a reliable option if the lunotriquetral joint is adequately decorticated, autogenous bone graft is used, the correct anatomic relationships of the various carpal bones are maintained, and ulnar abutment, if present, is properly addressed. Lunotriquetral fusion has been used widely with results varying from fair to excellent.29-34 A recent series by Guidera et al29 showed a 100% fusion rate with 83% reporting good to very good pain relief in a series of 26 wrists undergoing arthrodesis with cancellous bone graft and parallel K-wires. It is interesting to note that patients with a complete synostosis are generally asymptomatic, whereas partial synostosis is associated with ulnar-sided pain.35 Thus, one key to long-term success of arthrodesis may be the ability to obtain complete fusion.

If static VISI is present, lunate-capitate-hamate-triquetrum fusion should be considered. These treatments must be weighed against the options of wrist fusion or proximal row carpectomy, which are merely salvage procedures to relieve pain.

Finally, patients requiring surgical repair should be assessed properly for ulnar variance, which would result in increased ulnar load bearing and ulnar impaction syndrome. If present, ulnar shortening17 must be performed simultaneously, or the repair, reconstruction, or fusion most likely will fail.

**CONCLUSION**

Lunotriquetral injury is an unusual cause of wrist pain, but must be considered in the work-up of pain on the ulnar side. The pathomechanics of the injury have been described and standard clinical and radiographic patterns have emerged. As with other carpal instabilities, these injuries may be stable, dynamically unstable, or unstable. The diagnosis usually can be made on the basis of a good history and physical examination and confirmed by plain radiography, arthroscopy, and, occasionally, MRI. A treatment algorithm can be made based on the acuity of the injury and the degree of the instability. Acute stable injuries are amenable to conservative treatment. Acute dynamically unstable injuries can be treated with arthroscopically assisted percutaneous pinning or conservative management. Acute dissociations, whether isolated or in combination with other injuries, should be opened and repaired under direct vision. The treatment of chronic injuries depends on the degree of stability and arthroscopic assessment. Stable injuries may be treated with arthroscopic debridement. Dynamically unstable injuries require arthroscopic debridement and pinning. Unstable injuries do best with either a reconstruction or an arthrodesis. The ultimate choice of treatment will have to reflect multiple factors, including patient needs (age, occupation), associated findings (static VISI, ulnar variance), and the experience and preference of the surgeon.

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