Triangular Fibrocartilage Complex Injury and Ulnar Wrist Pain
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Introduction
Ulnar wrist pain is considered by some as the low-back pain of hand surgery. Multiple afflictions occur at this site, and the hand surgeon must keep each in mind in the diagnosis of ulnar wrist pain. The triangular fibrocartilage complex has been extensively studied over the last few years. We have come to better understand the anatomy and biomechanics of the TFCC in the laboratory and have further refined the diagnostic work-up. The disorders have been identified and classified in a pattern of injury.

Alternative lesions, as well, are considered in the diagnosis of ulnar wrist pain, including dislocation, subluxation, and arthritis of the distal radioulnar joint, medial carpal, and lunotriquetral ligament instability, extensor carpi ulnaris subluxation and rupture, calcific extensor and flexor carpi ulnaris tendonitis, hamate hook fractures and pisotriquetral subluxation, and arthritis. The clinical findings for these lesions help define the diagnostic work-up required in the evaluation of ulnar wrist pain.

In the diagnostic work-up, the general principles include a differentiation between acute and chronic injury. Also, the stability of the distal radioulnar joint and medial carpus by palpation as well as the site of localized tenderness are important elements in the initial evaluation. Further examination studies include wrist range of motion and pinch and grip strength. The diagnostic studies include standard PA radiographs of the wrist in neutral forearm rotation to assess ulnar variance specifically as well as the articular surfaces. Other studies helpful in the evaluation of ulnar wrist pain include three-compartment wrist arthrogram and MRI studies for ligamentous and TFCC lesions, as well as CT scan studies to evaluate distal radioulnar joint articulation, the pisotriquetral joint, and the hamate hook.

Anatomy
The term TFCC was introduced to describe the ligamentous and cartilage structure that suspends the distal radius and ulnar carpus from the distal ulna (Fig. 11-1). The TFCC incorporates the poorly identifiable dorsal and volar radioulnar ligaments, the ulnar collateral ligament, the meniscus homologue, as well as the clearly definable articular disk, extensor carpi ulnaris sheath, ulnolunate and lunotriquetral ligaments. The complex arises from the ulnar aspect of the lunate fossa of the radius. It courses toward the ulna where it inserts about the fovea at the base of the ulnar styloid. The fovea is an area rich in vascular foramen, which provides vascularity to the peripheral element of the TFCC, with a more central radial portion being relatively avascular.

TFCC Lesions: Injury Patterns and Treatment
A classification of TFCC abnormalities has been recently developed based on mechanism and site of injury (Table 11-1).

Traumatic lesions of the TFCC result from a fall on the outstretched upper extremity or hyperrotation injury to the forearm. These traumatic lesions occur from the origin or insertion of the TFCC. Degenerative lesions of the TFCC result from repetitive loading known as ulnar impaction syn-
Table 11-1. TFCC Abnormalities

Class 1: Traumatic
A. Central perforation
B. Ulnar avulsion
   With distal ulnar fracture
   Without distal ulnar fracture
C. Distal avulsion
D. Radial avulsion
   With sigmoid notch fracture
   Without sigmoid notch fracture

Class 2: Degenerative (ulnocarpal abutment syndrome)
Stage:
A. TFCC wear
B. TFCC wear
   + lunate and/or ulnar chondromalacia
C. TFCC perforation
   + lunate and/or ulnar chondromalacia
D. TFCC perforation
   + lunate and/or ulnar chondromalacia
   + L-T ligament perforation
E. TFCC perforation
   + lunate and/or ulnar chondromalacia
   + L-T ligament perforation
   + ulnocarpal arthritis

A classification of triangular fibrocartilage complex injuries.

drome. A spectrum of injury results from early TFCC wear to TFCC perforation, lunate chondromalacia, LT ligament tears, and ulnocarpal arthritis.

Traumatic Lesion (Class 1 Lesions—TFCC)

Traumatic lesions are classified as: 1A—a lesion of the horizontal portion of the TFCC (Fig. 11-2), 1B—an avulsion of the complex from the distal ulna either with or without bone (Fig. 11-3), 1C—an avulsion of the complex from its insertion into the lunate or triquetrum (Fig. 11-4), 1D—an avulsion

Figure 11-2. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1A lesion. The perforation is a dorsal palmar tear (arrow) just medial to the radial origin of the TFCC. R, radius; U, ulna; L, lunate; T, triquetrum.

Class 1B

Figure 11-3. (Top) The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1B lesion. In this instance, the TFCC is avulsed from the distal ulna with an associated fragment of bone, i.e., the distal ulna. R, radius; U, ulna; L, lunate; T, triquetrum. (Bottom) The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1B lesion. In this case, the triangular fibrocartilage complex is torn free from the base of the ulnar styloid without an associated fracture (arrow). R, radius; U, ulna; L, lunate; T, triquetrum.

Class 1C

Figure 11-4. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1C lesion. The triangular fibrocartilage complex is avulsed distally from its bony insertion to the lunate by the ulnolunate ligament and/or the triquetrum by the ulnotriquetral ligament (arrows). R, radius; U, ulna; L, lunate, T, triquetrum.
Figure 11-5. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1D lesion. Arrows indicate an avulsion of the TFCC from its radial origin. The avulsion can be with or without a fragment of bone. R, radius; U, ulna; L, lunate; T, triquetrum.

Figure 11-6. (Top) Arthrogram identifying a traumatic, horizontal tear in the triangular fibrocartilage (arrows). (Bottom) The debridement of the torn portion of the triangular fibrocartilage utilizing a suction punch and the wrist arthroscope. R, radius; U, ulna; L, lunate; T, triquetrum; C, capitate; H, hamate.

Evaluation and Treatment

Traumatic lesions of the TFCC generally occur secondary to a fall on an outstretched hand or are associated with hyper-rotation injuries to the forearm. Examination of the wrist should include the site of localized tenderness and range of motion of the wrist, including forearm rotation. Pain at the extremes of motion should be noted as well. Evidence of instability by manipulation of the distal ulna with attention to wrist symptoms, clicks, and snaps are noted. Pinch and grip strength as well as routine PA and lateral radiographs complete the exam.

All traumatic lesions of the TFCC should be treated with immobilization when seen acutely, if no instability pattern, subluxation, or fractures are noted. Complete disruption of the complex from the attachment to the distal aspect of the sigmoid notch of the radius (Fig. 11-5).
the TFCC from the radius, carpus, or ulna is generally associated with a clinical or radiographically detectable instability. In these cases, wrist arthrography and arthroscopy are indicated for evaluation and treatment. With arthroscopy, if the lesion reduces closed, then four weeks of immobilization in ulnar deviation and slight flexion is usually indicated. If positioning does not reduce the torn structures, arthroscopic or open repair is indicated. When the lesion is in the centrum (the avascular portion of the TFCC), arthroscopic debridement has been shown biomechanically and clinically to produce the desired effect. Enlargement of the tear preserving intact the volar and dorsal ligaments frequently relieves the symptomatic clicking and does not disrupt the stability or the load-bearing characteristic of the TFCC. Osterman and associates reported excellent results with arthroscopic limited TFCC debridement for perforations in the avascular region. A relative contraindication to TFCC debridement is an ulnar positive variance.

The technique of wrist arthroscopy is generally performed under regional or general anesthesia with distraction of the wrist in finger traps (Fig. 11-6). The anatomic landmarks on the dorsum of the wrist are identified, including the intervals between the extensor pollicis longus and extensor digitorum communis (three to four portal), extensor digitorum communis and the extensor digiti quinti (four to five portal), and the intervals radial and ulnar to the extensor carpi ulnaris (6R and 6U portals). After the wrist is distended, the arthroscope is carefully introduced by initially using a blunt trochar through the three to four portal. Inspection of the radiocarpal joint begins in sequential fashion with examination of the articular surfaces of the radius, scaphoid, lunate, and triquetrum, as well as the interosseous ligaments, the volar carpal ligament and the TFCC. The TFCC is specifically examined with a probe to "feel" the triangular fibrocartilage perforations if present, as well as to assess the integrity of the TFCC by its "trampolining."

Following careful assessment of all pathology, if partial excision of the TFCC is elected, the perforation should be enlarged to the point where there are no redundant margins. This usually requires removal of the central two-thirds of the triangular fibrocartilage. The instruments generally required are a suction punch, a banana blade or hook knife, and a motorized shaver utilized to "trim up" the margins of the debridement. The wrist is then copiously irrigated with normal saline, and the wounds are closed.

Early motion is encouraged. Patients are allowed to resume activity as symptoms permit. One can expect patients who undergo partial excision of a perforated triangular fibrocartilage to improve markedly within three to six weeks following the procedure for Type 1A and 2C lesions. If the procedure has been done for degenerative lesions with associated chondromalacic changes, particularly in patients with an ulnar positive variance, symptoms may not be completely relieved, but merely improved.

For peripheral tears of the TFCC, arthroscopic or open repair is indicated in lesions that do not reduce closed. Hermansdorfer and Kleinman have identified the trampoline test on arthroscopic evaluation in the identification of peripheral tears. Since there is good vascularity of the TFCC in the peripheral regions, suture repair is possible, either through an arthroscopic or open technique. They have reported good results in a series of these patients.

**Degenerative Lesions (Class 2 Lesions—TFCC)**

From Mikic's study in 1978, the TFCC has been shown to undergo changes with age. The term ulnar impaction syndrome has frequently been used to describe the pathologic sequence (Fig. 11-7). Individuals more than 50 years of age have degenerative TFCC changes (many with perforation). Based on this work and the clinical experience of others, degenerative lesions of the TFCC are defined in the following classes: 2A—wear of the TFCC without cartilage abnormality (Fig. 11-8), 2B—wear of the TFCC with either ulnar head or lunate chondromalacia (Fig. 11-9), 2C—degenerative perforation of the TFCC with associated lunate and ulnar head chondromalacia (Fig. 11-10), 2D—the addition of lunotriquetral ligament tear with the findings of 2C (Fig. 11-11), 2E—degenerative arthritis of the
Figure 11-8. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 2A lesion. Both the proximal and distal aspects of the TFCC histologically and at times, grossly, evidence degenerative changes as illustrated by the stippling on this illustration (arrow). R, radius; U, ulna; L, lunate; T, triquetrum.

Figure 11-9. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 2B lesion. In addition to the degenerative changes of the TFCC seen in a Class 2A lesion (stippling), cartilage erosion of the ulnar head beneath the TFCC is seen (arrow), or of the kissing area of the medial border of the lunate distal to the TFCC (arrow). R, radius; U, ulna; L, lunate; T, triquetrum.

Figure 11-10. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 2C lesion. Further progression of the Class 2 degenerative lesions of the TFCC evidences now a large central perforation of the TFCC (proximal arrow), as well as the underlying cartilage abnormality of the ulnar head and distally, the medial aspect of the lunate. R, radius; U, ulna; L, lunate; T, triquetrum.

Figure 11-11. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 2D lesion. Further progression of the degenerative TFCC abnormalities reveals a through and through perforation of the horizontal portion of the TFCC (proximal arrow), cartilage abnormalities of the ulnar head and of an adjacent area of the medial border of the lunate (distal radial arrow), and a disruption of the lunotriquetral ligament (distal ulna arrow). R, radius; U, ulna; L, lunate; T, triquetrum.
	sigmoid notch, ulnar head, and ulnar carpus with a large perforation of the TFCC (Fig. 11-12).

Evaluation and Treatment

The evaluation of Class 2 lesions is similar to Class 1 lesions with particular attention to ulnar variance on the neutral PA radiograph. Triple-injection wrist arthrography further defines the pathology and helps determine the lesion class.

The treatment of Class 2 lesions or ulnar impaction syndrome begins with a conservative program of nonsteroidal anti-inflammatory agents, a trial of immobilization until symptoms resolve, and steroid injections into the distal
Dislocations of the Distal Radioulnar Joint

Coincident with TFCC injuries, more severe ulnar pathology can occur with major wrist trauma. Isolated dislocations occur involving the distal ulna with the ulna volar or dorsal relative to the distal radius.

Dislocation Distal Radioulnar Joint—Ulna Dorsal

This injury results from hyperpronation with disruption of the dorsal distal radioulnar joint ligaments in partial or complete TFCC injury. Clinically, a dorsal prominence over the wrist is noted with the forearm locked in pronation. Attempts at supination are painful. CT scan of the distal radioulnar joint confirms the diagnosis. Closed reduction with cast immobilization for four weeks in supination is the treatment of choice. Open reduction is required in late cases or when closed reduction is unsuccessful.

Dislocation Distal Radioulnar Joint—Ulna Volar

Volar dislocations of the distal radioulnar joint are associated with forced supination of the forearm or can be secondary to a direct blow. Pathomechanics may require complete disruption of the TFCC. Clinically, the forearm is locked in supination with pain over the distal radioulnar joint. A furrow or indentation is noted on the ulnar side of the distal radioulnar joint. Evaluation by CT scan will show the volar position of the distal ulna. Treatment, as in dorsal dislocations, consists of a closed reduction with direct pressure over the ulna volarly with gentle forearm pronation. The arm is immobilized in pronation for four weeks. In late cases or in unsuccessful closed reductions, open reduction is required.

Distal Radioulnar Joint Dislocation Associated with Radial Head Fractures (Essex-Lopresti Lesion)

Injuries to the distal radioulnar joint associated with radial head fractures can occur at the time of injury (Type 1) or result from proximal migration following excision of the radial head (Type 2). Migration generally occurs within the first two years following radial head excision.

Treatment recommendations for Type 1 injuries include an open reduction of the radial head or neck fracture with closed reduction and pinning of the distal radioulnar joint. If the radial head is not reconstructable, then a radial head silastic implant with distal radioulnar joint pinning is performed. In Type 2 injuries, a formal ulnar shortening with plate fixation is done to reduce the distal radioulnar joint, and a radial head implant is added to prevent further proximal migration of the radius. Problems associated with silastic radial head implants are recognized, and the implants may require removal at a future time. This area is
being intensely studied for possible attempts at reconstruc-
tion of the interosseous membrane. If the distal radioulnar
joint shows significant degenerative changes, then recon-
structive options including a hemiresection arthroplasty
with ulnar shortening, distal radioulnar joint fusion with
proximal pseudarthrosis (Suave-Kapandji procedure), or
distal ulna excision may be required. A final salvage tech-
nique may be conversion to a one-bone forearm.

Subluxation of the Extensor Carpi Ulnaris Tendon

Spinner and Kaplan have described the anatomy of the sixth
dorsal compartment and a fibrousseous tunnel overlying
1.5 cm to 2.0 cm of distal ulna. The extensor carpi ulnaris
alone occupies this compartment. It is held tight to the
ulnar group by the extensor carpi ulnaris tendon sheath. The
extensor retinaculum, a separate structure from the ECU
Carpus and Distal Radius

**Figure 11-14.** Wafer procedure is diagrammed with excision of the distal 2mm of ulnar head. This can be performed as an open technique or arthroscopically.

**Wafer Procedure**

Figure 11-15. Subluxated ECU tendon with extensor retinaculum reflected above shows tendon's fibrous sheath attenuated yet intact.

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**Carpus and Distal Radius**

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**Calcific Tendonitis**

The sudden onset of pain without history of trauma to the ulnar aspect of the wrist, particularly associated with repetitive ulnar deviation, can occur. Clinical presentation includes swelling over the extensor carpi ulnaris or flexor carpi ulnaris tendon sheaths with occasional crepitation on range of motion. Radiographs may show calcific deposits within the tendon sheath consistent with calcific tendonitis. Most cases generally respond to oral nonsteroidal anti-inflammatory agents or steroid injection with splinting.

**Lunotriquetral Instability**

Pain over the ulnar aspect of the wrist distal to the distal radioulnar joint may be associated with disruption of the lunotriquetral ligament. In cases not associated with the ulnar impaction syndrome, well-localized tenderness over this site as well as pain is associated with manipulation of the lunate and triquetrum and/or pain associated with stress at the midcarpal joint. Further progression of these symptoms may lead to a volar carpal instability or VISI pattern or an associated dynamic midcarpal instability. In isolated lunotriquetral instability, with a lunotriquetral ligament tear, ulnar variance is carefully examined for ulnar impaction syndrome (i.e., an ulnar positive variance). In cases of ulnar negative variance, multiple procedures for lunotriquetral instability have been attempted. Wrist dorsal capsulorrhaphy, ligament reconstruction, and lunotriquetral fusion have been tried with mixed results.

**Pisotriquetral Subluxation, Dislocation, and Osteoarthritis**

Subluxation and dislocation of the pisotriquetral joint have been studied by Vasilas and associates on the radiographic aspects of the pisotriquetral joint. A pisotriquetral view of the joint is required with the forearm positioned 30° supinated off the neutral position. Loss of symmetry between the pisiform and triquetrum is examined and required for the diagnosis. A carpal tunnel view may be helpful in further assessment of this joint.

Pisotriquetral osteoarthritis is more a common problem associated with localized tenderness over the pisotriquetral joint. Frequently on clinical exam, manipulation of the pisiform over the triquetrum causes intense pain. Local anesthetic injection into the pisotriquetral joint confirms the diagnosis. The radiographic views as described above, the 30° supinated view, as well as carpal tunnel views, will frequently show loss of joint space and osteophyte formation (Fig. 11-16).

Initial treatment of pisotriquetral pathology involves rest, nonsteroidal anti-inflammatory agents, and steroid injec-

ally is required and involves the medial wall of the extensor carpi ulnaris tendon sheath.
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Tions into the pisotriquetral joint. If conservative therapy fails, then operative treatment is required with pisiform excision from the flexor carpi ulnaris tendon sheath.

Other Causes of Ulnar Wrist Pain

The complete evaluation of the ulnar aspect of the wrist must include a careful neurologic and vascular exam of the hand. A careful sensory exam as well as motor exam is required for all patients with ulnar wrist pain. Specific attention to the evaluation of the ulnar nerve in Guyon's canal as well as the dorsal cutaneous branch of the ulnar nerve and its anatomic variations are important in this analysis. The vascular status, as well, must be carefully evaluated with an Allen's test to evaluate the patency of the ulnar artery. Other conditions can be referred to the ulnar aspect of the wrist, such as hamate hook fractures, Kienböck's disease, intraosseous and extraosseous ganglions, tumors of the carpal bones, distal ulna and radius, and medial facet arthritis of the lunate.

Conclusion

In the evaluation of the patient with a TFCC injury or ulnar wrist pain secondary to other causes, the clinician must be complete in the evaluation process to confirm the diagnosis. As a general rule, conservative options should be tried in most instances of TFCC injury with operative treatment preserved for patients unresponsive to conservative care or when instability is present. One will frequently see the patient who has undergone multiple procedures for ulnar wrist pain with continued disability. Care must be taken to identify the cause of the problem as well as the subsequent goals of the patient in the rehabilitation of this wrist injury.

Annotated Bibliography

TFCC Lesion: Injury Patterns and Treatment


Study of 20 patients with failed distal ulna resections suggested that the procedure should be avoided in young patients and those with ligamentous laxity.


Two to 4mm of cartilage and subchondral bone was excised from the ulnar head in seven patients with a TFCC tear and ulna positive variance. Six patients had either complete or marked improvement in symptoms.


The ulna was shortened an average of 2mm in 10 consecutive patients with ulnar wrist pain associated with TFCC tears. Six patients had ulnolunate abutment and/or cartilage degeneration. Pain relief and grip strength were excellent, but flexion decreased an average of 23.8° postoperatively.


A literature review of distal ulna procedures for the treatment of posttraumatic conditions of the distal radioulnar joint. Options are
outlining, and included in the discussion are the origins of the names of the procedures attributed to certain authors.


Thirty-six wrists in 35 patients were treated with an ulnar shortening osteotomy to stabilize or decompress the distal radioulnar joints. Twenty-eight of the 36 wrists had good to excellent results at a 24.5-month follow-up.


In 13 patients with traumatic peripheral separation of the TFCC, reattachment was done with nonabsorbable sutures passed through drill holes at the medial base of the ulnar styloid. Eight of the 11 patients returned to painless activities. Two of the three other patients did well after additional surgery (distal ulna resection in one and ulnar shortening osteotomy in the other).


Hemiresection-interposition arthroplasty with repair of the torn TFCC was performed in 16 wrists to prevent ulnar head impingement on the TFCC. There was complete pain relief in 10 wrists. Grip strength and range of motion improved in all wrists.


A prospective study of 52 consecutive patients showed that 86% had a positive initial arthrogram and 66% had a positive bone scan at the time of diagnostic arthroscopy; 34% of the tears were linear, 46% central perforation, and 20% ulnar or peripheral perforation. Eleven patients had no visible tear. The author concluded that arthroscopic debridement reduced symptoms without increasing clinical ulnar instability.


Anatomic data is presented showing an inverse relationship between positive ulnar variance and TFCC thickness.


Excision of less than two thirds of the horizontal part of the TFCC cadavers did not alter axial load transmission.


Biomechanical testing of nine cadaver specimens showed that the TFCC was the main stabilizer of the radioulnar joint. Internal fixation of the ulnar styloid avulsion fractures restores stability in all forearm rotation positions.


Computerized analysis of pressure-sensitive film measurement of five cadaver specimens was used to analyze three stages of radioulnar instability. In forearm supination, all stages of radioulnar instability resulted in decreased lunate contact area. In neutral forearm rotation, stage 3 instability demonstrated decreased lunate contact area. In stage 3 instability the lunate high pressure was shifted volar.

Dislocations of the Distal Radioulnar Joint


A systemic review is presented of the mechanism, presentation, and treatment of fractures and dislocations of the distal radioulnar joint. These injuries included ulna dorsal and ulna volar dislocations as well as lesions associated with fractures of the radial head (Essex-Lopresti lesion) and dislocations of the distal radioulnar joint associated with radial shaft fractures (Galleazzi fractures).

Extensor Carpi Ulnaris Subluxation


Four cases of extensor carpi ulnaris subluxation secondary to sheath attenuation are presented. Sheath reconstruction was successful in relieving symptoms.

Lunotriquetral Instability


Stereoradiographic analysis of five cadaver specimens showed that the essential lesion to produce a static palmar flexed intercalated segmented instability was transection of the dorsal radiotriquetral and dorsal scaphotriquetral ligaments in addition to the division of the lunotriquetral ligament and interosseous membrane.

Eleven patients with chronic lunotriquetral ligament tears were treated with lunotriquetral fusion using a compression screw. All patients had fusion achieved at two to five months. Only three patients had persistent pain postoperatively.


The spectrum of ulnar-sided perilunate instability is described in three stages based on anatomic disruption and instability. Stage I: lunotriquetral ligament tear without instability. Stage II: lunotriquetral ligament tear and palmar ligamentous tears with dynamic VISI deformity. Stage III: Complete lunotriquetral disruptions with palmar and dorsal disruption with static VISI deformity.

### Pisotriquetral Joint Disorders


This paper reviewed 216 reported cases of pisotriquetral disease in the last 65 years. The authors' experience with 16 cases of pisotriquetral joint disease is described. Pathologic study suggests repetitive trauma leads to dysfunction of the pisotriquetral joint, then to instability, followed by degenerative changes.


Pain from the pisotriquetral joint was present in 1.1% of 500 patients six months postoperatively following carpal tunnel release. Pisiform excision was curative.