COMMUNICATIONS

ORIGINAL COMMUNICATIONS

Triangular fibrocartilage complex lesions: A classification

Based on anatomic and biomechanical studies and review of our clinical experience of the past 10 years, a classification of injuries to the triangular fibrocartilage complex is presented. This classification is based on the clinical examination, routine x-ray films, wrist arthrograms, wrist arthroscopy, and wrist arthrotomy. The classification recognizes both traumatic and degenerative lesions. Traumatic lesions are classified according to their location. Degenerative lesions are classified by the location and severity of degenerative changes of the triangular fibrocartilage complex, ulnar head, ulnocarpal bones and lunotriquetral ligament. (J HAND SURG 1989;14A:594-606.)

Andrew K. Palmer, MD, Syracuse, N.Y.

One of the most common wrist problems seen by practicing hand surgeons is a patient with ulnar wrist pain. At times, there is a clearcut history of trauma, the examination reveals definitive pathologic conditions, the radiographic or other ancillary studies performed (such as bone scan, tomogram, computed tomography (CT) scan, or arthrogram) are confirmatory of the presumed diagnosis and treatment is quite straightforward. Unfortunately, however, the opposite more often is true, i.e., the pain is chronic, is not associated with a clearcut history of trauma, the examination is relatively normal, and the plain x-ray films, or ancillary studies reveal "no significant abnormality." These latter patients, more often than not, have enough symptoms to limit employment and demand treatment.

There are presently more than three dozen recognized causes of acute and chronic ulnar wrist pain including fractures, dislocations, ligament injuries, avascular necrosis and degenerative changes of the distal radioulnar joint and ulnar carpus. In addition, lesions of the triangular fibrocartilage complex (TFCC) have been, and are, a recognized cause of ulnar wrist pain. Unfortunately, TFCC problems have usually been thought of in terms of "tears" of the horizontal portion of this complex only. A careful review of published anatomic, biomechanical, radiographic, and clinical data, as well as a retrospective review of the patients we have treated with wrist pain, have revealed that many abnormalities of the TFCC other than tears of the horizontal portion exist. This article will introduce a classification of traumatic and degenerative lesions of the TFCC that we have noted.

Anatomic review

The TFCC is a complex anatomic and biomechanical structure about which much is presently known. It is a cartilaginous, ligamentous structure interposed between the ulna and the ulnar carpus that arises from the radius and inserts into the distal ulna and ulnar carpus (Fig. 1). Its horizontal cartilaginous portion, often referred to as the triangular fibro-cartilage (TFC) proper, is relatively avascular whereas its peripheral-ligamentous portion is highly vascularized. The TFCC is composed of a number of anatomic components that are more easily recognized as separate anatomic entities in some persons than in others. The horizontal portion of the TFCC (the TFC) is bordered both dorsally and palmarly by thick ligamentous portions that have previously been termed

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Classification of TFCC lesions

Fig. 1. An anatomic specimen showing the triangular fibrocartilage complex (TFCC) arising from the radius and inserting into the ulnar styloid base and ulnar carpal bones. S, Scaphoid; L, lunate; T, triquetrum. (Reprinted with permission from Palmer AK, Werner FW. The triangular fibrocartilage of the wrist: anatomy and function. J HAND SURG 1981;6:153).

Fig. 2. Dorsal exposure of a cadaver wrist with the wrist acutely flexed showing the triangular fibrocartilage (TFC) arising from the radius and flowing ulnarily and distally. Other components of the triangular fibrocartilage complex pictured are the dorsal radial-ulnar ligaments ( ), the palmar radial-ulnar ligament ( ), the ulnolunate ligament (ULL), and the ulnotriquetral ligament (UTL). S, Scaphoid; L, lunate; T, triquetrum.

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the dorsal and palmar radioulnar ligaments. These, in turn, are further strengthened and their fibers oriented to insert into the ulnar head at the ulnar styloid base, the lunate as the ulnolunate ligament, the triquetrum as the ulnotriquetral ligament, and the hamate and base of the fifth metacarpal as the ulnocollateral ligament (Fig. 2). When the wrist is viewed externally, the TFCC appears as a homogeneous ligamentous structure with diffuse attachments to the radius, ulna, and ulnocarpal bones. The individual components of the complex, when recognizable, are best seen with internal inspection of the wrist, either with an arthrotomy or through the arthroscope.

The horizontal portion of the TFCC is not normally perforated. Mikic \(^{38}\) in a now classic study, evaluated the TFCC of 180 cadaver wrists ranging in age from premature infants to 97 years. There was no evidence of degenerative change of any part of the disc in fetuses, the first or second decade. He found no perforations before the age of 30. He further noted a relative linear progression of perforations with age so that over the age of 50, all specimens showed degenerative changes, many with a perforation of the horizontal portion of the TFCC.

Biomechanical review

The TFCC has been shown to have three major functions: (1) it functions as a cushion for the ulnar carpus, carrying approximately 20% of the axial load of the forearm in a cadaver specimen; (2) it is the major stabilizer of the distal radioulnar joint, and (3) it is a stabilizer of the ulnar carpus.*

Variable loads are borne on the ulnar aspect of the wrist by the TFCC as the forearm moves through pronation and supination. \(^9, 10, 35, 41, 49, 53-56\) Supination results in a relative negative ulnar variance and pronation, a more relative positive ulnar variance. \(^2, 57-60\) These changes in ulnar variance result in relatively small but potentially significant changes in load borne by selected portions of the TFCC as the ulnar head becomes un-

*References 1, 2, 9, 10, 41, 42, 53, 54
Table I. TFCC abnormalities

<table>
<thead>
<tr>
<th>Class</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Traumatic</td>
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<tr>
<td>A</td>
<td>Central perforation</td>
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<td>B</td>
<td>Ulnar avulsion</td>
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<td>C</td>
<td>Distal avulsion</td>
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<td>D</td>
<td>Radial avulsion</td>
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<tr>
<td>2</td>
<td>Degenerative (ulnocarpal abutment syndrome)</td>
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<tr>
<td>Stage</td>
<td>Description</td>
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<tr>
<td>A</td>
<td>TFCC wear</td>
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<td>B</td>
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- A classification of triangular fibrocartilage complex injuries

Fig. 3. The ulnar impaction syndrome with evidence of chondromalacic changes on the ulnar head and lunate. U, Ulna; R, radius; TQ, triquetrum; L, lunate; S, scaphoid; H, hamate; C, capitate; TZ, trapezium; TP, trapezoid; 2, 3, 4, 5, metacarpals.

Materials and methods

The records of patients with ulnar wrist pain who were evaluated and patients who were treated surgically for lesions of the TFCC over the past 10 years were reviewed. Records of 525 patients were reviewed. Of those judged to have an abnormality of the TFCC, the majority were treated conservatively. The charts of 75 patients who had surgical treatment for a TFCC lesion were available for review. Treatment of these patients included observation only, conservative care (splints, antiinflammatory medication, rest, job restriction), and operative care (excision, repair, or reattachment of the TFCC, ulnar shortening, ulnar head excision, limited wrist fusion and complete wrist fusion). Our understanding of the TFCC including its anatomy, biomechanics, mechanism of injury, injury patterns, and potential for response to various forms of treatment have matured greatly over that period of time. Concomitant with this maturation, we have altered some of our original concepts regarding the TFCC and some treatment programs. This article represents our present understanding of the types of injury patterns seen and our present method of evaluating a patient for each specific injury pattern.

Pathogenesis

The TFCC may be injured in its horizontal portion, its more peripheral portions, or at its attachments. As a result of injury patterns to the TFCC, surrounding structures may at times also be injured or diseased, i.e.
the cartilage surfaces of the ulnar head, radius or ulnocarpal bones or ligamentous structures such as the lunotriquetral ligament. Lesions of the TFCC may be traumatic or degenerative.

Traumatic injuries to the TFCC usually result from a fall on the pronated outstretched upper extremity, an acute rotational injury to the forearm, or an axial load and distraction injury to the ulnar border of the forearm. It is our impression that these lesions are more common in ulnar neutral or ulnar plus variants. Degenerative problems of the TFCC, on the other hand, result from repetitive loading of the ulnar aspect of the wrist and are thus variants of the ulnar impaction syndrome. Repetitive pronation and supination appears to lead to progressive degenerative changes of the proximal and distal aspects of the horizontal portion of the TFCC. Review of our clinical cases substantiates this concept as does the experimental work of regarding TFCC degeneration and age. With time and continued loading, the adjacent cartilage surfaces of the ulnar head and lunate begin to show changes of chondromalacia (Fig. 3). If the repetitive load lasts long enough, perforation of the TFCC frequently follows. These perforations may or may not cause symptoms. Chondromalacia of the ulnar aspect of the lunate or of the opposing ulnar head may be symptomatic (Fig. 4). With time, in a high proportion of people with TFCC perforations develop attenuation or rupture of the lunotriquetral ligament. Finally, with ulnocarpal abutment and lunotriquetral instability and persistent loading of the ulnar aspect of the wrist, degenerative arthritis of the ulnocarpal and distal radioulnar joint appears.

**Classification**

In an attempt to organize the many different lesions of the TFCC that have been seen, we have elected to classify lesions as traumatic (Class 1) or degenerative (Class 2) (Table I). The traumatic lesions, which in our experience are far less common than the degenerative lesions, are classified according to the location of the pathology. Degenerative changes follow a chronological order as a result of repetitive loading from ulnocarpal abutment affecting the horizontal portion of the TFCC, the ulnar head and lunate, and the lunotriquetral ligament.

**Traumatic lesions: Class 1**

We have chosen to classify traumatic lesions as Class 1 with a subclassification of type A, B, C, or D, depending on the location of the lesion. A Class 1A lesion is a tear or perforation of the horizontal portion of the TFCC. The tear is usually a 1 to 2 mm wide dorsal palmar slit located 2 to 3 mm medial to the radial attachment of the TFCC (Fig. 5). Frequently, the medial border of the slit or perforation is redundant. Occasionally, there is a flap of cartilage that is attached
Class 1A

Fig. 5. The ligamentous supports of the ulnar aspect of the wrist (the triangular fibrocartilage complex) illustrating a Class 1A perforation. 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.

only at the palmar aspect of the slit. A triple injection wrist arthrogram using either a radiocarpal or distal radioulnar joint injection technique performed on such a wrist will reveal a perforation of the TFCC near its attachment to the radius (Fig. 6).34, 46, 61-66

Class 1B lesions represent traumatic avulsions of the TFCC from its insertion into the distal ulna (Figs. 7, A and B). These may or may not be accompanied by a fracture of the ulnar styloid at its base. As the TFCC represents the major stabilizer of the distal radioulnar joint, these lesions are usually associated with distal radioulnar joint instability. An arthrogram performed on such a wrist will reveal no abnormality with a radiocarpal injection. An arthrogram done on such a wrist via a distal radioulnar joint injection may reveal dye leakage out ulnarly from beneath the TFCC (Fig. 8).

Class 1C lesions represent tears of the TFCC in its periphery, i.e., avulsion of the TFCC from its distal attachment to the lunate (the ulnolunate ligament) or the triquetrum (the ulnotriquetral ligament) (Fig. 9). As the TFCC is a major stabilizer of the ulnar carpus, these lesions frequently result in ulnar carpal instability manifested by palmar translocation of the ulnar carpus in reference to the radius and/or ulnar head. An arthrogram done on such a wrist will show no perforation of the horizontal portion of the TFCC but may very possibly reveal a capsular leak with either a radiocarpal or midcarpal injection, depending on the location of the tear (Fig. 10).

Class 1D lesions are traumatic avulsions from its attachment to the radius at the distal or sigmoid notch (Fig. 11). An arthrogram of such a wrist can be expected to show a communication between the radiocarpal and distal radioulnar joint at the location of the TFCC disruption with either radiocarpal or distal radioulnar injection, unless synovium or axial load at time of the study obscures the perforation.

Degenerative lesions: Class 2

Degenerative lesions of the TFCC are, as has previously been mentioned, a result of chronic load to the ulnar wrist, i.e., the ulnar impaction syndrome (Fig. 3). We have chosen to categorize these lesions as 2A, B, C, D, or E, depending on the extent and location of degenerative changes present.
Fig. 7. A, 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. B, 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 2A represents wear of the horizontal portion of the TFCC distally, proximally, or both, without perforation (Fig. 12). Mikic elegantly describes this form of TFCC abnormality anatomically and histologically. The neutral forearm rotation PA x-ray films of such a wrist will usually, as with all Class 2 lesions, reveal a neutral or positive ulnar variant. The arthrogram in such a case is usually normal. However, with careful scrutiny one may see raggedness of the horizontal portion of the TFCC on its proximal aspect with a distal radioulnar joint injection or on its distal aspect with a radiocarpal injection (Fig. 13). The pathology, as with a Class 2B lesion, can best be seen with arthroscopy and less easily with an arthrotomy.

Class 2B lesions represent wear of the horizontal portion of the TFCC and additional wear or chondromalacia of the ulnar aspect of the lunate or the radial aspect of the ulnar head or both (Fig. 14). Again, the neutral forearm rotation PA x-ray film of such a wrist will usually show an ulnar neutral or positive variant.
Fig. 8. (Left) PA x-ray film of a wrist after trauma with a small avulsed fragment of bone adjacent to the ulnar styloid (arrow). (Center) A radiocarpal injection arthrogram showing a midcarpal communication but no abnormality of the TFCC. (Right) A distal radioulnar joint injection showing a tear of the TFCC from its insertion onto the distal ulna allowing contrast leakage out into the ulnar soft tissues (arrows).

Class 1C

Fig. 9. 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 lunotriquetral ligament (arrows). R, Radius; U, ulna; L, lunate; T, triquetrum.

Occasionally, subchondral erosive changes of the lunate or ulnar head may be seen (Fig. 15). The arthrogram is usually normal except for subtle changes on the horizontal portion of the TFCC.

Class 2C lesions represent further progression or degenerative change to the point that the horizontal portion of the TFCC becomes perforated (Fig. 16). This perforation tends to be ovoid, whereas a traumatic perforation tends to be a dorsal palmar slit. Degenerative perforations are located in the thin avascular portion of the TFCC, i.e., ulnar to the location of a traumatic perforation. Wrist arthrograms with either radiocarpal or distal radioulnar joint injections usually demonstrate a perforation of the horizontal portion of the TFCC that confirms the anatomic location and shape of the perforation as just described (Fig. 17).

Class 2D lesions represent even further progression of the degenerative process where there is evidence of degenerative changes of the articular surface of the lunate and ulnar head, the horizontal portion of the TFCC is perforated, and the lunotriquetral ligament is disrupted (Fig. 18). We postulate that chronic loading of the ulnar aspect of the lunate leads to degenerative laxity and eventual attenuation of the intersseous portion of the lunotriquetral ligament. An arthrogram of such a wrist with a midcarpal, radiocarpal, or distal radioulnar joint injection will usually show the TFCC perforation and lunotriquetral ligament disruption (Fig. 19).

Class 2E lesions represent the final stages of the impaction syndrome, i.e., degenerative arthritis of the ulnocarpal and occasionally, distal radioulnar joints. In these cases, the horizontal portion of the TFCC is usually completely absent and the lunotriquetral intersseous ligament is completely disrupted.

Discussion

We believe that classification of lesions of the TFCC is helpful as a plethora of TFCC problems have been seen, the pathogenesis of these lesions is recognized, and the treatment for each frequently needs individualization. Differentiation of these various lesions has been difficult in the past. A careful physical examination including palpation for localization of tenderness, stress testing for detection of ulnocarpal...
Fig. 10. A-B. A, A radiocarpal injection arthrogram showing dye leakage out ulnarily (two arrows) and B, palmarly (one arrow).

Class 1D

Fig. 11. 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.

Class 2A

Fig. 12. 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.

distal radioulnar joint instability, and observation for swelling or deformity are frequently helpful in localizing the lesion. The presence or absence of an avulsion fracture or positive ulnar variance as determined by neutral forearm rotation PA x-ray films are helpful in classifying lesions. Arthrographic studies, until late, have been used to demonstrate a "tear" of the TFCC. It is now recognized, however, that triple injection arthrography of the wrist, including injections into the radiocarpal, distal radioulnar, and midcarpal joints allows better delineation of the complex abnormalities of the TFCC and by localization of the tear, differentiation between a traumatic tear and the degenerative perforation. An injection into the radiocarpal joint may reveal a perforation through the central portion of the TFCC, peripheral partial tears of the TFCC, peripheral disruptions of the TFCC, and in a high percentage of patients with a perforated horizontal portion of the TFCC, leakage of dye across the lunotriquetral perforation, indicating a lunotriquetral ligament abnormality. Dye injection into the distal radioulnar joint can reveal a perforation of the horizontal portion of the TFCC, tears of
the peripheral aspect of the TFCC (either partial or total), and complete disruption of the TFCC from the distal ulna.

Recently, Roth and Haddad\(^6\) showed that wrist arthroscopy is more accurate in evaluating perforations of the TFCC than is arthrography. In this well-controlled study, arthrograms were done with a single compartment injection. Perhaps with the triple injection technique, more accurate information could have been gained.\(^6\)\(^2\)\(^6\) Arthroscopy is, in some hands, replacing arthrography for the evaluation of chronic ulnar wrist pain, for arthroscopy allows one to evaluate the size and shape of a TFCC perforation, the presence or absence of chondromalacic changes on the carpal bones and/or ulnar head, and the integrity and strength of the intrinsic wrist ligaments.\(^44\)\(^6\) Of most importance, however, a torn TFCC can be debrided or an area of chondromalacia abraded at the time of the arthroscopy.

The association between ulnar variance, as obtained in a neutral forearm rotation film and TFCC abnormalities is now well-recognized.\(^1\)\(^2\)\(^9\)\(^12\) Positive and neutral ulnar variance is more commonly associated with abnormalities of the TFCC. It is uncommon to see an individual with a TFCC abnormality with negative ulnar variance. We believe that positive ulnar variance is an etiologic factor in the production of Class 2 lesions of the TFCC and ulnocarpal complex.

The classification of TFCC lesions presented here is based on our anat0mical dissection, biomechanical studies, review of the work of others who have studied TFCC problems, and review of the patients we have seen and treated with these lesions for more than 10 years. During that period of time, many treatment programs have been tried for different TFCC lesions. We have learned to never excise the TFCC completely. The TFCC is not the appendix of the wrist joint. We have discarded some procedures that we originally thought would be successful in the treatment of problems of the TFCC such as repair of tears of the horizontal portion of the complex. The treatment program that we presently use has been in place for the past 2 years and appears to offer promise. As our classification outlines, nine different lesions, almost all patients are treated conservatively originally and the operative treatment for each lesion varies depending on the physical examination, plain films, arthrographic studies, and operative findings; large groups of patients in each treatment group are not presently available for long-term follow-up. Many TFCC lesions respond to conservative measures and never come to surgical intervention.\(^1\)\(^2\)\(^9\)\(^12\) Traumatic tears of the horizontal portion of the TFCC that do not respond to conservative care are best treated with limited TFCC debridement, or in other words, enlargement of the size of the perforation.* For TFCC avulsions or midsubstance tears, reattachment

*References 7, 24, 25, 27-29, 31-33, 44, 45, 68, 69
Fig. 15. (Left) PA radiograph of a wrist with subchondral bony erosion of the lunate as a result of an ulnar impaction syndrome (arrow). (Right) A radiocarpal injection arthrogram of the same patient evidencing a tear of the distal aspect of the horizontal portion of the TFCC (arrow) without through and through perforation and dye leakage into the distal radioulnar joint.

Fig. 16. 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.

Fig. 17. PA arthrogram of the wrist after a radiocarpal injection illustrating a large perforation of the TFCC with dye communication between the radiocarpal and distal radioulnar joints (arrows).

Summary

A classification of traumatic and degenerative lesions of the TFCC has been presented. The clinical, radio-
Class 2D

Fig. 18. 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 TFC (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.

graphic, and arthrographic findings associated with each lesion has been specifically outlined. Our experience in treating patients with lesions of the TFCC, as well as the accumulated knowledge of the last few years regarding the anatomy, biomechanics and pathogenesis of TFCC lesions, has helped us develop this classification. It has also shown us the need for a classification on which to base treatment for the myriad of lesions that are seen in patients with injuries to the TFCC. Patients do not suffer from "just a torn TFCC" but have a distinct lesion that is classifiable. It is our hope that others will, using this classification schema as a framework, be able to develop appropriate treatment programs or test previously developed treatment programs for the treatment of specific TFCC lesions. Patients with ulnar wrist pain need no longer be considered the low back pain of the wrist.

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