The Triangular Fibrocartilage Complex

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The Game Plan

• Importance
• Function
• Anatomy
• Clinical History
• Palmer Classification of TFCC injuries
• Treatment
• Imaging
  – Types
  – Review of literature
• Cases
TFCC Importance

• Previously, pts with pain related to TFCC underwent excision of TFC or of DRUJ

• Expanded knowledge of the TFCC
  – Histology
  – Imaging techniques
  – Arthroscopic Techniques

Palmer (1990)
TFCC Function

• Most important function
  – Stabilizer of the DRUJ
• Stabilizes the ulnar carpus
• Cushion
• Distributes stresses from ulnar carpus to ulna
  – Carries 20% of axial load across the wrist in the neutral position
TFCC Anatomy

• A complex composed of a fibrocartilaginous disc & multiple interlinked ligamentous structures

http://www.rearmyourselftexas.com/wrist/triangular-fibrocartilage-tear/
Anatomy

1. Triangular fibrocartilage
2. Triangular ligament*
3. Dorsal radioulnar ligaments
4. Volar radioulnar ligaments
5. Meniscus homologue
6. Ulnar collateral ligament *
7. Subsheath of the Extensor Carpi Ulnaris tendon
8. Ulnolunate ligaments
9. Ulnotriquetral ligaments

Yoshioka et. al (2012)
Distal Radius & Ulna Anatomy
TFCC

- Ulnotriquetral ligament
- Extensor carpi ulnaris tendon sheath
- Ulnolunate ligament
- Meniscus homologue
- Ulnar collateral ligament
- Triangular ligament (lower lamina)
- Ligamentum subcruentum
- Triangular ligament (upper lamina)
- Disc proper (Articular disc)
TFCC

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Volar:
1. Ulnotriquetral ligament
2. Ulnolunate ligament
3. Volar radioulnar ligament

Floor:
1. Triangular Cartilage
2. Triangular ligament

Ulnar:
1. Meniscus homolog
2. UCL (ulnar capsule)
3. ECU subsheath

Dorsal:
1. Dorsal radioulnar ligament
Triangular Fibrocartilage

- AKA: Articular Disc, Central portion, Horizontal portion
- Attachment: Sigmoid Notch of radius, triangular ligament, volar and dorsal radioulnar ligaments
- Broad based, continuous transition from the disc to the hyaline cartilage of radius
  - intermediate signal intensity

Burns, et al. (2011)
Triangular Ligament

- Attachments: articular disk
  - Usually bifurcates into 2 laminae
    - Proximal attaches to the fovea of ulna
    - Distal to tip of ulnar styloid (occurs variably)

Yoshioka et al. (2012)
Triangular Ligament

- Inc signal with a striated pattern
  - Vascular loose knit connective tissue with bundles of collagen fibers
- Proximal lamina
  - Fibers are denser and rise vertically
- Distal lamina
  - Horizontally oriented and extend from cartilage of styloid tip
- Ligamentum subcruentum
  - In between the lamina
  - Increased signal due to vascular tissue

Burns, et al. (2011)
Triangular Ligament

- Neutral forearm: coronal orientation
- Pronation and supination: sagittal

Pfirrmann et al. (2001)
Ulnar carpi ulnaris tendon sheath

Meniscus homologue

Ulnar collateral ligament

Triangular ligament (lower lamina)

Triangular ligament (upper lamina)

Disc proper (Articular disc)

ECU tendon

Prestyloid recess

Capsule

Ulnotriquetral ligament

Ulnocapitate ligament

Ulnolunate ligament

Short radioulnate ligament

Long radioulnate ligament

Dorsal distal radioulnar ligament

Dorsal radiocarpal ligament

Triangular articular disc

Just what is the Meniscus Homolog?!

Yoshioka et. al (2012)
Meniscus Homolog

- Ill defined region of complex, dense fibrous tissue
- “has not independent histologic identity”
- Difficult to ID on anatomic dissections
- Triangular
- Attachments: Articular disc, ulnar styloid, subsheath of ECU, UCL & triquetrum

Burns, et al. (2011)
Ulnar Collateral Ligament

- Not enough evidence to consider this structure as a ligament – ulnar capsule
- Attachments: palmarly at the ulnar margin of ulnotriquetral ligament, ECU subsheath, triquetrum, 5th MC base
ECU Tendon Sheath

- ECU tendon subsheath fibers fuse with the dorsal-ulnar aspect of the TFCC
- Attachments: triquetrum, ulnar styloid
- More rigid and thicker than ulnar capsule
  - More important stabilizer at ulnar side of wrist
Prestyloid Recess

- Direct site of communication with radiocarpal compartment (pisotriquetral joint)
  - Synovium-lined pouch between the triangular ligament and the meniscus homologue
  - Variable shape

Burns, et al. (2011)
Volar
Ulnotriquetral & Ulnolunate Ligaments

- Attachments: volar articular disc and volar radioulnar ligament and not ulna itself¹
  - Ulnolunate Lig: volar portion of lunate
  - Ulnotriquetral Lig: volar aspect of triquetrum
  - Vary in size
  - Single inhomogenous structure

¹ Yoshioka et. al (2012)
Volar Radioulnar Ligament

- Attachments: volar rim of sigmoid notch, fovea and base of ulna
- Volar periphery of the TFC
- Direct, focal osseous attachment to the sigmoid notch of the radius

Yoshioka et al. (2012)
Dorsal
Dorsal Radioulnar Ligament

- Attachments: dorsal rim of sigmoid notch, fovea of ulna
- Dorsal periphery of the TFC
- Direct, focal osseous attachment to the sigmoid notch of the radius

Yoshioka et al. (2012)
Other Important Anatomy

• Blood Supply of TFCC
• Distal Radioulnar Joint
• Ulnar Variance
TFCC Blood Supply

- From ulnar artery
  1. Ulnar artery proper near ulnar styloid process
  2. Dorsal branches of anterior interosseous artery
  3. Palmar anterior interosseous artery
- Rich peripheral blood supply to the outer 10-40%
  - Can mount a reparative response
- Avascular central portion and radial attachment
  - Unable to heal
Distal Radioulnar Joint (DRUJ)

- **TFCC**
  - Volar and dorsal radioulnar ligaments are structures primarily responsible for stabilization of the DRUJ

- Important to assess alignment

*Fig. 8. Distal radioulnar joint (DRUJ). Axial FSE T2-weighted MR image. Note the distal ulna within the sigmoid notch of the radius. The volar (V) and dorsal (D) radioulnar ligaments are seen. Also note the ECU tendon within a notch in the distal ulna (arrowhead).*

Zlatkin et al. (2006)
Ulnar Variance

• Thickness of TFC inversely proportional to ulnar length
  – Thinner TFC with ulnar positive variance
Positive Ulnar Variance

- Associated with ulnocarpal abutment syndrome due to increased ulnar carpal loading
  - Occurs most commonly in ulnar + wrist
  - Can also occur in wrist with either ulnar - or neutral variance
  - Erosive changes in the cartilage of ulnar head and lunate, deg perforation of disc, tear of lunotriquetral lig
- These changes have been described in pts with degenerative perforation of TFCC
- More susceptible to tears of TFCC
- Studies found no sign correlation between (congenital) ulnar positive variance and TFC tears (Manaster et al., Iordache et al.)
  - But if acquired (eg. post traumatic shortening of radius) change of ulnar variance
  - 1mm change inc mechanical load across the ulnocarpal joint by more than 25%

Zlatkin et al. (2006)
Negative Ulnar Variance

- Ulnar minus leads to relative decrease load on the distal portion of the ulna
  - TFC is thicker and TFCC abN are less common
  - If torn, more likely to be traumatic and in younger pts
  - Associated with Kienbock’s disease

Zlatkin et al. (2006)
TFCC Mechanism of Injury

• Traumatic Injuries
  – Fall on a pronated, ulnar deviated, outstretched extremity
  – Rotational injury to the forearm
    • Electric Drill (bit is stuck and torque is transmitted to wrist)
  – Axial load to wrist
  – Distraction injury to the ulnar side of the wrist

• Degenerative Injuries
  – Repetitive
    • Loading of ulnar aspect of wrist
    • Pronation and supination
    • Gripping
      – Can inc ulnar variance by 2mm
  – Tennis players
  – Gymnasts
History - Symptoms

- Ulnar sided wrist pain
- Pain
  - ulnar deviation activities
  - Activities with gripping and twisting - eg opening a jar
- Clicking & snapping
Physical Exam

- Ulnar Snuff Box tenderness
- Ulnar Grind Test
- TFCC pathology can be difficult to diagnose with history and physical exam
Differential Diagnosis of TFCC Injury

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<td>a. Ulnar styloid fracture</td>
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<td>b. Hamate fracture</td>
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<td>c. 5th metacarpal base fracture</td>
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<td>d. Pisiform fracture</td>
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<td>e. Kienbock's disease</td>
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<td>b. Extensor carpi ulnaris (ECU) disorders</td>
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<td>1. subluxation, dislocation</td>
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<td>2. tendinopathy, tenosynovitis</td>
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<td>3. rupture</td>
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<td>c. Flexor carpi ulnaris tendinitis</td>
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<td>d. Ulnar styloid impaction syndrome</td>
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Mayo Clinic Classification of TFC Tears

Diagram showing different classifications of TFC tears:
- Ulna
- Radius
- Palmar surface
- III (avulsion tear)
- IV (linear)
Palmer Classification

• Cause, Location & Extent
• Type 1
  – Cause: Traumatic Injury
• Type 2
  – Cause: Degenerative Injury
  – Can be thought of progressive stages of ulnocarpal abutment syndrome
Palmer Classification

• Type 1
  – A: Central Perforation
  – Avascular articular disc
  – B: Ulnar avulsion +/- without distal ulnar fracture
    – Base of the ulnar styloid
  – C: Distal Avulsion
    – Carpal detachment
  – D: Radius Avulsion

• Type 2
  – A: Wear of the articular disc (without perforation)
  – B: Wear + chondromalacia of lunate or ulna
  – C: Central perforation + Chondromalacia
  – D: Perforation + chondromalacia + LT lig disruption
  – E: Perforation + chondromalacia + LT lig disruption + ulnocarpal arthritis (End Stage)
Palmer Classification

- Communicating tear in TFCC
  - full-thickness
- Non-communicating tear
  - partial thickness
- Must describe each lesion
  - Eg. Dorsal and volar radioulnar ligaments injuries not described under the Palmer Classification

Traumatic TFCC Injury
Type 1
Type 1A
Central Perforation

- Central tear or perforation of the articular disc of TFCC
- Avascular articular disc
- Slit like, sagittally oriented
- 2-3mm medial to radial attachement of TFCC
- 10% of type 1 tears
Type 1A
Central Perforation

Maizlin et al. (2009)
Type 1B

Ulnar avulsion +/- without distal ulnar fracture

• Avulsion from its attachment at the distal ulna
• +/- # at Base of the ulnar styloid
• 1/3 have associated with DRUJ instability
  – Injury to ulnar attachment of dorsal and palmar radioulnar ligaments
• 15% of type 1 tears
Type 1B
Ulnar avulsion +/- without distal ulnar fracture

Yoshioka et. al (2012)
Type 1B
Ulnar avulsion +/- without distal ulnar fracture

Daunt (2002)
Type 1C
Distal Avulsion

- Distal avulsion of TFCC at site of attachment to lunate or triquetrum
- Reflects tear of ulnolunate and ulnotriquetral ligaments the volar attachment of the TFCC to the carpus
  - Volar translation of carpus on ulna
- Carpai detachment
- 13% of type 1 tears
Type 1C
Distal Avulsion

Daunt (2002)
**Type 1D Radius Avulsion**

- Avulsion of TFCC form attachment to radius at distal aspect of sigmoid notch
- may be associated with avulsion # or distal radial #
- **Ra**Di**u**s Avulsion
- May lead to instability of the DRUJ
  - Involves attachment of radioulnar ligaments
- 50% of type 1 tears
Type 1D
Radius Avulsion

Zanetti et al. (2007)
Degenerative TFCC Injury
Type 2
Type 2A
Wear of the articular disc

- Wear or thinning of the distal and proximal surfaces or Articular disc
- Fraying without perforation
Type 2A
Wear of the articular disc

Oneson et al. (1996)
Type 2B
Wear of TFCC + chondromalacia of lunate or ulna

- Cartilage changes on the inferomedial aspect of lunate or radial portion ulna
- Abnormal signal intensity, irregularity, thinning of cartilage
Type 2B
Wear of TFCC + chondromalacia of lunate or ulna

Oneson et al. (1996)
Zlatkin et al. (2006)
- Central perforation with ulnolunate chondromalacia
- More ulnar location than that seen in traumatic injury (1A)
- Ovoid perforation with tapered appearance of TFC at margins of perforation (vs. straight, margins of traumatic slitlike tear)
Type 2C
Central perforation + chondromalacia

Zanetti et al. (2007)
Type 2D
Perforation + chondromalacia + LT lig disruption

- TFC perforation with ulnolunate chondromalacia
- Lunotriquetral ligament disruption
- Lunotriquetral instability
Type 2D
Perforation + chondromalacia + LT lig disruption

Oneson et al. (1996)
Type 2E
Perforation + chondromalacia + LT lig disruption + ulnocarpal arthritis

• All of above with ulnocarpal arthritis
• End Stage
• May also be degenerative arthritis of DRUJ
  – The TFC is usually completely absent
Type 2E
Perforation + chondromalacia + LT lig disruption + ulnocarpal arthritis

Yoshioka et Al (2012)
TFCC Degeneration

- Older pts may show abnormal inc
- Without thinning or extension of high signal to the articular surfaces (tearing)
- Globular or curvilinear pattern
- Thought to be due to mucoid degenerative changes

Burns, et al. (2011)
Asymptomatic Abnormalities of the TFCC

- Several studies demonstrating not all signal abnormalities or defects of the TFC are symptomatic \(^{3,14, 38-41}\)
  - 12%-73% of asymptomatic subjects
- In 180 cadaveric wrist (Mikic et al.)
  - Fetuses, 1\(^{st}\) & 2\(^{nd}\) decade= no deg changes
  - 3\(^{rd}\) decade =7.6% had perforation
  - all > 50yo showed deg changes
- In 103 Axymptomatic volunteers (Iordache et al. 2012)
  - > 60% abN findings in > 50yo
- An associated pattern of deg changes in the wrist as a whole
- Important to know location, age and clinical history

\(\text{Iordache et al.}\)
\(\text{Yoshioka et. al (2012)}\)
Tears of Ulnar Attachment of TFCC

• Peripheral tears:
  – SN 17%, Sp 79%, accuracy 64% when disruption was used as a marker of tearing at ulnar attachment was used
  – SN 42%, SP 63%, accuracy 55% when high signal (Haims et al.)
  – Accuracy 25% (Onesone et al.)

• Central & Radial tears: 97% accuracy

• Attention to focal synovitis may improve SN

• Tears to the UCL and ECU are sparsely described in literature

• Lesions located close to ulnar insertion are more likely to be symptomatic & perforation requiring surgical treatment

Haims et al. (2002)
Treatment

• Conservative treatment with immobilization
  – No instability
  – for most acute TFCC injuries

• Surgical management
  – Failed conservative management
  – Acute instability
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<td>1B- Avulsion from base of ulnar styloid +/- ulnar styloid fracture</td>
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<td>Usually no mechanical symptoms (no perforation or flap to cause clicking) Conservative Management. Arthroscopy is not indicated.</td>
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<td>Conservative management. May treat as ulnar impaction. Ulnar shortening. Wafer procedure: Open procedure or arthroscopic. Resect 2 mm of distal ulnar head down to subchondral bone, leaving TFCC attachments and DRUJ. Unloads the TFCC while maintaining DRUJ stability.</td>
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Imaging

- Radiographs
- Conventional Arthrography
  - Single compartment
  - Multicompartment
- CT Arthrography
- MRI
- MR Arthrography
- US
Imaging- Radiographs

- Look for osseous cause of pain
- Alignment
- Neutral PA forearm films to evaluate for ulnar variance
Imaging- Single & Double Injection
Conventional Arthrography

- Radiocarpal
- Distal radioulnar
- Multicompartment
  - To minimize false negative results in cases with flap tears or one way valves
    - Minimal additional defects are ID
    - In 75 cases of complete defects, only 2 additional defects were found with DRUJ inj (Levinsohn et al.)
    - None were missed with RCJ injection alone (Manaster et al.)

Levinsohn et al.
Imaging- Conventional Arthrography

• Arthrography vs arthroscopy
  – 42%-70% agreement with arthroscopy (Chung et al., Schers et al., Levinsohn et al., Roth et al.)
  – SN 52 %, SP 50% (Vanden Eyde et al.)

• Partial ulnar sided tears most difficult to detect
Imaging- MRI

• Better at localizing site of injury and type of tear than arthrography
• Demonstrates surrounding soft tissues
• Allows assessment of other potential ST & osseous abnormalities which may be causing pt’s symptoms
• Complete tears are better visualized than partial tears\textsuperscript{27}
MR Arthrography

- Some suggest injecting the most clinically relevant compartment
  - adding additional injections if a tear is not seen on conventional arthrogram preceding MRAr^{28}

- Some recommend injecting DRUJ^{27, 29} first as non communicating defects of the ulnar attachments of TFC are more frequently symptomatic

MRI vs. MR Arthrography (MRAR)

- Meta-analysis
- 21 studies
- Full thickness tears, insufficient data to compare partial thickness tears
- Insufficient data to compare single, double and triple compartment MRAR

- Diagnostic accuracy of MRAR superior to MRI
  - MRI: SN 75%, SP 81%
  - MRAR: SN 84%, SP 95%

- 3T MRI greater diagnostic test accuracy than 1.5T MRI
  - 1.5T: SN 70%, SP 79%
  - 3T: SN 86%, SP 100%

- 3T MRA greater diagnostic test accuracy than 1.5T MRA
  - 1.5T: SN 83%, SP 95%
  - 3T: SN 100%, SP 100%

Stehling et al.
Indirect MR Arthography

- Does not require radiation from fluroscopy or joint injection
- Hyperemic or inflamed tissue will enhance
- Well-vascularized regions (periphery) of TFCC will also enhance
  - Difficult to ID tear from normal findings
- Does not significantly improve ability to evaluate TFCC or lunotriquetral ligament
MR Technological Advances

- Higher Field Strengths
- Ultrafast 3D imaging sequences
- 3D High-resolution isotropic sequence
- High Resolution wrist microscopy coils
MR Technological Advances - Short TE

Yoshioka et. al (2012)

Bae, Chang, Chung. EMR 2012
Arthroscopy

- Gold standard for diagnosis of internal derangement of wrist
- SN and SP in ID tears of TFCC and coexisting lesions
- More expensive than MRI
- Risks of surgery
- Peripheral tears involving the fovea more difficult to detect
Cases
Case 1

33 yo. F
Ehlers-Danlos.
Rt wrist pain

Courtesy of Dr. Michael Thompson
Central TFCC Perforating tear (1A)
Peripheral Tear of TFCC (Palmer 1B)

Synovitis and peripheral TFCC tear
Arthroscopic Treatment

Peripheral TFCC tear

Debridement and repair
Case 2

15 yo M.
Fell skateboarding

Courtesy of Dr. Brady Huang
• Radiographs
  – Scaphoid waist fracture
  – Avulsed fragment along the distal to the DRUJ
Avulsion of the radial attachment of the dorsal radioulnar ligament
- AbN communication of contrast between the radiocarpal joint and the distal radioulnar joint. Site of communication at the radius.
- Avulsion of the radial attachment of the dorsal radial ulnar ligament and tearing of the radial aspect of the central TFC.

(Palmer 1D)
Case 3
41 yo. F.
Rt wrist pain
Fall 2 yrs ago

Courtesy of Dr. Michael Thompson
Arthroscopy & MR Ar Cor T1FS

- Central Unstable tear with flap.
- Chondromalacia along the lunate.

- Communication of contrast between the RC and DRUJ.
- Central full thickness tear of TFC.
- Ulnar sided and DRUJ synovitis.
Arthroscopy Treatment

- Central Unstable tear with flap

Palmer 1A vs 2C
(acute on chronic)

- Debridement

- Radiofrequency ablation, saucerization
Recap

• 9 components to the TFCC
• Palmer Classification
• Not all abnormalities of TFCC are symptomatic, important to correlate with clinical history
• Important to describe the injured structures
• MR Arthrography and higher MR field strengths are superior in detecting full thickness TFCC tears
• Lower sensitivity and accuracy for peripheral tears
• But arthroscopy remains the gold standard
• If Dx is missed progressive instability of DRUJ, OA, loss of motion, pain, loss of grip strength, ADLs
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Special Thanks to Dr. Michael Thompson
Department of Orthopedics Scripps Hospital