Capsulolabroligamentous Structures of the Hip: Anatomy and Pathology

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MSK Fellow Lecture
May 7, 2009
Lecture Outline

I. Normal Articular Anatomy of the Hip
II. Pathology of Joint Capsule and Ligaments
III. Labrum:
   I. Normal Anatomy
   II. Pathology
   III. Pitfalls
IV. Miscellaneous
   I. Supraacetabular fossa/Stellate lesion
Hip Joint: Articular Anatomy
Hip Joint

- Synovial ball-and-socket joint
- Rotate around 3 planes
  - **Transverse axis**: flexion and extension
  - **Longitudinal axis**: medial and lateral rotation
  - **Sagittal axis**: abduction and adduction
Hip Joint: Osseous Anatomy

- **Femoral Head**
  - Half a sphere
  - Directed upward, medially and slightly anteriorly
  - Smooth surface xc for roughened pit, the fovea

- **Femoral Neck**
  - Entire anterior surface intracapsular
  - Medial third of posterior surface intracapsular
**Acetabulum**

- Cup-shaped socket
- Elevated bony rim with lunate cartilaginous surface
- Bony rim/cartilage absent inferiorly at the acetabular notch
- Acetabular fossa
  - Devoid of cartilage
  - Filled with fat
  - Covered by synovium

- Acetabular notch
- Acetabular fossa
- Lunate surface
- Ilium
- Pubis
- Ischium
**Labrum**
- Fibrocartilaginous rim attached to edge of the acetabulum
- Deepens the acetabular side of the joint
- Ends and merges inferiorly with the transverse ligament

**Transverse Ligament**
- Spans the acetabular notch, converting notch to foramen
- A non-cartilaginous extension of the labrum

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- Fibrocartilaginous rim attached to edge of the acetabulum
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**Transverse Ligament**
- Spans the acetabular notch, converting notch to foramen
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Ligamentum Teres Femoris

- Pyramidal ligament
- Covered by synovium
- Extends from femoral fovea as round band
- Inserts distally as 2 flattened bands on either side of acetabular notch, blending with fibers of transverse ligament
- Sometimes only synovial covering is present
- Contributes to stability in fetal and neonatal hips
- Debated function in adult hips

Ito et al. J of Ortho Res 2009
### Table I. Proposed functions of the ligamentum teres (LT)

<table>
<thead>
<tr>
<th>Function</th>
<th>Arguments for</th>
<th>Arguments against</th>
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<tbody>
<tr>
<td>Mechanical</td>
<td></td>
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<tr>
<td>Stability</td>
<td>Rich in collagen(^9) stiffness comparable to other ligaments;(^9) hip joint stability gradually decreases during gestation;(^20) while the collagenous component of LT increases(^10)</td>
<td>Presence of numerous static and dynamic stabilisers around the hip; minimal increase in range of movement after sectioning the LT(^7)</td>
</tr>
<tr>
<td>Proprioception/co-ordination</td>
<td>Presence of FNE(^\ast) in LT;(^29,30) episodes of recurrent subluxation in athletes with injured LTs(^26) may be caused by loss of fine coordination</td>
<td>FNE identified in 100% of normal(^28) but only 66.6% of dysplastic(^30) hips; cause-and-effect relationship between subluxation and injury to LT not proven</td>
</tr>
<tr>
<td>Biological</td>
<td></td>
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<tr>
<td>Nociception</td>
<td>Presence of FNE(^\ast);(^29,30) pain reported in otherwise healthy hips with ruptured LTs(^3,5) pain in inflammatory/degenerative arthropathy</td>
<td>Multiple potential sources of pain in inflammatory/degenerative arthropathy</td>
</tr>
<tr>
<td>Vascularity to femoral head</td>
<td>Vessels present in LT(^10,65-67)</td>
<td>Penetration of fovea by vascular canals limited and extremely variable(^10)</td>
</tr>
<tr>
<td>Distribution of synovial fluid</td>
<td>None</td>
<td>Lack of experimental proof(^13)</td>
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</table>

\(^\ast\) FNE, free nerve endings
Hip Joint: Synovial Cavity

**Synovial Membrane**

- Covers portion of femoral neck, femoral head articular surface, ligamentum teres
- Intimate with deep fibers of capsular ligaments
- Covers acetabular labrum and fossa
**Fibrous capsule**

- **Circular and longitudinal fibers**
- **Strongest anteriorly and superiorly**
- **Attachments:**
  - Proximal: acetabular margin (5-6mm above labrum), labrum, transverse ligament
  - Anterior/distal: surrounds femoral neck to trochanteric line
  - Posterior/distal: femoral neck to 1cm above trochanteric crest

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Hip Joint: Capsule

Zona orbicularis

- Deep circular fibers of capsule
- Collar about femoral neck
- No connection to bone
- Blends with the more superficial capsular ligaments
- Abundant at inferior and posterior capsule
- Tension at extreme flexion or extension
- Hip stability in distraction
- “femoral arcuate ligament“
Capsular Ligaments

- Hip joint capsule is intimate with and reinforced by capsular ligaments
- Strongest anteriorly
- **Anterior Ligaments:**
  - Pubofemoral Ligament
  - Iliofemoral Ligament
Anterior Capsular Ligaments

- **Iliofemoral Ligament**
  - Ligament of Bigelow
  - Strongest capsular ligament
  - "Y" shaped
    - Apex attached to or near lower portion of anterior inferior iliac spine (AIIS)
    - Base attached along trochanteric line
  - Two bands (majority)
    - Lateral band (L)
    - Medial band (M)
  - Possible 3 bands

www.prohealthsys.com
Iliofemoral Ligament

- **Main restrictor of external rotation and extension**
- **Medial Band (A)**
  - **Anatomy**
    - Origin: between AIIS and acetabular rim
    - Insertion: more distal trochanteric line of femoral neck
  - Almost vertical orientation
  - **Function**
    - Inhibitor of external rotation, especially in extension


Cadaveric analysis of anatomy and function: Internal and external rotation thru ROM fr 30° flexion to 10° extension along neutral swing path
**Lateral Band (B)**

- **Anatomy**
  - Origin: AIIS
  - Insertion: superior portion of trochanteric line
  - More horizontal oblique orientation along femoral neck

- **Function**
  - Main inhibitor of external rotation, along neutral swing
  - Also inhibitor of internal rotation, esp in extension

*Martin H et al. Arthroscopy 2008; 24(2): 188-195*
Iliofemoral Ligament

Anterior Capsular Ligaments: Pubofemoral Ligament

- **Resembles a sling**
- **Anatomy** \(^{12}\)
  - **Origin:** Wide attachment to iliopectineal eminence, superior ramus and obturator crest
  - **Insertion:** Blends with capsule and deep surface of medial band of iliofemoral ligament. Attaches to femoral neck
- **Function** \(^{12}\)
  - Inhibitor of external rotation in extension and abduction
Anterior Capsule: Inherent Weak Area

- Inherent weak area of anterior capsule between the medial band of the iliofemoral ligament and the pubofemoral ligament
- Potential communication between hip joint and iliopsoas bursa
Posterior Capsular Ischiofemoral Ligament Anatomy

**Anatomy**

- **Origin:** Ischial portion of acetabular rim and extends superolaterally as 2 bands
- **Superior Band**
  - Spirals across posterior femoral neck, blends with zona orbicularis
  - Inserts medial to anterosuperior base of greater trochanter
- **Inferior Band**
  - Crosses posterior femoral neck
  - Inserts medial to base of greater trochanter along posterior trochanteric crest

**Function:** Inhibitor of external rotation in extension
Capsule: Normal Arthrogram

**Anterior Joint Capsule**
- Blue arrows
- Extends to trochanteric line

**Posterior Joint Capsule**
- Black arrowheads
- More medial and proximal than anterior joint capsule
UCSD/VASD MRA Protocol

- Surface coil to maximize signal-to-noise ratio
- MR arthrogram is indicated to evaluate hip articular anatomy and pathology
- Fluoro-guided intraarticular injection of 1:200 dilution of Magnevist, about 10ml
- Unilateral hip with small FOV=18 cm, slice thickness=5mm
- Image matrix size=320x224 xc sag plane 256x224
- **T1W-fat sat** (TR 600 msec/TE 14 msec): all 3 planes
- **T2W-fat sat** (TR 3000 msec/TE 90 msec): coronal plane
- **PD** (TR 3000 msec/TE 30 msec): axial oblique plane

Coronal T1FS Anterior to Posterior

Iliofemoral ligament

Iliopsoas T.
Iliofemoral ligament (lateral)

Anterior Labrum

Iliopsoas t.

Iliofemoral ligament (medial)
Iliofemoral ligament

Transverse ligament

Iliofemoral ligament (medial)
Iliofemoral ligament
Labrum
Fovea
Transverse ligament
Region of pubofemoral ligament
Ischiofemoral ligament

Labrum

Ligamentum Teres

Transverse ligament

ZO
Sagittal T1FS Medial to Lateral

Transverse ligament
Transverse ligament
Ischiofemoral ligament

Iliofemoral ligament

Ischiofemoral ligament
Iliofemoral ligament

Obturator Externus Tendon

ZO
Iliofemoral ligament

Labrum

Ischiofemoral ligament

Fovea

Acetabular Fossa

Labrum
Iliofemoral ligament

Ischiofemoral ligament

Transverse ligament

Ligamentum Teres

ZO

Ischiofemoral ligament
Iliofemoral ligament

Ischiofemoral ligament
Pathology of Capsule and Ligaments
Capsular Laxity and Hip Instability

- Traumatic (acute): Dislocation or subluxation
- Atraumatic (non-acute):
  - Overuse (chronic repetitive microtrauma)
  - Connective tissue disorders (Marfan, Ehlers-Danlos)
- Capsular ligaments (iliofemoral ligament) and labrum are static stabilizers of hip
  - Once injured, the psoas major muscle (dynamic stabilizer) constantly contracts to provide hip stability
  - Leads to stiffness, flexion contractures of hip, back pain
- Treatment: Thermal capsulorrhaphy +/- plication and labral repair

Traumatic Posterior Subluxation

- Seen in athletes (American football)
- Fall on flexed adducted hip
- Low-energy trauma
- Difficult clinical diagnosis
- Avulsion fracture of posterior acetabulum
- Disruption of iliofemoral ligament and anterior capsule
- Hemarthrosis
- Risks: AVN, chondrolysis

Moorman CT et al. JBJS 2003; 85A(7):1190-6.
Traumatic Posterior Subluxation
Traumatic Posterior Subluxation
Hip Dislocation

- Posterior >> anterior dislocation
- Joint capsule is stronger anteriorly
- High-force impact
  - Flexed adducted internally rotated hip → Posterior dislocation
  - Abducted externally rotated hip → Anterior dislocation
- Risks: AVN, post-traumatic osteoarthrosis
Hip Dislocation

**Imaging Findings**

- Iliofemoral ligament disruption
  - 16 of 18 pts with traumatic dislocation\(^{14}\)
- Labral and chondral injuries +/- entrapment
- Capsular/Ischiofemoral ligament disruption
- Ligamentum teres disruption\(^{15}\)
- Femoral head or acetabular fracture
- Marrow and muscle edema
- Sciatic nerve injury
Ligamentous Injuries in Dislocation

Iliofemoral Ligament Disruption: contrast extends outside capsule

Ischiofemoral Ligament Tear: contrast extends outside posterior capsule
### Table 2. Hip Pathologies Identified at Arthroscopy

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Months*</th>
<th>Spontaneous Reduction</th>
<th>Labral</th>
<th>Adhesions</th>
<th>Capsule Tear</th>
<th>Ligamentum Teres</th>
<th>Cam</th>
<th>Pincer</th>
<th>Chondral Defect</th>
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*Months from dislocation to hip arthroscopy.
### Gray and Villar Classification

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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</table>
| **Type I**    | **Complete Rupture:**  
|               | Usually acute and associated with major trauma/surgery  
|               | Often associated with other significant abnormalities (labral or chondral injuries) |
| **Type II**   | **Partial Rupture:**  
|               | Usually associated with chronic hip pain  
|               | Often seen in athletes (ballet dancers, martial arts or high impact sports).  
|               | Third most common finding at arthroscopy in young athletes |
| **Type III**  | **Degenerative:**  
|               | Usually associated with osteoarthritis in older patients |
Traumatic Ligamentum Teres Tear: A source of Hip Pain

- Mechanism:
  - Fall on flexed adducted hip
  - Twisting injury, ext rotation
  - Hyperabduction

- Clinical Symptoms:
  - Deep anterior groin pain
  - Locking, clicking, popping

- 23 cases of traumatic tears of LT (15 major trauma, 8 twisting)

- 2 detected by preop MRA (7 MRA, 20 MRI done)

- Young pts (avg age=28)

- 8 cases were isolated findings.

- Treatment:
  - Debridement of torn fibers
  - Improved sx after treatmt

MR Imaging of Ligamentum Teres

MR Arthrogram$^{18,19}$:

- Axial oblique planes may be optimal
- Normal: Homogeneous low SI on both T1 and T2W
- Partial Tear: Intermed/high T2 signal and abnormal morphology
- Hypertrophied ligament: 2 mm medial extension beyond foveal insertion on axial oblique images.
  - If ligament is hypertrophied, either abnormal T2 signal or morphology determines partial tear.
- Occasionally will see bony intra-articular fragments from avulsion injuries of LT (more common with complete/type I injuries

Ligamentum Teres Tears

- Normal
- Hypertrophied
- Partial Tear

24 yo professional soccer player with left hip pain

Coronal T2FS

Courtesy of Drs Craig Stewart and Tudor Hughes
24 yo professional soccer player with left hip pain

Arthroscopic Findings:

Type 2 partial tear of left ligamentum teres at its foveal attachment
Labrum: Normal Anatomy and Pathology
**Labrum**

- **Fibrocartilaginous structure:**
  - Attached to acetabular perimeter
  - Inferiorly, attached to transverse acetabular ligament
  - Collagen fibers contiguous with those in transverse ligament

- **Morphology:**
  - Anterior labrum: Wider and thinner
  - Posterior labrum: Less wide and thicker

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Labrum

- **Function:**
  - Provides seal, keeping fluid between femoral head and acetabulum during mild compression
  - Helps contain femoral head during extreme ROM, esp hip flexion

- **Histology**:
  - Dense connective tissue
  - Fibrocartilage
  - Collagen fibers (longitudinal circumferential bundles)
  - Neuroreceptors within labrum provide proprioception of hip

![Image of labrum anatomy]

![Cross-section view of hip joint]
Labrum: Vascularity

- Most vascular at peripheral 1/3 of labrum
- Kelly et al. divided labrum into capsular zone IA/IB and articular zone IIA/IIB
  - Capsular zone most vascular due to abundant blood supply from joint capsule
  - Some blood supply from adjacent bone
  - Least blood supply in central and articular labrum

Peripheral labral tears near capsulolabral junction may heal better.

Shindle et al. JBJS 2008;90 Suppl 4:2-19
Labrum: MR Evaluation

- MR arthrography is sensitive and specific in detecting labral pathology
  - Debate that noncontrast MRI just as accurate\(^{33}\)
- Radial imaging has been suggested as better way to evaluate labrum.
Labrum Types: MR Imaging\textsuperscript{21,26}

- Triangular 69-80%
- Round 13-16%
- Irregular/Flat 7-13%
- “Absent” 1-2.5%
  - May not have been seen d/t technique
  - Degenerative or torn, not truly absent\textsuperscript{22,23}

Normal Labrum: MR Imaging

**MR Findings:**
- Triangular (most common)
- Homogeneous dark signal intensity on all sequences
- Closely attached to articular cartilage
- Clock face: sagittal plane
  - 12:00 superior
  - 3:00 anterior
  - 6:00 inferior
  - 9:00 posterior

Labral Abnormalities/Tears

### Causes

1. **Degeneration**
   - Intrasubstance abnl signal

2. **Femoroacetabular Impingement**
   - Cam type: femoral head/neck offset
   - Pincer type: abnormal acetabular morphology
   - Mixed type: most common
   - Developmental hip dysplasia
   - Coxa magna

3. **Trauma**

4. **Repetitive activity in athletes**

### Clinical Findings:

- Asymptomatic: >70 yo
- Hip/Groin Pain
- Clicking

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Femoroacetabular Impingement: Cam type

- Pain w/flexion and internal rotation and limited ROM w/internal rotation
- Offset at femoral head/neck junction causes impingement on labrum with flexion
- “Pistol grip” deformity
- Young athletic persons
- Labral and chondral abnormalities
- Alpha angle > 55°
- Herniation pits may be early osteoarthritis

Femoroacetabular Impingement: Pincer-type

- Abnormal acetabular morphology
  - Acetabular protrusion
  - Acetabular retroversion
  - Os acetabuli
  - Trauma
- Older female patients
- Over-coverage of femoral head → linear contact on acetabular labrum
- Mostly labral abnormalities
- Contrecoup chondral injury in posteroinferior acetabulum and femoral head

Normal (a/b): Labrum clears with flexion
Pincer type (e/f): Over-acetabular coverage of femoral head. Abnormal linear contact on acetabular labrum on flexion

Acetabular Protrusio

Measure fr medial acetabular wall to ilioischial line
Acetabular Protrusio > 3mm in men; > 6mm in women

MR measurement B is the distance between the medial most point of the acetabular fossa and a line perpendicular to the horizontal axis that passes through the lateral most point of the posterior inner pelvic wall (curved arrow) at the level of the ischial spine.

Chen L, Boonthathip M et al. Skel Rad 2009(38):123
Acetabular Retroversion

Anterior acetabular rim is more lateral and crosses over posterior acetabular rim. “Figure of 8” or crossover sign

Labral Tears Classification

- Arthroscopic classification by Lage\(^27\)
  - Radial flap
  - Radial fibrillated
  - Longitudinal peripheral
  - Unstable

- Initial MR Imaging classification by Czerny et al\(^28\)
  I. Intralabral signal
  II. Contrast extends into labrum
  III. Labral detachment

- BUT, these 2 systems do not correlate well with each other\(^25\)

Best to use clock-face
Resnick’s MR Classification of Labral Tears

- Use sagittal plane for location of tear
- Coronal plane (cross reference to other planes) for type of tear

**Types:**
1. Longitudinal vertical
2. Longitudinal horizontal
3. Radial
4. Complex
5. Labral detachment
   - From bone or articular cartilage
6. Acetabulolabral articular destruction (ALAD)

Resnick D. IDJ Advanced Intensive MR Imaging Course Feb 2009
Labral Tears: Location is Everything

- Most tears are anterior or anterosuperior
  - Theories: poorer vascular supply, mechanically weaker and subject to greater stress
  - Marginal attachment to cartilage, parallel collagen fibers to cartilage\textsuperscript{32}
- Posterosuperior tears can occur in younger pts and more common in Japan
- Normal labral variants are more likely in the lower quadrant
14 yo female ballerina with “snapping” sensation of right hip

MR Arthrogram: Coronal T1 FS

Axial T1 FS

Anterosuperior Labral Tear

Courtesy of Dr Tudor Hughes
68 yo woman with anterosuperior labral tear

38 yo male with avulsion of anterosuperior labrum

Dinauer et al. AJR 2004;183:1745-53
Labral Tears: Paralabral Cyst

38 yo female with right hip pain for 7 yrs, no trauma

Courtesy of Dr Tudor Hughes
Acetabulolabral articular destruction (ALAD)

40 yo male with right hip pain

Courtesy of Dr Tudor Hughes
Labral Imaging Pitfalls

**Terminology:**
- **Perilabral recess or sulcus:** between labrum and capsule
  - NORMAL
- **Sublabral recess or sulcus:** between labrum and articular cartilage or subchondral bone
  - Normal or not??

![Normal Perilabral Recess](image)
Sublabral Sulcus: Confusing Topic

- **Breakdown of literature**
  - 1994 Keene: 100 pts arthroscopy. 2 posteroinferior sublabral sulci.
  - 1996 Petersilge: 10 MRA. No sublabral sulcus.
  - 1999 Czerny: 40 MRA; 6 cadavers. No sublabral sulcus.
  - 2004 Dinauer: 54 MRA, 4 MRI. 13 Posteroinferior sublabral sulci.
  - 2006 Saddik: 24 noncon MRI, 3 MRA. 12 anterosuperior, 14 posteroinferior, 2 anteroinferior, 2 posterosuperior sulci.
  - 2008 Studler: 57 MRA. 7 anteroinferior, 1 anterosuperior, 2 anterior sulci.

- **Definition per above:** Partial separation of labrum fr articular cartilage with normal underlying labrum. Gold standard was arthroscopy.

- **BUT,** there were some examples of sublabral sulcus on MR proven to be tear on arthroscopy.
Posteroinferior Sublabral Sulcus
Posteroinferior Sublabral Sulcus
Posterosuperior Sublabral Sulcus\textsuperscript{39}
Anterosuperior Sublabral Sulcus \(^{39}\)
Anteroinferior Sublabral Sulcus$^{40}$
Tear or Sublabral Sulcus\textsuperscript{39}? Anterosuperior labral tear on arthroscopy
Tear or Sublabral Sulcus$^{37}$?

- Anterior labral tear
- Posterior sublabral sulcus
Sublabral Sulcus: Bottom Line

- Describe the labral finding.
- Location is key.
- If in anterosuperior labrum, consider a tear.
- If in posteroinferior labrum, likely a sulcus since most labral tears are anterosuperior in location.
- In other quadrants, be careful dismissing finding as normal sulcus.
Miscellaneous:
Supraacetabular Fossa
Stellate Crease/Lesion
Supraacetabular Fossa

- Normal notch within the acetabulum deficient of cartilage
- Located above the acetabular fossa at 12:00
- Usually seen in young people

Stellate Crease

- Normal area of stellate appearance of deficient cartilage at or near supraacetabular fossa, seen on arthroscopy

**FIG. 27.** The stellate crease is frequently found directly superior to the acetabular fossa (AF) characterized by a stellate pattern of chordromalacia (arrows). This appears to be a normally occurring process, even in young adults, without clear prognostic significance. (Courtesy of J. W. Thomas Byrd, MD.)
Stellate Lesion

- A subchondral osseous fragment within the stellate crease
- A plica attached to the medial aspect of the fragment, extending medially and inferiorly
- May be symptomatic
- Hip plica described in arthroscopy literature\textsuperscript{41}

Courtesy of Drs Resnick and Sampatchalit

Stoller D. MRI in Orthopaedics and Sports Medicine 3\textsuperscript{rd} Edit.
Summary

- Normal anatomy and pathology of the capsule, ligaments and labrum of the hip
- Pitfalls in imaging of the labrum
- Stellate lesion
Thank you! Come visit in SF!
References

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