MR IMAGING OF THE MENISCUS: LEARNING OBJECTIVES

• Review relevant anatomy/MR imaging planes
• Review MR appearance of meniscal tears and associations
• Discuss post-surgical meniscus
• Discuss mimics/pitfalls of meniscal tears
• Surgical implications:
  “What the surgeon wants to know”
  – The radiology report
MR IMAGING KNEE TECHNIQUE

- Dedicated knee coil
- High resolution imaging; FOV 16cm or less
- Slice thickness - 3-4 mm
- Matrix - 256x192 or higher
- Imaging planes
  - Sagittal (meniscus/cruciate/cartilage)
  - Coronal (collaterals/cartilage/meniscus/cruciate)
  - Axial (cartilage/cruciate/meniscus)
MR IMAGING KNEE
OUR PROTOCOL

- Sagittal oblique PD FSE nonfat suppressed
- Sagittal oblique T2 FSE fat suppressed
- Coronal T1
- Coronal T2 FSE fat suppressed
- Axial PD FSE fat suppressed
MR IMAGING KNEE
TECHNIQUE: T1

• Important to get one plane with this sequence
  – Overall Anatomy
  – Osseous structures (marrow)
  – Distinguish fat/hemorrhage
  – Soft tissue/osseous masses
  – Muscle (atrophy)
  – Menisci (high sensitivity and specificity)
MR IMAGING KNEE TECHNIQUE: PD

- Menisci (no fat suppression)
  - High sensitivity and specificity
- Hyaline cartilage (fat suppression)
- FSE or SE  - Speed vs. blurring
  - Increase bandwidth
  - Short effective TE (less than 20)
  - Echo train length of 5 or less
  - Decrease interecho spacing
MR IMAGING KNEE TECHNIQUE: T2

- STIR or fat suppressed
- Menisci - high specificity, low sensitivity
- Hyaline cartilage - high sensitivity and specificity
- Marrow pathology
- Soft tissue/collateral ligament injury
MR IMAGING KNEE TECHNIQUE: GRADIENT

- SPGR and 3D volumetric
- Menisci - high specificity, high sensitivity
- Hyaline cartilage - high sensitivity and specificity
- Poor for marrow pathology
- Poor for cruciate/collateral ligament injury
- Increased susceptibility artifacts
MENISCAL FUNCTION

- Distribute torsional and compressive forces
  - Shock absorber
- Limit abnormal movement
- Joint congruity
- Distribute synovial fluid over articular surface
- Prevent synovial impingement
Resist longitudinal loading
“hoop stresses”
Microstructure
- Collagen bundles
  Circumferential
  Transverse ("tie fibers")

Bullough, JBJS, 1970
Microstructure

- Collagen bundles

Circumferential

Transverse ("tie fibers")

*Bullough, JBJS, 1970*
Microstructure

- Collagen bundles
- Circumferential

Transverse ("tie fibers")

Bullough, JBJS, 1970
MENISCAL ANATOMY

- Fibrocartilage
- 4-7 mm in size, triangular and taper to point
- Innervated
- Peripheral 1/3 vascular
- Medial and lateral
- Anterior, body and posterior horns
Arnockzky 1982
Arnockzky 1982

White Zone
Newborns 50% of meniscus vascularized decreases to 10%-30% in adults
MEDIAL MENISCUS
NORMAL ANATOMY

- Larger radius of curvature or “C”
- Covers 50% contact surface of tibial plateau
- Anterior, body and posterior horns
- Larger posterior horn compared to anterior
- Firmly attached to capsule
MEDIAL MENISCUS NORMAL SAGITTAL MR IMAGING

- Low signal intensity sideways triangles
- Larger posterior horn compared to anterior
- No more than 2 bow ties
- No surfacing intermediate or high signal
MEDIAL MENISCUS NORMAL CORONAL MR IMAGING

- Low signal intensity sideways triangles
- Larger posterior horn compared to anterior
- No surfacing intermediate or high signal
- Posteriorly should extend toward midline
  - Meniscal root
- Firmly attached to capsule
MEDIAL MENISCUS
NORMAL AXIAL MR IMAGING

- Do not forget about this plane
- May not have any images through menisci
- Often only see 1 or at most two images
LATERAL MENISCUS NORMAL ANATOMY

- Smaller radius of curvature or tighter “C”
- Covers 75% contact surface of tibial plateau
- Anterior, body and posterior horns
- Posterior horn equal in size to anterior
- More loosely attached to capsule and mobile
  - Popliteal tendon
  - Meniscal fascicles
LATERAL MENISCUS NORMAL SAGITTAL MR IMAGING

- Low signal intensity sideways triangles
- Same sized anterior and posterior horns
- No more than 2 bow ties
- Meniscus not attached to capsule
  - Popliteus tendon/ hiatus
  - Superior and inferior fascicles
- No surfacing intermediate or high signal
Seen in 90% of asymptomatic knees on MR
LATERAL MENISCUS
NORMAL CORONAL
MR IMAGING

- Low signal intensity sideways triangles
- Same sized anterior and posterior horns
- Posteriorly should extend toward midline
  - Meniscal root
- Meniscus not attached to capsule
  - Popliteus tendon/ hiatus
- No surfacing intermediate or high signal
LATERAL MENISCUS NORMAL AXIAL MR IMAGING

• Do not forget about this plane
• May not have any images through menisci
• Often only see 1 or at most two images
LATERAL MENISCUS DISCOID

- Common normal variant (0.4-17%)
- More common in the Asian population
- Enlarged meniscus; lateral (10-20X) >> medial
- Complete, incomplete or Wrisberg variants
- Too many “bow-ties” on MR
- Predisposed to tears (up to 22%) often horizontal or longitudinal type
MENISCAL SIGNAL

- Grade I: myxoid, hyaline, mucinous degeneration
- Grade II: bands of degeneration
- Grade III: tear
INTRAMENISCAL SIGNAL

TYPE 1

TYPE 2
MENISCAL TEAR

• Intrameniscal linear signal
  – Needs to touch articular surface on two images (definite tear, 94%-96% PPV)
  – Touch on one image (possible tear)
    (Medial 43%-55%; Lateral 18%-30% PPV)
  – Short TE images most sensitive
  – Diffuse signal touching a free edge (57%-78% PPV)

• Abnormal morphology
  – Size
  – Blunt tip
MENISCAL TEAR
MRI ACCURACY

• 50% on sagittal images only
• 3%-5% on coronal images only
• Medial meniscus
  – Sensitivity 86%-96%
  – Specificity 84%-94%
• Lateral meniscus
  – Sensitivity 70%-92%
  – Specificity 89%-98%
MENISCAL TEAR TYPES

• Horizontal/oblique
• Vertical/Longitudinal
  - Meniscocapsular separation
• Radial (vertical perpendicular)
• Displaced fragments (Bucket handle/flaps)
• Complex
MENISCAL TEAR
HORIZONTAL/OBLIQUE

• Most common, may require partial meniscectomy
• Degenerative
• May be asymptomatic
• 20% of people over age 50
• Divides meniscus into superior and inferior components
MENISCAL TEAR
HORIZONTAL/OBLIQUE
MENISCAL TEAR VERTICAL/LONGITUDINAL

- Along axis of meniscus
- Common to occur with ACL tears [medial 90% (Ramp lesion) lesions & lateral 83%]
- May be reparable
- May be peripheral and heal (outer third red zone)
- Divides meniscus into outer and inner components
MENISCAL TEAR
VERTICAL/LONGITUDINAL
PERIPHERAL MEDIAL MENISCAL TEAR AND CONTUSION (RAMP LESION)
PERIPHERAL MEDIAL MENISCAL TEAR AND CONTUSION (RAMP LESION)
PERIPHERAL MEDIAL MENISCAL TEAR AND CONTUSION (RAMP LESION)
MENISCOCAPSULAR SEPERATION
Be careful not to over diagnose, look for very high signal on T2.
MENISCOCAPSULAR SEPERATION

Can be unstable
MENISCAL TEAR
RADIAL TYPE

• Vertical tear perpendicular to meniscal curve, often require partial meniscectomy
• Traumatic or degenerative (15%)
• PHMM (53%); PHLM (26%)
• Hoop stress function destroyed
• Mechanically equivalent of total menisectomy (unrepairable)
  – Increased risk of subchondral fracture “SONK”
MENISCAL TEAR: RADIAL TYPE
Radial tears disrupt ability of meniscus to:

Resist longitudinal loading

“hoop stresses”
MENISCAL TEAR
RADIAL TYPE
MR IMAGING FEATURES

- Cleft or globular sign (also seen in vertical longitudinal tears)
  - Body (sagittal plane), Horns (coronal plane)
- Marching cleft sign
- Truncated triangle sign
- Ghost meniscus sign
- Axial images important for morphology
- May involve meniscal root and lead to extrusion
CLEFT SIGN
MARCHING CLEFT SIGN
MARCHING CLEFT SIGN
CLEFT SIGN
TRUNCATED TRIANGLE SIGN
GHOST MENISCUS SIGN
GHOST MENISCUS SIGN
GHOST MENISCUS SIGN
Normal

Radial meniscal root tear
Normal

Radial meniscal root tear
Subchondral Fracture
Spontaneous Osteonecrosis (SONK)
Subchondral Fracture
Spontaneous Osteonecrosis (SONK)
MENISCAL TEAR
RADIAL/ PARROT BEAK
MENISCAL TEAR

RADIAL/ PARROT BEAK

Combination of radial and longitudinal
MENISCAL TEAR
RADIAL/ PARROT BEAK
Parrot Beak Tear
Parrot Beak Tear
MENISCAL TEAR
DISPLACED FRAGMENTS

- Bucket handle
- Flipped
- Gutter
- Extruded
MENISCAL TEAR
DISPLACED FRAGMENTS

• Early diagnosis for surgical repair
• Decreased volume of meniscal tissue
  – Displaced meniscus
  – Postoperative partial meniscectomy
• Best appreciated on T2 weighted images
  – Fluid signal in meniscus
  – Fragments in effusion
MENISCAL TEAR
DISPLACED FRAGMENTS
BUCKET HANDLE TEAR

Coronal
• Displaced fragment (94%)
• Blunted body (64%)

Sagittal
• Too few “bow ties” (97%)
• Double PCL (30%)
Too few “bow ties”
Blunted body
Displaced fragment
Displaced fragment
Concurrent BHMMT and ACL tear

“Triple PCL sign”? 
FLIPPED MENISCUS
FLIPPED MENISCUS
FLIPPED MENISCUS
FLIPPED MENISCUS
FLIPPED MENISCUS INTO GUTTER
FLIPPED MENISCUS INTO GUTTER
FLIPPED MENISCUS INTO GUTTER
FLIPPED MENISCUS INTO GUTTER

CASE COURTESY KIRK DAVIS MD
FLIPPED MENISCUS INTO GUTTER

CASE COURTESY KIRK DAVIS MD
FLIPPED MENISCUS INTO GUTTER
FLIPPED MENISCUS INTO GUTTER
FLIPPED MENISCUS
INTO GUTTER
FLIPPED MENISCUS INTO GUTTER
MENISCAL TEAR COMPLEX

- Combination of patterns
- Meniscal extrusion (>3mm from bone)
  - Root tear, macerated body tear
  - Prominent hyaline cartilage loss
- Extensive maceration usually associated with prominent degenerative disease/hyaline cartilage loss
- Older patients
MENISCAL TEAR ASSOCIATED FINDINGS

• Popliteal cyst
  – 80%-90% associated with meniscal pathology

• Meniscal (perimeniscal) cyst (2:1 M-F ratio)
  – 85%-100% association with meniscal tear (>90% PPV) (1.7%-4% incidence); except anterolaterally (64%-67% PPV)
  – Lateral meniscus most commonly involved
    (3-10:1 now more equivalent)
  – Medial meniscus cysts often smaller and intrameniscal due to tight capsular attachment
  – Connect directly to tear (horizontal type)
MENISCAL RETEAR POST-SURGICAL

- Challenging
  - Signal may contact articular surface
  - May appear truncated

- Noncontrast MR
  - OK < 25% meniscus removed
  - Findings of retear
    - Fluid signal in defect or meniscal cyst
    - Displaced fragment
    - New finding remote from surgical site
MENISCAL RETEAR POST-SURGICAL

• Noncontrast MR
  – Look for other causes of pain
    • Chondral defects
    • Subchondral fractures
• Arthrography
  – MR direct or indirect
  – CT direct
  – Contrast extends into defect
MR ARTHROGRAPHY

TECHNIQUE

• 0.2 cc Gd + 20 cc saline
• Approximately 40cc of this mixture of contrast
• Axial, sagittal and coronal fat suppressed T1-weighted images
• Additional fluid sensitive sequences
MR ARTHROGRAPHY
MR ARTHROGRAPHY
MENISCAL TEARS
PITFALLS: FALSE POSITIVES

• Normal structures: ligaments (transverse, meniscofemoral, oblique meniscomeniscal), popliteus tendon, geniculate vessels
• Artifacts: patient motion, phase encoding, magic angle
• Chondrocalcinosis, gas, hemosiderin
• Meniscal ossicle and flounce
• Partial meniscectomy
• Meniscal repair/ healed meniscus
• Arthroscopic “gold standard” (really yellow)
Present in 90% of dissections and 83% on MR
MENISCOFEMORAL LIGAMENT OF HUMPHRY
MENISCOFEMORAL LIGAMENT OF HUMPHRY
At least one meniscofemoral ligament present in 89% of dissections and 93% on MR
POPLITEUS TENDON
Oblique menisco-meniscal ligament
(1%-4% of cases)

Sanders, Radiology 1999
Meniscal Flounce
Meniscal Flounce
MENISCAL OSSICLE
MENISCAL OSSICLE

Probably due to previous tear and heterotopic bone formation (AJR 2014 November)
MENISCAL OSSICLE

Probably due to previous tear and heterotopic bone formation (AJR 2014 November)
Patient motion artifact
MENISCAL TEARS
PITFALLS: FALSE NEGATIVES

- Lateral meniscus
  - ACL tear
  - Posterior horn and body
- Small tears
  - Contrast
- Opposed edges
- Arthroscopic “gold standard” (really yellow)
SURGICAL IMPLICATIONS

• Correlation between amount of meniscal tissue removed and forces transmitted to articular cartilage
• Primary goal to preserve as much meniscal tissue as possible
SURGICAL IMPLICATIONS
MENISCAL TEAR CHARACTERISTICS

- Stable or Unstable?
  - Displaced fragment
  - Complex tear/Radial tear
  - Horizontal tear >10mm in length
  - Longitudinal tear >10 mm in length
  - Fluid signal in tear on T2 images
- Associated chondral defect
  - Surgery less likely to result in long term pain relief
SURGICAL IMPLICATIONS
MENISCAL TEAR CHARACTERISTICS

• Repairable
  – Longitudinal >10 mm
  – Peripheral third
  – Bucket handle

• Not repairable
  – Radial and horizontal tear
  – Complex body tears
  – Tears in central 2/3
  – Stable tear
WHAT THE SURGEON WANTS TO KNOW: RADIOLOGY REPORT

- Know the normal anatomy
- Identify abnormal meniscus
  - Abnormal signal touching free edge or morphology
  - Two slice touch rule definite tear; one slice possible tear
  - Use all sequences and planes
- Identify tear location
  - Anterior, body or posterior horn
Characterize the type of meniscal tear
- Horizontal/oblique, vertical/longitudinal, radial, displaced fragments, complex
- Use all sequences and planes
- Associated abnormalities (chondral lesions)

Stable versus unstable tears
Repairable versus not repairable
MR IMAGING OF THE MENISCI

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