

# MRI of the Meniscus, ACL, MCL, and PCL

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## Disclosures

- Book Royalties: Elsevier
- Consultant: Bioclinica
- Advisory Board: POCUSPRO
- Not relevant to this talk

Syllabus on line and other educational material:  
[www.jacobsonmskus.com](http://www.jacobsonmskus.com)

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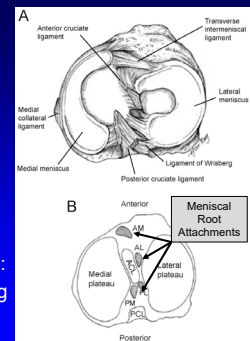
## Outline: MRI Meniscus

- Anatomy
- MRI parameters and accuracy
- Tear criteria on MRI
- Tear classification and examples
- Miscellaneous topics
- Pitfalls

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## Meniscus: anatomy

- Medial meniscus
  - Posterior horn larger
- Lateral meniscus
- Anterior horn, body, posterior horn
- Attached to tibia:
  - 4 meniscal roots
- Menisiofemoral ligaments:
  - Humphrey and Wrisberg
- Intermeniscal ligaments

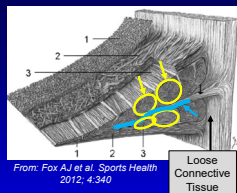


From: Fox AJ et al. Sports Health 2012; 4:340

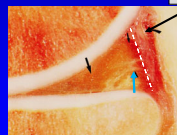
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## Meniscus: microanatomy

- Fibrocartilage
- Circumferential Type 1 collagen bundles (yellow)
- Interwoven radial "tie" fibers (blue)
- Peripheral vascular "red zone"
  - 10 – 30% medial meniscus
  - 10 – 25% lateral meniscus
- Inner avascular "white zone"



From: Fox AJ et al. Sports Health 2012; 4:340



From: Hauger O et al. Radiology 2000; 217:340

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### Meniscus Tear: MRI parameters

- Spin echo or fast spin echo
  - No difference in tear detection rate
- Proton density: favored over T2w (except root tears)
- Slice thickness (3 – 4 mm), FOV (16 cm or less), matrix (at least 192 x 256)
- Tesla: any
  - No difference in detection rates
  - Higher T: higher spacer resolution / faster
    - Improved reader confidence

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal tear: diagnostic accuracy

- No significant difference between 1.5 and 3 Tesla

	Medial Meniscus		Lateral Meniscus	
	1.5 T	3 T	1.5 T	3 T
Sensitivity	93%	96%	77%	82%
Specificity	90%	88%	99%	98%

Van Dyck P et al. JBJS 2013; 95:916

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### Meniscus Tear: MRI criteria

- Abnormal morphology
  - Truncation, absence
- Abnormal signal
  - “Two-slice-touch rule”
  - Extends to articular surface (unequivocally)
  - Two consecutive or orthogonal images



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### Meniscus Tear: MRI criteria

- Positive predictive value for meniscus tear: One slice versus two slice touch

	1 Slice	2 Slice
Medial Meniscus	43%	94%
Lateral Meniscus	18%	96%
Reporting	“Possible Tear”	“Tear”

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscus: internal signal

- Not in contact with articular surface
- Vascularity (periphery): children
- Radial tie fibers (periphery)<sup>1</sup>
- Contusion: globular, ill-defined<sup>2</sup>
- Degenerative signal
  - If linear in medial meniscus: progress to tear
  - If middle aged without osteoarthritis<sup>3</sup>



<sup>1</sup>Hauger O et al. Radiology 2000; 217:340  
<sup>2</sup>Cothran RJ et al. AJR 2001; 177:1189  
<sup>3</sup>Kumm J et al. Radiology 2015; 278:164

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### Meniscus Tear: indirect signs

- Meniscal extrusion: relative to tibia
  - May also occur without meniscal tear<sup>1</sup>
  - Cartilage damage, malalignment
- Abnormal superior popliteomeniscal fascicle<sup>2</sup>
  - Abnormal in 29/30 with lateral meniscal tear
  - Normal in 29/29 with no lateral meniscal tear
- Parameniscal cyst<sup>3</sup>
  - 90 – 100% association (except AHLM: 64%)

<sup>1</sup>Crema MD et al. Radiology 2012; 264:494  
<sup>2</sup>De Smet AA et al. AJR 2001; 176:63  
<sup>3</sup>De Smet AA et al. RJ 2012; 199:481

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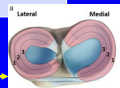
### Meniscal Tear: classification ISAKOS

- International Society of Arthroscopy, Knee Surgery, and Orthopaedic Sports Medicine

1	Tear depth	Partial or complete
2	Location / rim width	Zone 1, 2, or 3
3	Radial location	Anterior, middle, posterior
4	Central to popliteal hiatus	Yes or no
5	Tear pattern	Horizontal, radial, longitudinal, flap, complex
6	Quality of meniscal tissue	Degenerative, nondegenerative, undetermined
7	Tear length	Millimeters

Wadhwa V et al. Eur J Rad 2016; 85:15

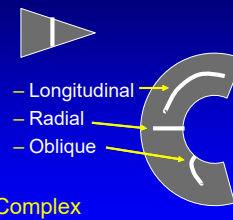
Meniscal Zones



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### Meniscus Tear: MRI Classification

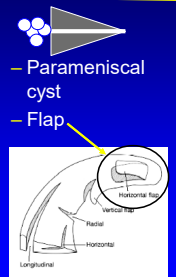
#### Vertical



#### Complex



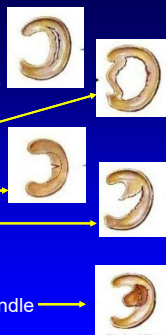
#### Horizontal



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### Meniscus Tear: Classification

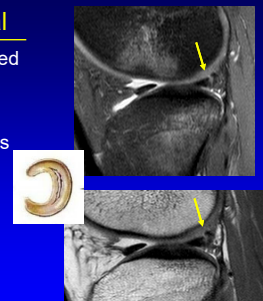
- Vertical
  - Longitudinal:
    - If displaced: bucket handle
  - Radial: possible root tear
  - Oblique: parrot beak or flap
- Horizontal:
  - Parameniscal cyst
  - Displaced: flap, hemi-bucket handle
- Complex



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### Meniscal Tear: vertical

- Longitudinal: non-displaced
- Usually peripheral
- Often traumatic
- Associated with ACL tears
  - 90% of medial tears
  - 83% of lateral tears
- >1 cm in length: unstable
- Pitfall: meniscofemoral ligament of Wrisberg



Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal Tear: vertical

- Longitudinal: displaced
  - Bucket-handle
    - Medial > lateral
    - Double-PCL (medial)
    - Intact meniscal ring
- *Pitfall*: oblique meniscomeniscal ligament

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal Tear: vertical

- Longitudinal: displaced
  - Flipped fragment
    - Connected at one end
  - Free fragment

Lance V et al. Skeletal Radiol 2015; 44:375

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### Meniscal Tear: vertical

- Radial
- Incomplete or complete
- Free edge tear
- Disrupted bow tie appearance of meniscus

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal Tear: vertical

- Radial
- Root tear
  - “Ghost meniscus”
    - Absent on one slice
- Possible meniscal extrusion (relative to tibia)

Choi JY et al. AJR 2014; 203:1286

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### Meniscal Tear: vertical

- Oblique vertical
  - Parrot beak
  - Vertical flap tear

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal Tear: horizontal

- Often to or near apex
- Parameniscal cyst
  - Multilocular
  - Axial plane around meniscus
  - Medial: away from meniscus
- *Pitfall*: AHLM ganglion cyst

Nguyen JC et al. Radiographics 2014; 34:981

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### Meniscal Tear: horizontal

- Horizontal flap tear
- Flap: deep to MCL
  - May not be low signal
- Superior 6x > inferior
- Key: truncated meniscus
- Also: hemi-bucket handle




Lecas LK et al. AJR 2000; 174:161  
Engstrom SK et al Skeletal Radiol 2012; 41:933

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### Meniscal Tear: complex

- Does not fit into one specific tear pattern
- Often degenerative and macerated



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### Miscellaneous

- Healed tear
- Discoid meniscus
- Meniscal flocule
- Meniscal ossicle

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### Healed Tear

- Meniscocapsular junction
- Width < 2 mm
- Only visualized on intermediate-weighted signal sequences
- Intermediate or bright T2 signal with bridging low signal strands




From: Kijowski R et al. AJR 2014; 202:585

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### Discoid Meniscus

- 1 – 5% of knees
- Lateral 10-20x than medial
- 3 variants:
  - Complete: block shape, tear
  - Incomplete: 80% or less tibial coverage
  - Wrisberg variant
- 15 mm on coronal image
- 3 or more bow ties on sagittal image (4 mm thick)

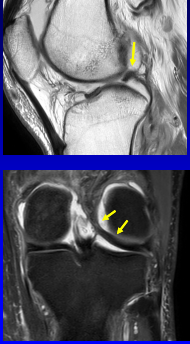


Nguyen JC et al. Radiographics 2014; 34:981

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### Wrisberg Variant

- Discoid meniscus variant
- Incidence: <1 %
- PHLM
  - Only attachment is via Wrisberg ligament
  - Sagittal plane: vertical orientation
  - Possibly thickened
- Hypermobile


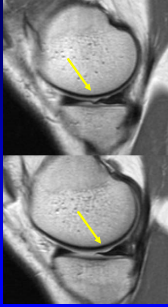


Singh K et al. AJR 2006; 187:384

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### Meniscal Flounce

- Transient physiologic distortion
- Rippled appearance
- 0°
- 30°
- 60°
- 90°
- 120°
- 150°
- 180°

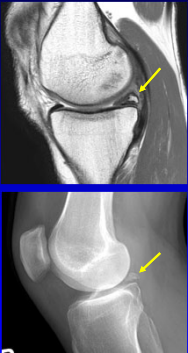



From: Park JS et al. AJR 2006; 187:364

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### Meniscal Ossicle

- Fat containing ossicle
- Posterior horn medial meniscus: 88%
- Incidence: 0.15%
- Traumatic: associated with meniscal or root tear
- Vestigial: Bengal tigers and some rodents
- Simulate tear or intra-articular body



Mohankumar R et al. AJR 2014; 302:1040

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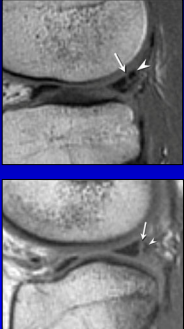
### Pitfalls

- Lateral meniscus "rip tear"
- Oblique meniscomeniscal ligament
- Meniscocapsular separation
- Parameniscal cyst: AHLM

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### PHLM Rip Tear

- Longitudinal tear PHLM
- Associated with ACL tears
- Pitfall: continuous with meniscomeniscal ligament
- Cleft >3 images lateral to PCL (>10 mm) = tear

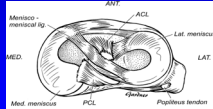



Park et al. Skeletal Radiol 2007; 36:399

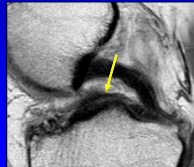
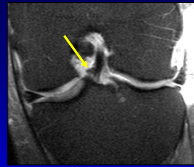
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## Oblique Meniscomeniscal Ligament

- Normal variant: 1 – 4%
- Crosses from medial to lateral meniscus
- Either direction
- Simulates bucket handle tear



Sanders TG et al. Radiology 1999; 213:213



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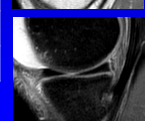
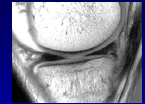
## Meniscocapsular Separation

- MRI inaccurate
- Positive predictive values:
  - 9% medial and 13% lateral

MRI Finding	Positive Predictive Value: Medial	Positive Predictive Value: Lateral
Meniscal displacement > 5 mm	0%	4%
Meniscal corner tear	0%	50%
Fluid signal at meniscocapsular border	0%	0%
Abnormal meniscal fascicle	---	8%

Rubin DA et al. Radiology 1996; 201:829

\*These cases were negative for meniscocapsular separation

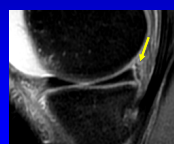
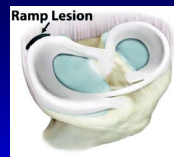


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## Ramp Lesion

- PHMM tear:
  - Longitudinal
  - Peripheral attachment
  - < 2.5 cm in length
- Associated with ACL tear
  - Seen in 17% of ACL tears
- Difficult to see at arthroscopy
- Form of meniscocapsular separation?

Chahla J et al. Ortho J Sports Med 2016  
Liu X et al. Am J Sports Med 2011; 39:832

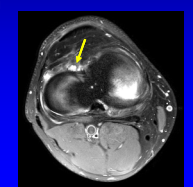
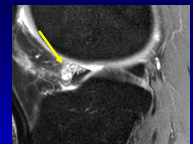


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## AHLM Cyst

- Parameniscal cyst
- Anterior horn lateral meniscus
- Multilocular
- Associated with meniscal tear in only 60% if AHLM
  - If at body and posterior horn lateral meniscus = 100% meniscal tear

De Smet AA et al. AJR 2011; 196:W180



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## Meniscus: Take Home Points

- MRI diagnosis:
  - 2-slice-touch rule
- Basic description:
  - Vertical, horizontal, complex
- Pitfalls:
  - Flap tear: look under MCL
  - Root tear: posterior
  - Meniscocapsular separation

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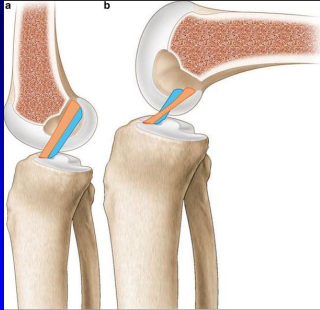
## Outline:

- ACL injury
- MCL injury
- PCL injury

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### ACL Anatomy

- Intra-articular but extrasynovial
- Anteromedial bundle
  - (orange)
  - Thin, taut in flexion
- Posterolateral bundle
  - (blue)
  - Thick, taut in extension
- Attaches to tibial eminence (anterior to tibial spines)



*From: Bicer EK, Knee Surg Sport Trauma, Arthros 2009*

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### ACL Tear

- Most common knee ligament injury
- 3x more common in women
- Complete tears > partial tears
- Midsubstance > femoral attachment
- 3 bruise / fracture patterns

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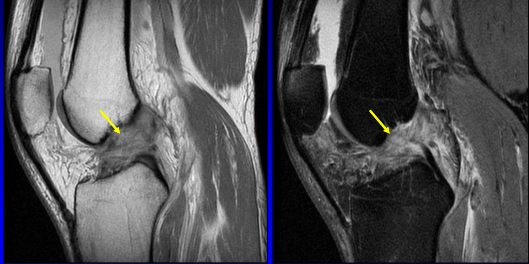
### ACL Tear:

- Abnormal signal
  - T1w, PDw: heterogeneous
  - T2w: fluid signal
- Ligament fiber discontinuity
- Abnormal horizontal orientation
- Accuracy >95% with MRI

*Umans, AJR 1995;165:893–897*

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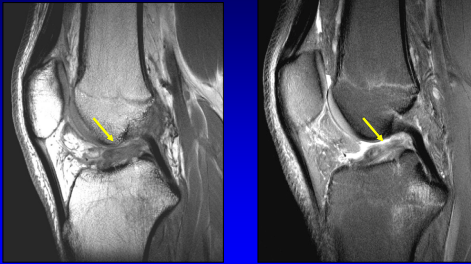
### ACL: full-thickness tear



PD-weighted      T2-weighted

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### ACL: full-thickness tear



PD-weighted      T2-weighted

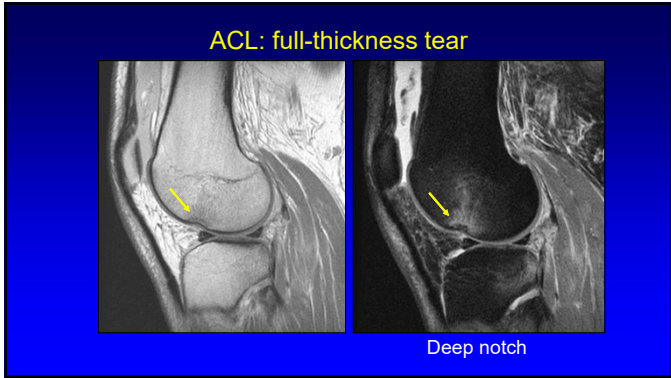
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### ACL Tear: Fracture pattern #1

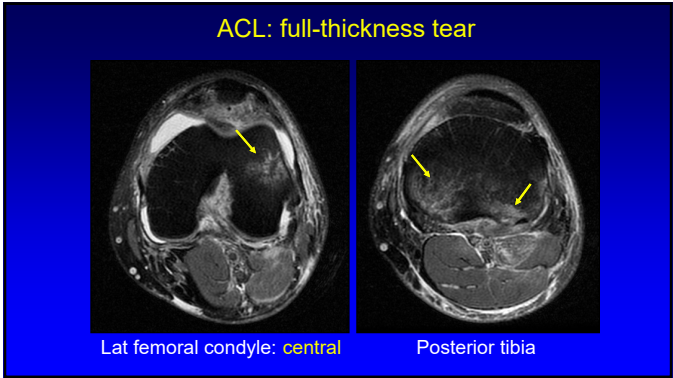
- Lateral femoral condyle impaction
  - MRI: bruise, possible fracture
  - Deep notch sign: >1.5 – 2 mm
- Tibia bruise: posterior
- MCL tear
- PFLM: longitudinal tear

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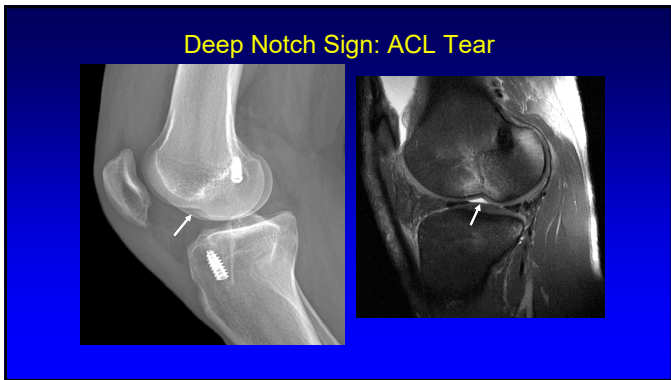




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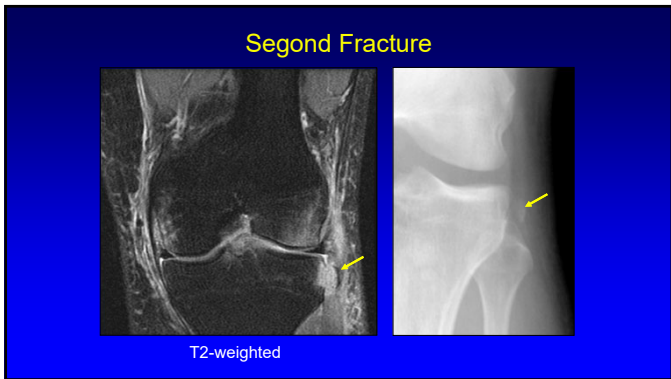
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**ACL Tear: fracture pattern #2**

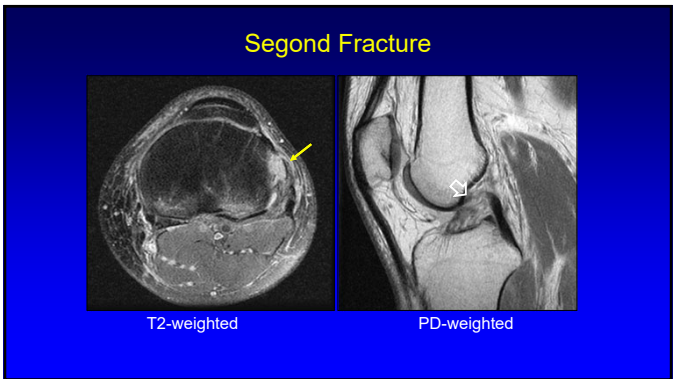
- Second fracture
  - Avulsion: lateral tibia
  - Anterolateral ligament attachment
  - Radiography: correlation
  - Indicates ACL tear in 75 – 100%

Campos JC et al. Radiology 2001;219:381.

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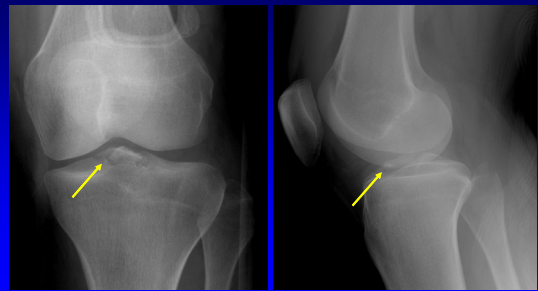
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### ACL Tear: fracture pattern #3

- Anterior tibial eminence avulsion
  - ACL intact
  - ACL effectively torn
  - More common in children

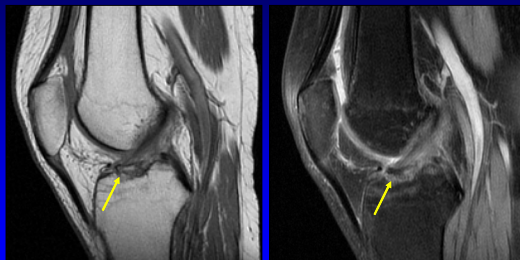
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### Anterior Tibial Eminence Avulsion



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### Anterior Tibial Eminence Avulsion



PD-weighted

T2-weighted

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### ACL Tear:

- Secondary signs:
  - Lateral compartment bone bruise
  - Anterior tibial translation
    - >5 mm
    - Measure from midline of lateral tibial plateau
  - 80% positive predictive value

Brandser AJR 1996;167:121

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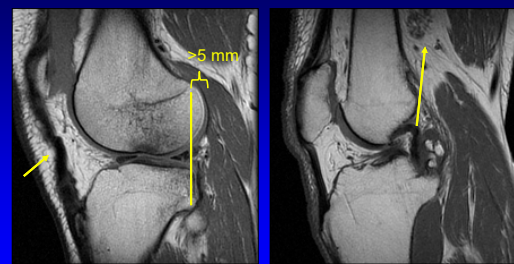
### ACL Tear:

- Other secondary signs:
  - Uncovered lateral meniscus
  - PCL buckling
  - Patellar tendon buckling
  - All related to anterior drawer sign

Brandser AJR 1996;167:121

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### ACL Tear: secondary signs



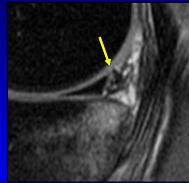
Anterior drawer,  
Buckled patellar tendon

Buckled PCL

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### ACL Injury

- Associate meniscal tears:
  - PHMM: peripheral, meniscocapsular separation →
  - O'Donoghue triad:
    - ACL, MCL, MM tear
  - PHLM: longitudinal tear



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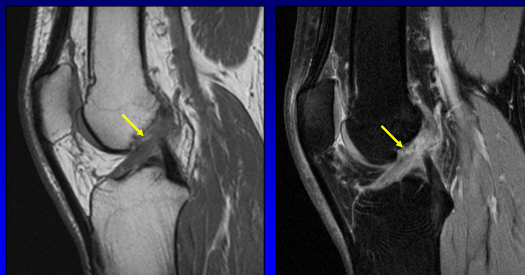
### ACL Tear: pitfalls

- Partial tear: some discontinuity, spared fibers
- Remote full-thickness tear
  - Scarred to PCL, more horizontal
  - No indirect signs (drawer, bruise, effusion)
- Mucoïd degeneration
  - Celery stalk, no indirect signs
  - Associated ganglion cysts, no instability

Bergin D et al. AJR 2004;182:1283.

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### ACL: partial-thickness tear

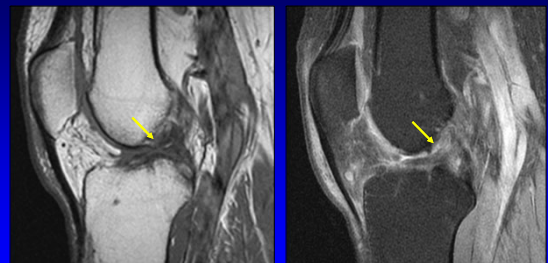


PD-weighted

T2-weighted

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### ACL: remote full-thickness tear

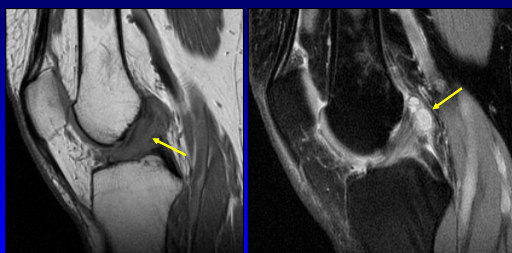


PD-weighted

T2-weighted

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### ACL: mucoïd degeneration + ganglion



PD-weighted

T2-weighted

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### Outline:

- ACL injury
- MCL injury
- PCL injury

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### MCL Anatomy

- 2 layers
- Superficial layer:
  - Tibial collateral ligament
  - 1 femoral attachment
  - 2 tibial attachments
- Deep layer
  - Meniscomemor ligament
  - Meniscotibial ligament

*From: LaPrade, JBJS(Am) 2007; 89:2000.*

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### MCL Anatomy

- Superficial layer
  - Tibial collateral ligament
  - 9.5 cm in length
  - Strongest layer
  - Courses under pes anserinus tendons

*From: LaPrade, JBJS(Am) 2007; 89:2000.*

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### MCL Injury

- Proximal tears more common
- Grading system:
  - Grade 1: surrounding edema
  - Grade 2: internal edema
  - Grade 3: complete discontinuity
- Grading system does not reflect clinical instability and is limited

*Schweitzer, Radiology 1995; 194:825*

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### MCL Tear

Grade 1                      Grade 2

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### MCL Tear: Grade 3

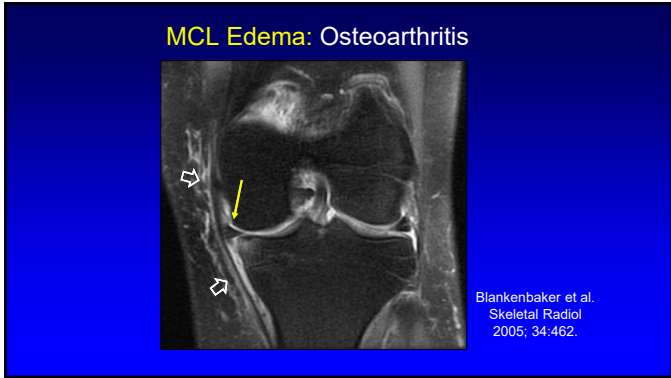
T2-weighted                      T2-weighted

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### MCL Tear: Grade ?

Anterior fibers torn, posterior fibers intact

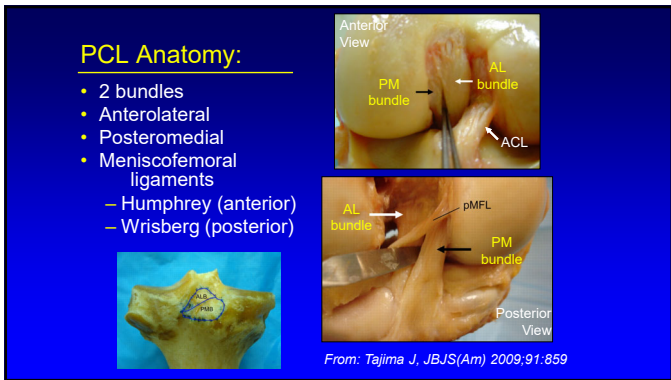
72



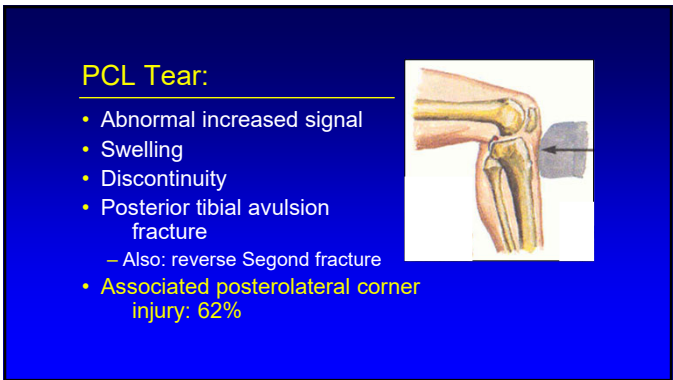
73



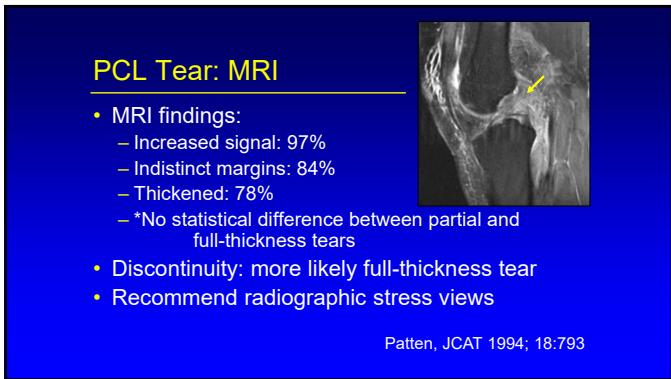
74



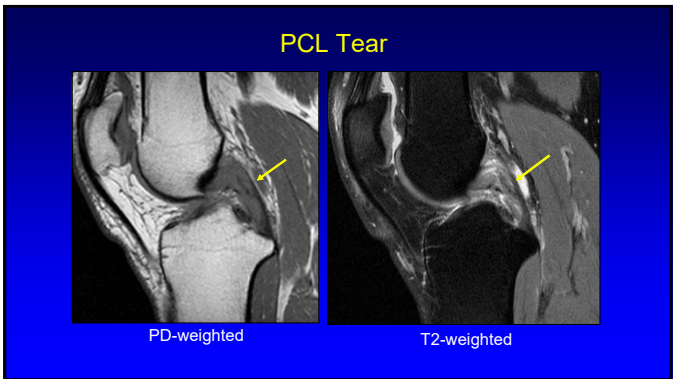
75



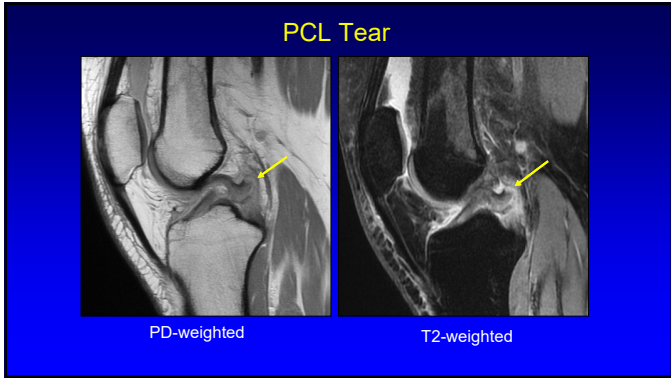
76



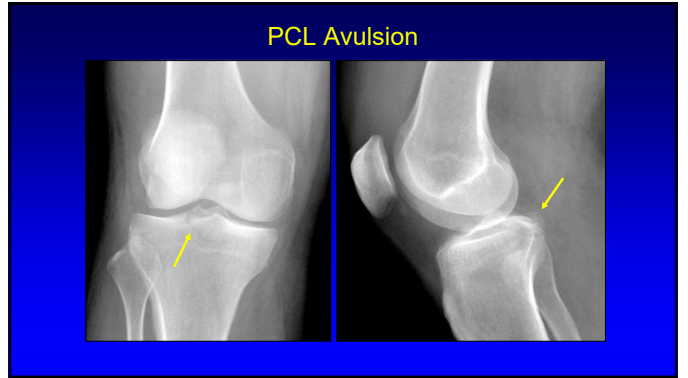
77



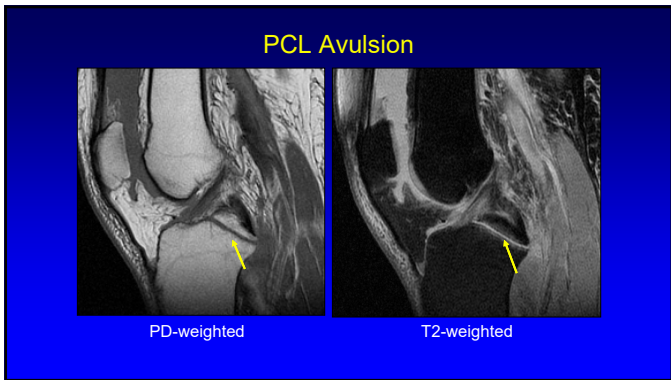
78



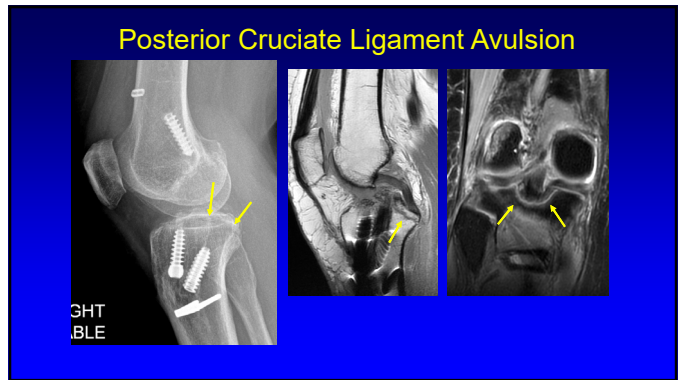
79



80





81



82

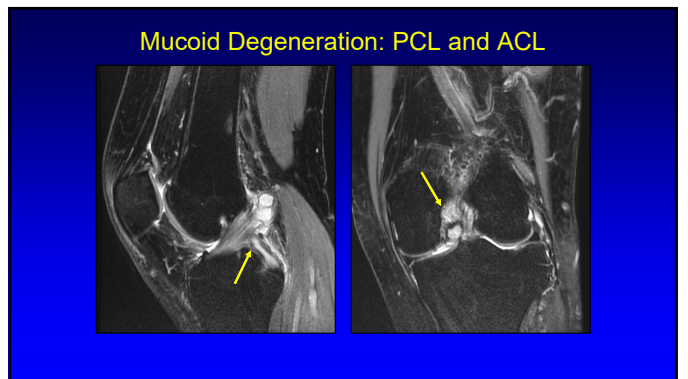
### Reverse Segond Fracture

- Avulsion: deep portion of MCL
- Associated:
  - PCL tear
  - PHMM tear

From: Escobedo AJR 2002; 178:979

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Thank you!

Syllabus on line and other educational material:  
[www.jacobsonmskus.com](http://www.jacobsonmskus.com)

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