MRI of the Knee

Cruciate and Collateral Ligaments

Jefferson MSK
ALL WE DO IS BONES

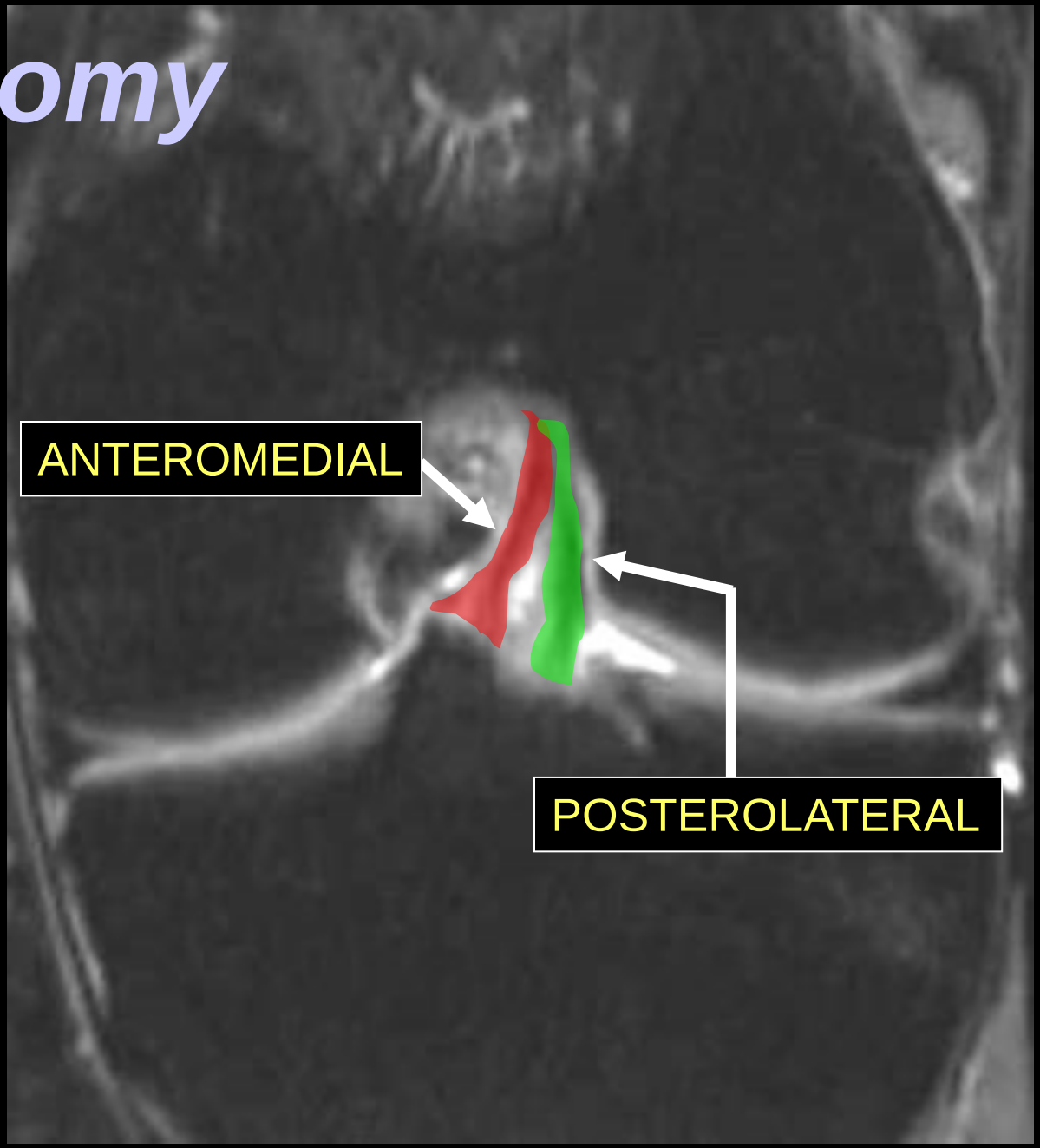
www.Jefferson.edu/MSK
Twitter: @MorrisonMSK
William.Morrison@Jefferson.edu

William B. Morrison, M.D.
Thomas Jefferson University Hospital
Philadelphia, PA

Cruciate Ligaments

ACL Anatomy

BUNDLES



ACL Anatomy

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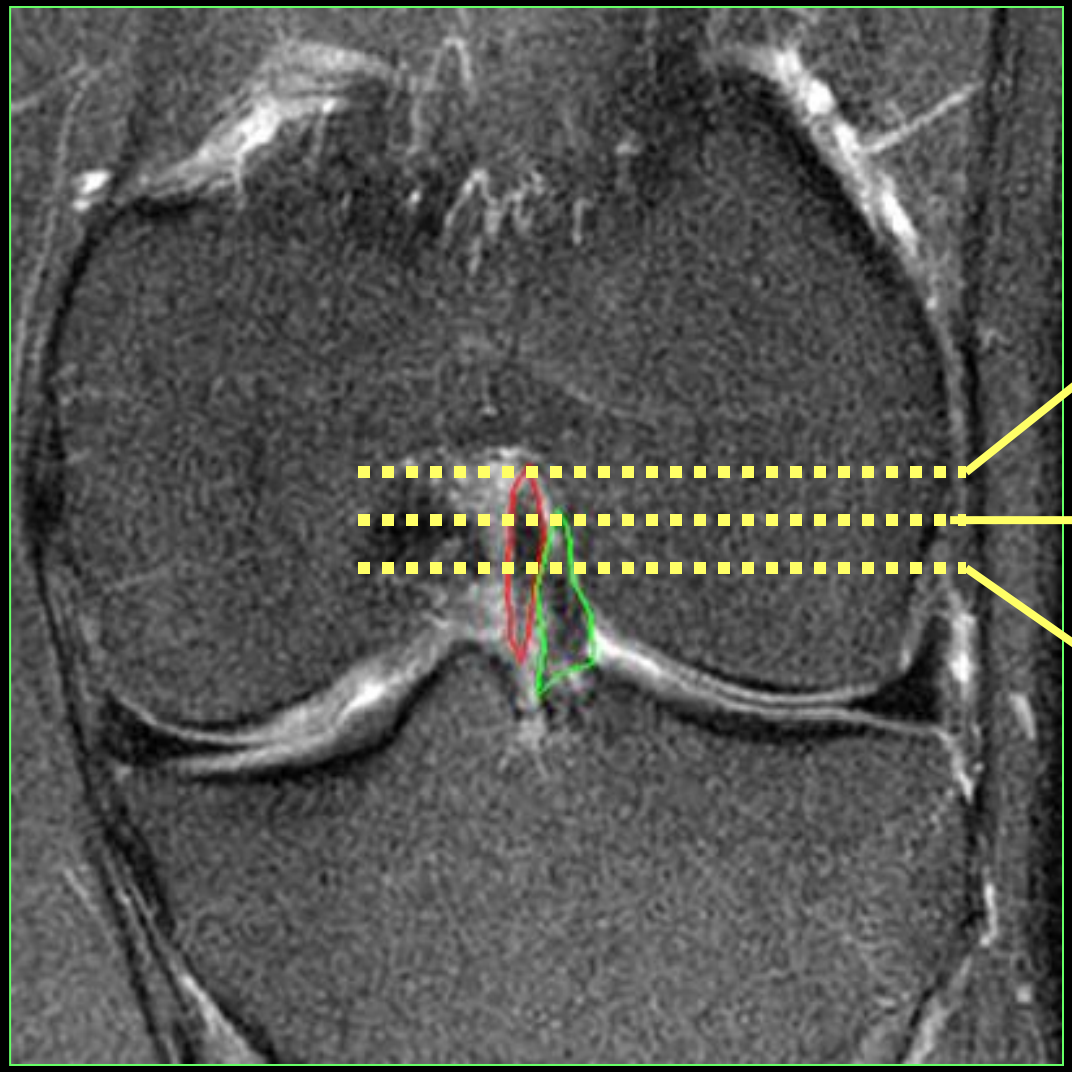
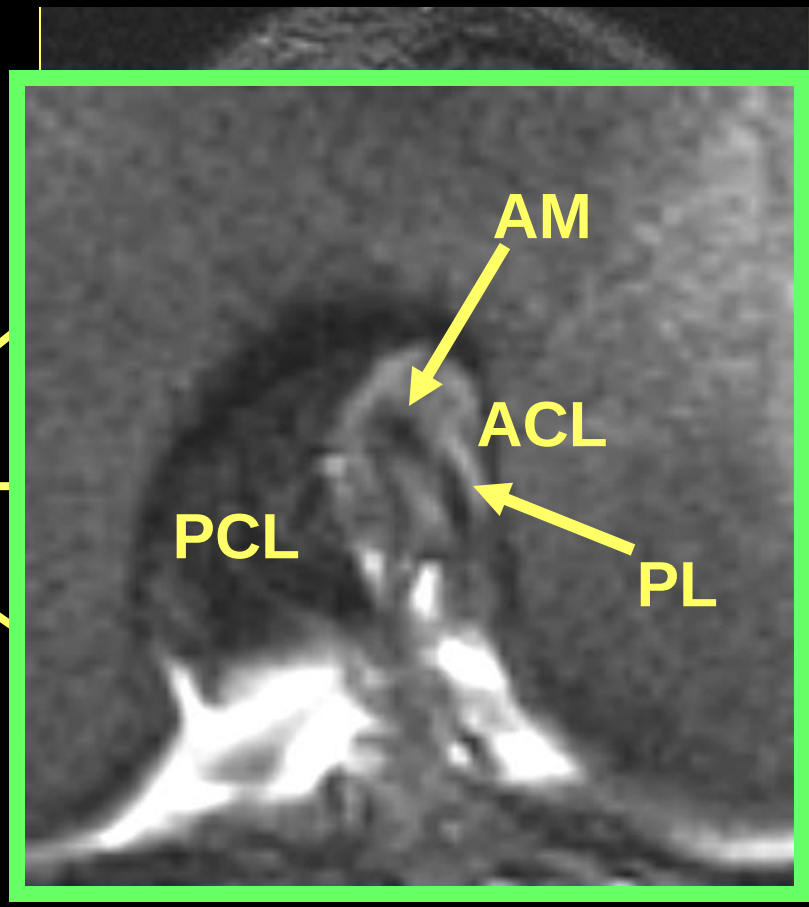


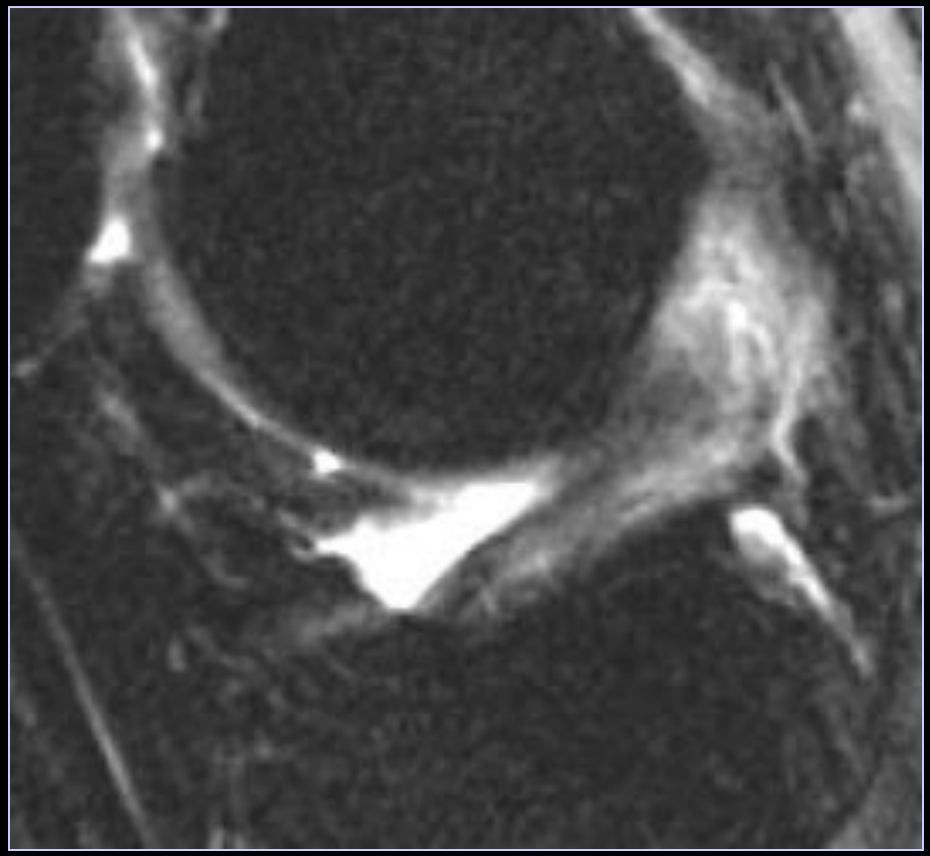


ACL Tear

- **MR**: 95-100% **accurate**
  - **midportion** > proximal > distal (avulsion)
- concomitant injuries common (**MCL, menisci**)
- **complete** >> partial
- **discordant findings**
  - T1 vs T2 discordant findings: ***believe T2***
  - Sag vs coronal / axial: all helpful – unequivocally intact in ***any*** plane **= *intact***

ACL Tear
Primary Signs

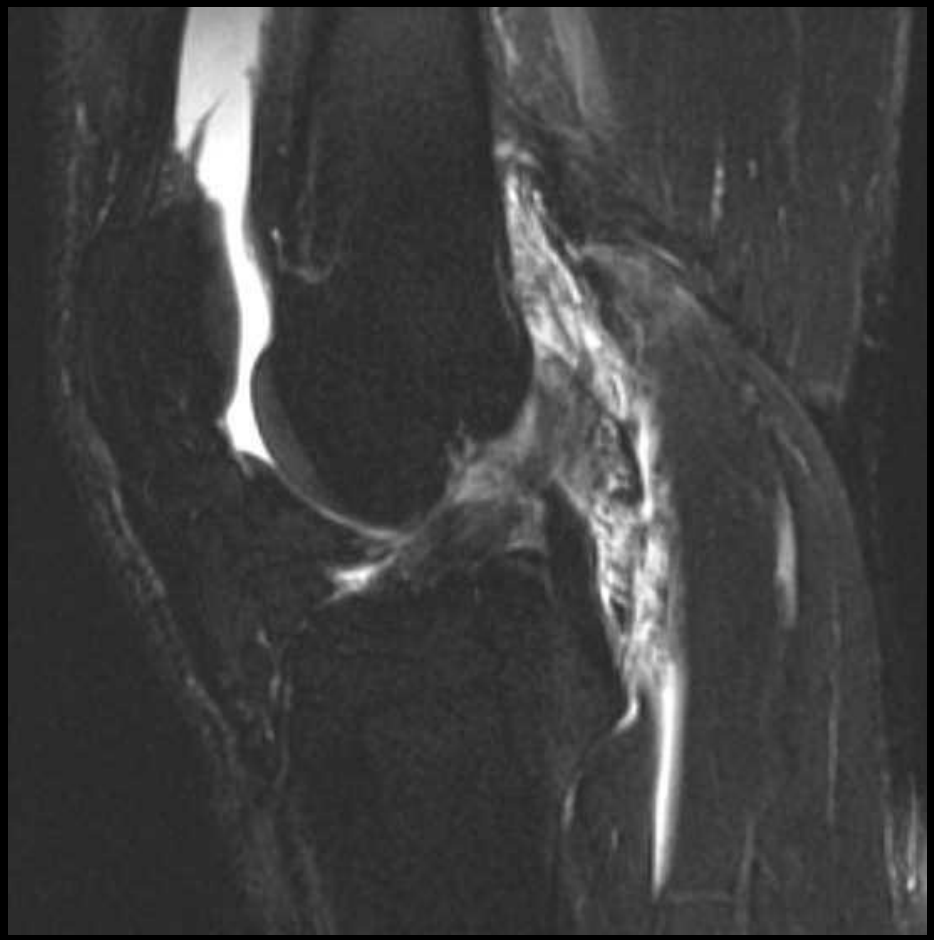
- Signal changes
  - Edema on T2w
- Morphologic changes
  - Discontinuity of fibers
  - Abrupt angulation/wavy
  - Fibers “fallen” – not parallel to Blumensaat line



Acute ACL Tear

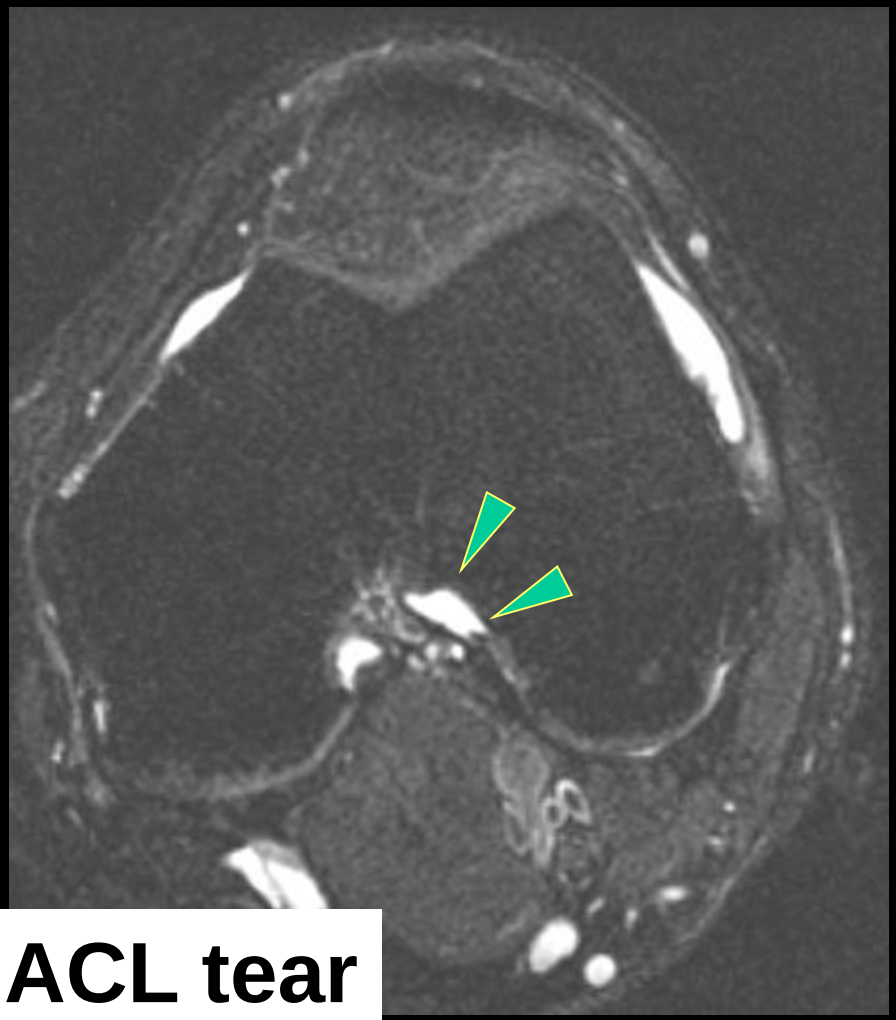
Edema, mass effect, discontinuity of fibers, characteristic bruises

Acute ACL Tear



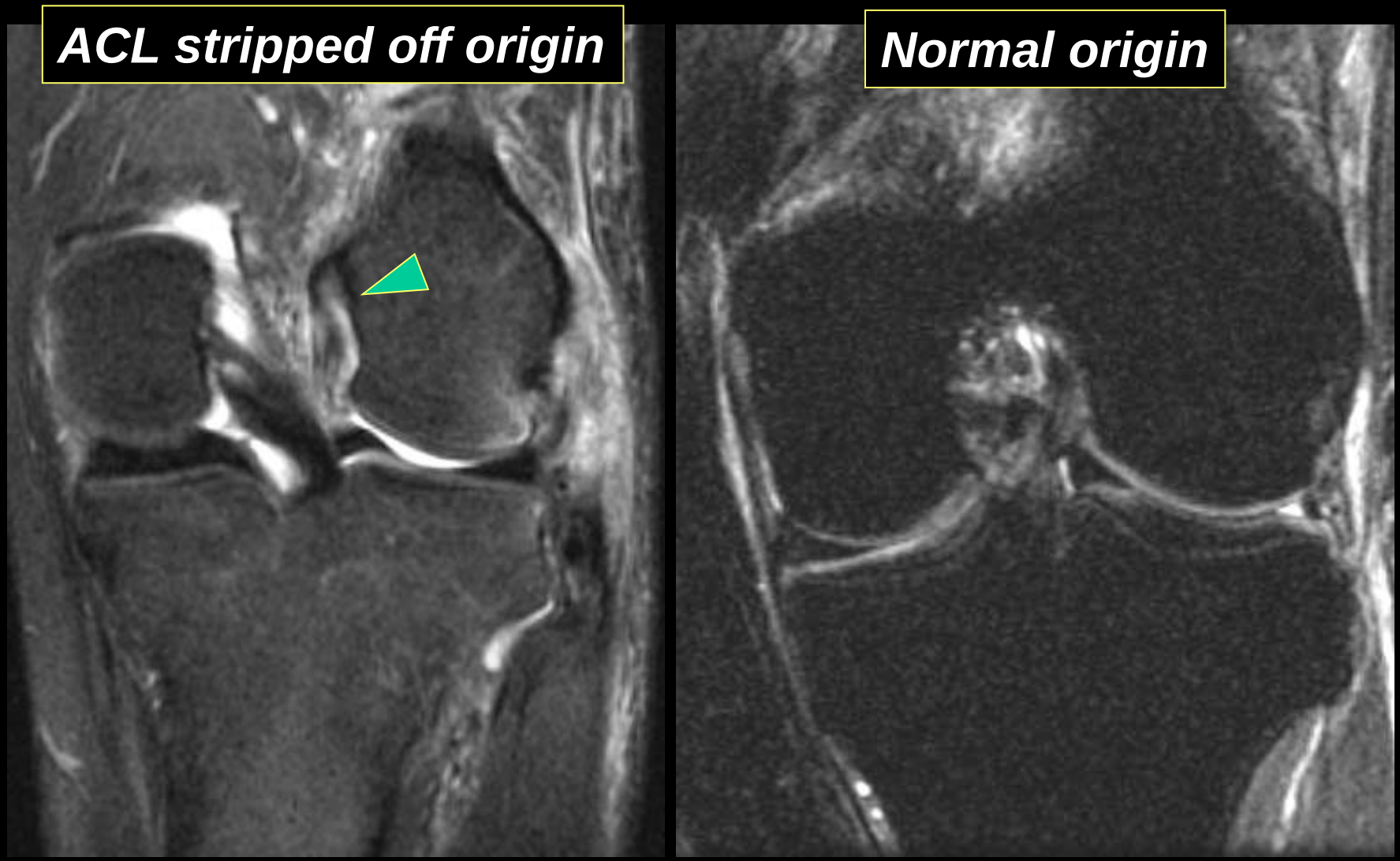
Midsubstance tear

ACL Tear:
“empty notch sign”



Proximal ACL tear

Acute ACL Tear



ACL Tear: Secondary Signs

Bone bruise pattern = BEST

- Characteristic bone contusion pattern
- Deep lateral femoral notch

Anterior drawer

- Anterior tibial translation
- PCL buckling

Hyperextension Injury

- Common mechanism for ACL (and PCL) tear
- Kissing anterior marrow edema pattern

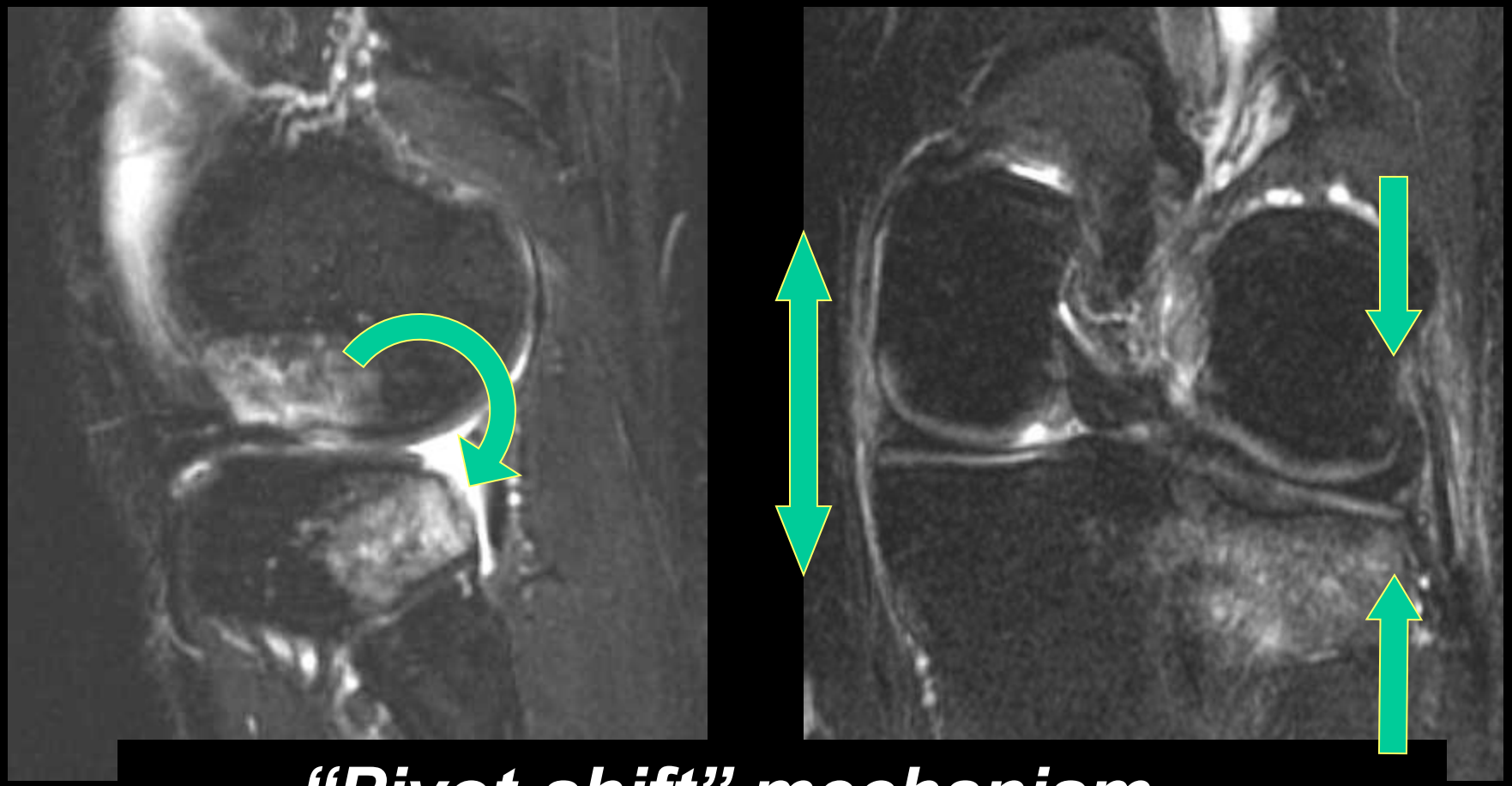
Hyperextension Injury

Kissing anterior marrow edema pattern

Usually medial

Secondary signs ACL tear

ACL Tear: Bone Bruise Pattern



"Pivot-shift" mechanism

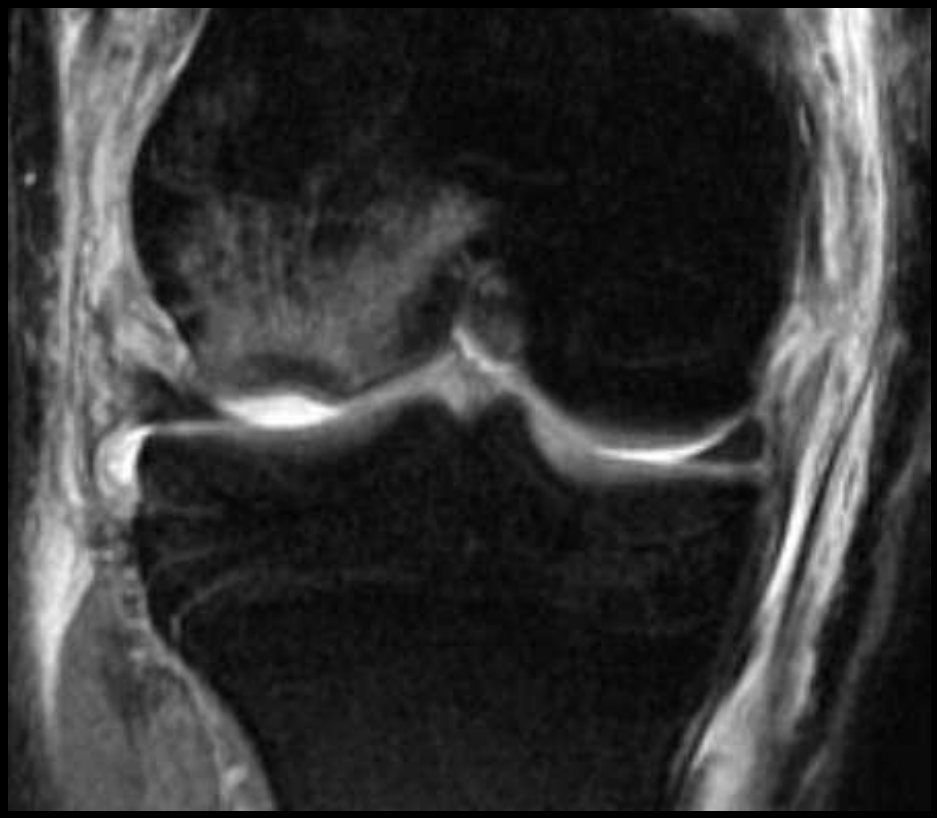
Lateral meniscal tear: impaction of posterior horn

+/- valgus stress: MCL, medial meniscal injury

Secondary signs ACL tear

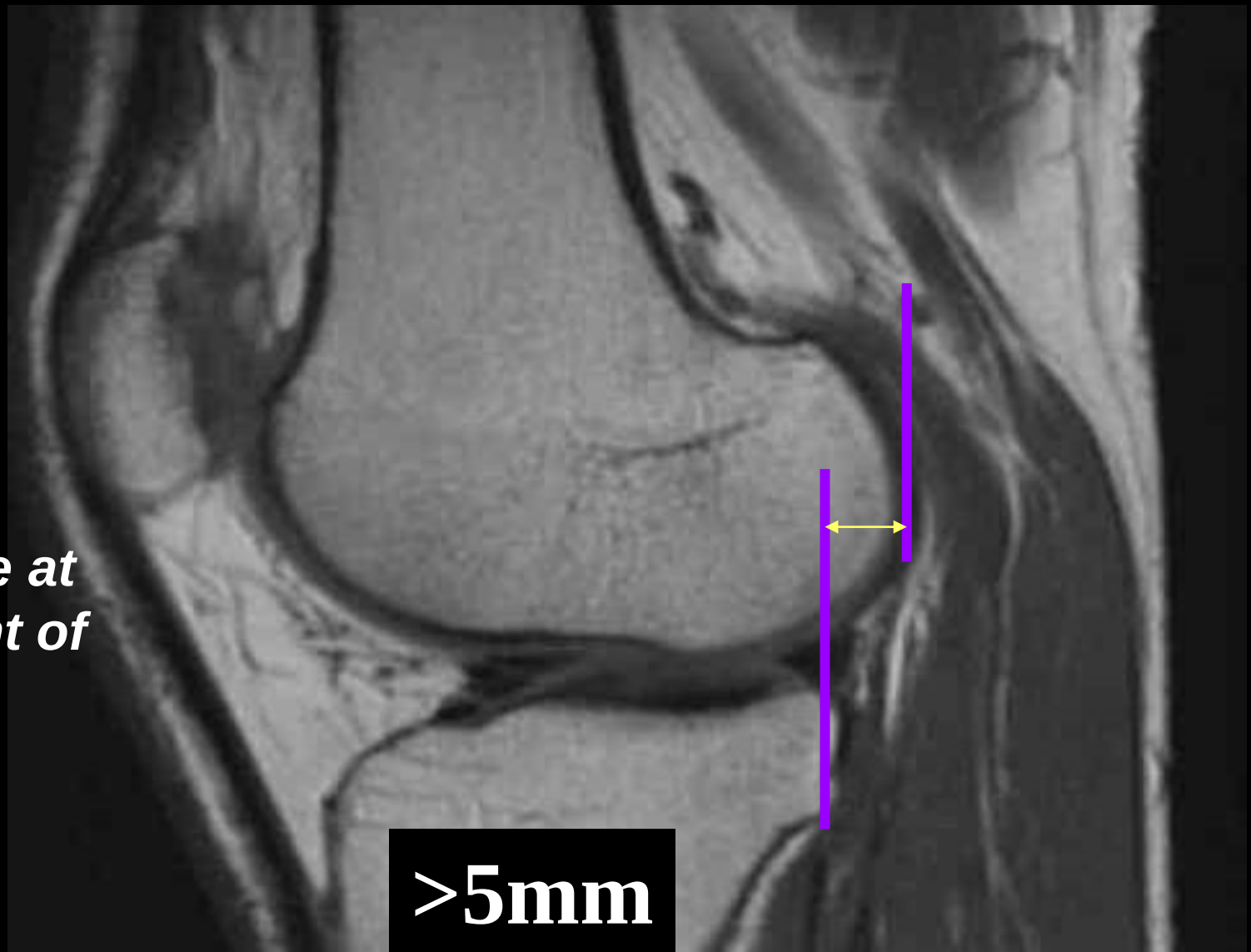
Deep Lateral Femoral Sulcus

Sulcus terminalis, junction of patellofemoral and tibiofemoral cartilage surfaces
-Normally a small dip, relatively thin cartilage



Secondary signs ACL tear

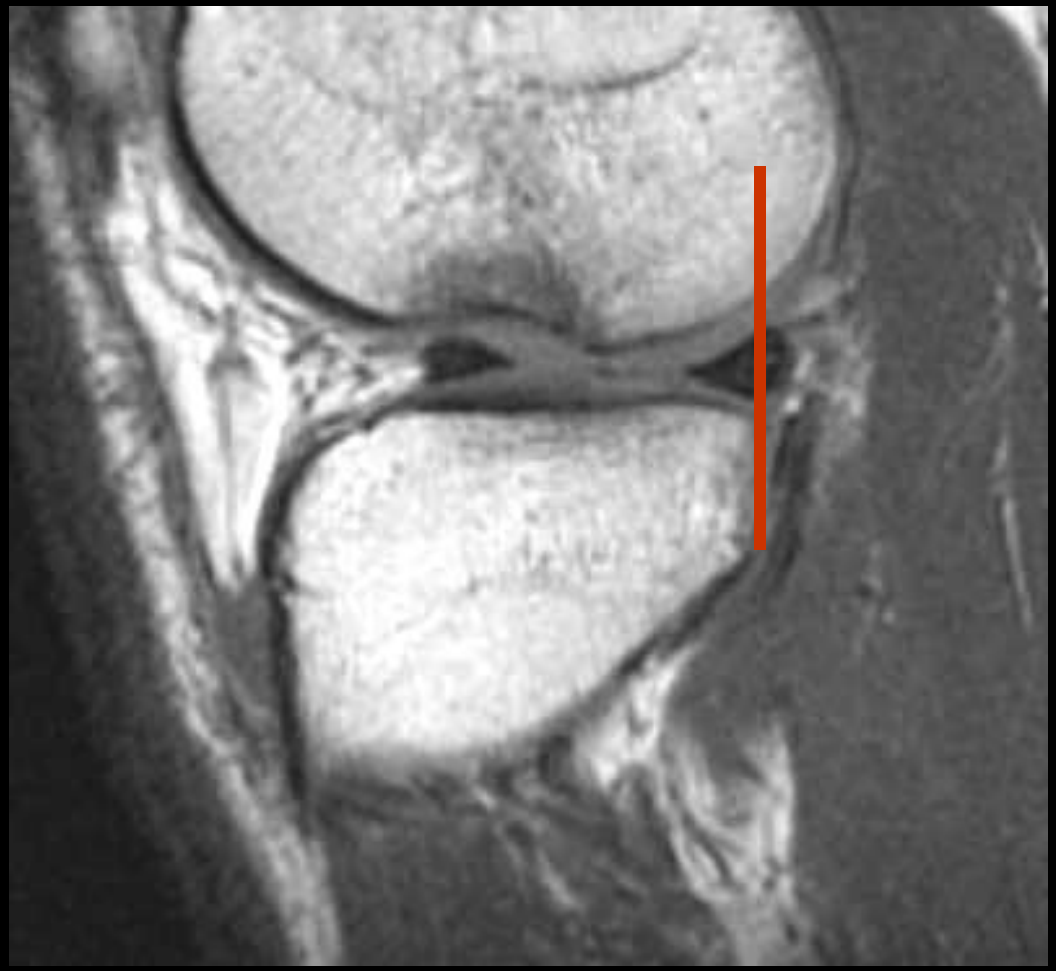
Anterior Tibial Translation



Measure at midpoint of lateral femoral condyle

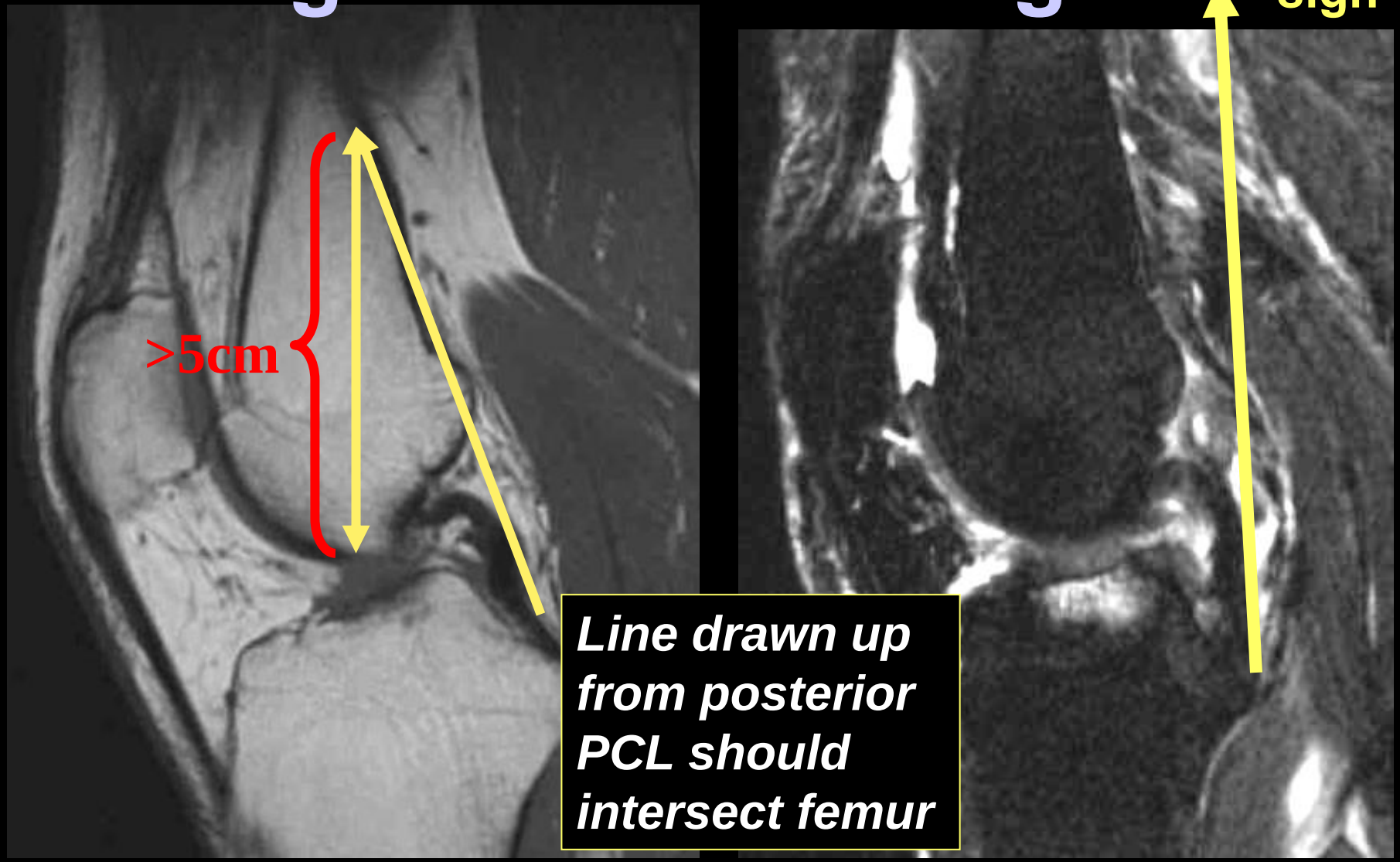
Secondary signs ACL tear

Uncovered Posterior Horn Lateral Meniscus



Secondary signs ACL tear

PCL Sign: PCL 'Buckling'



Secondary signs ACL tear

Fibular Collateral Ligament Sign

FCL seen on one coronal image (not a good sign, depends on technologist section prescription)

ACL Tear: Associated Fractures

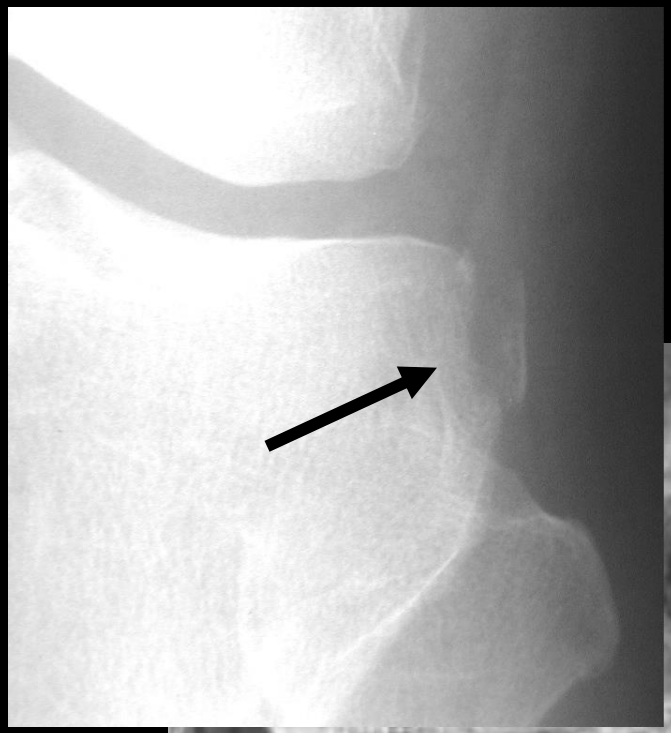
Segond fracture

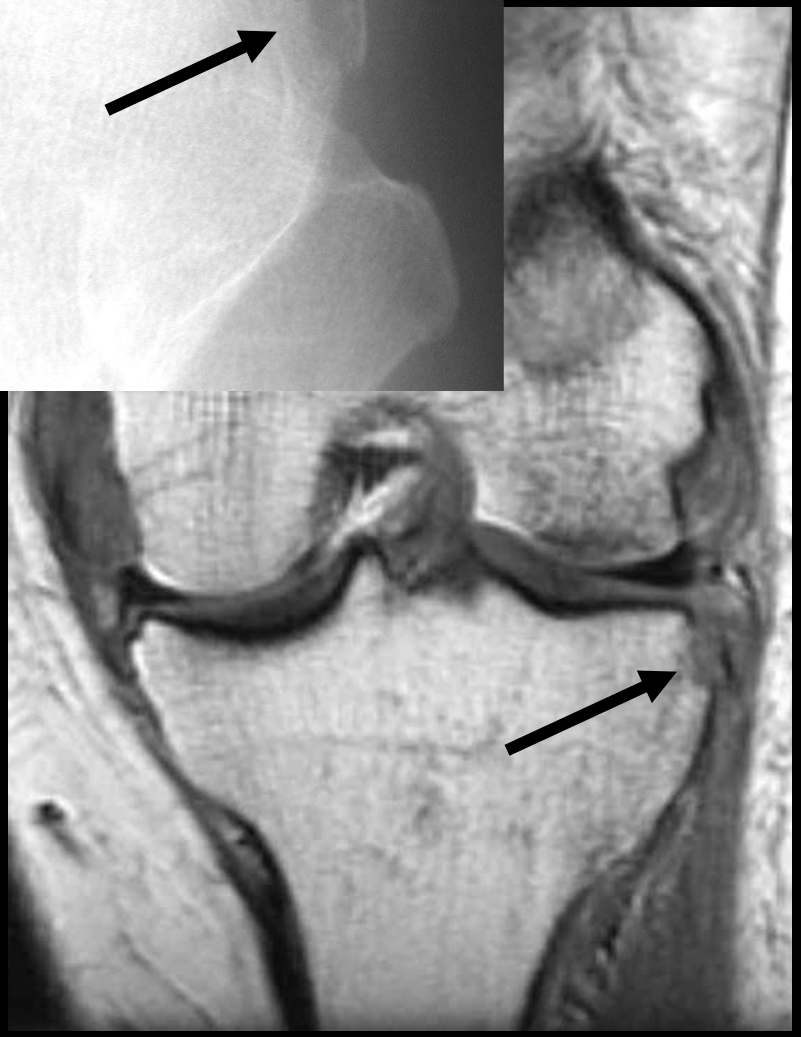
- Lateral capsular ligament avulsion
- Fracture itself minor
- 90% association with ACL tear
- 60% association with meniscal tear

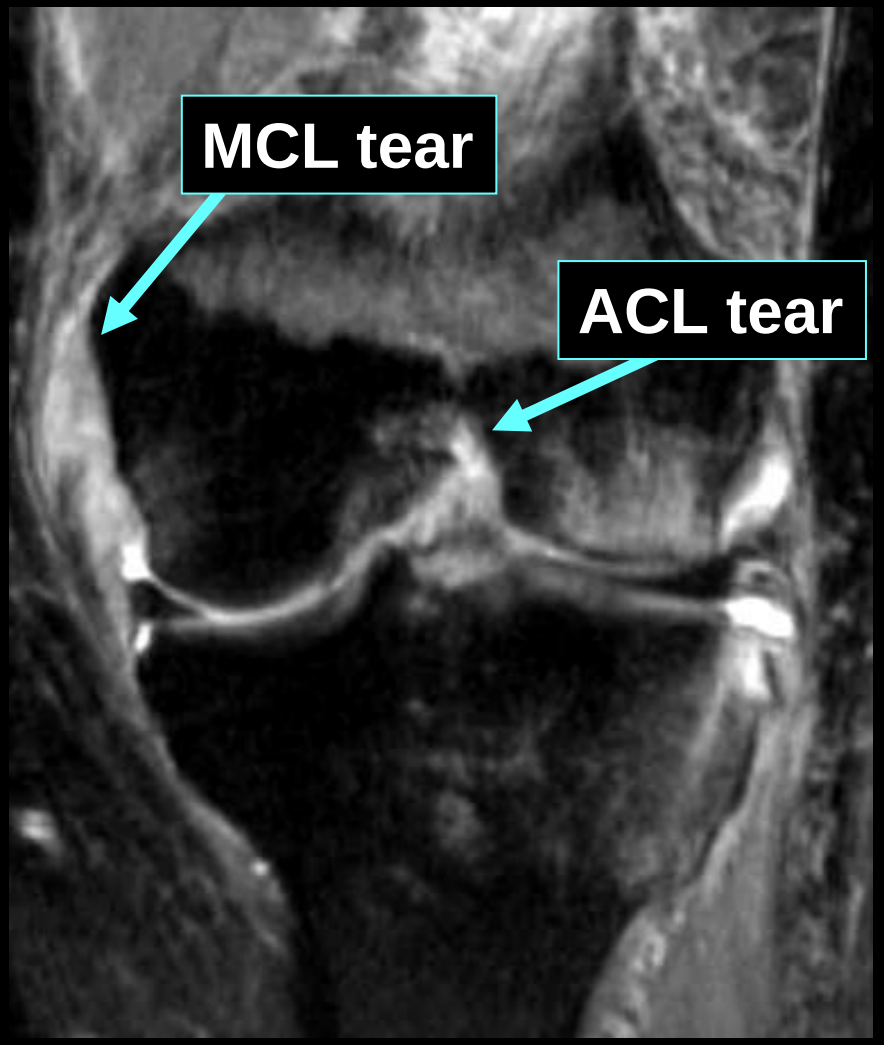
Tibial attachment of ACL

- Young males
- Potential for healing

Segond Fracture





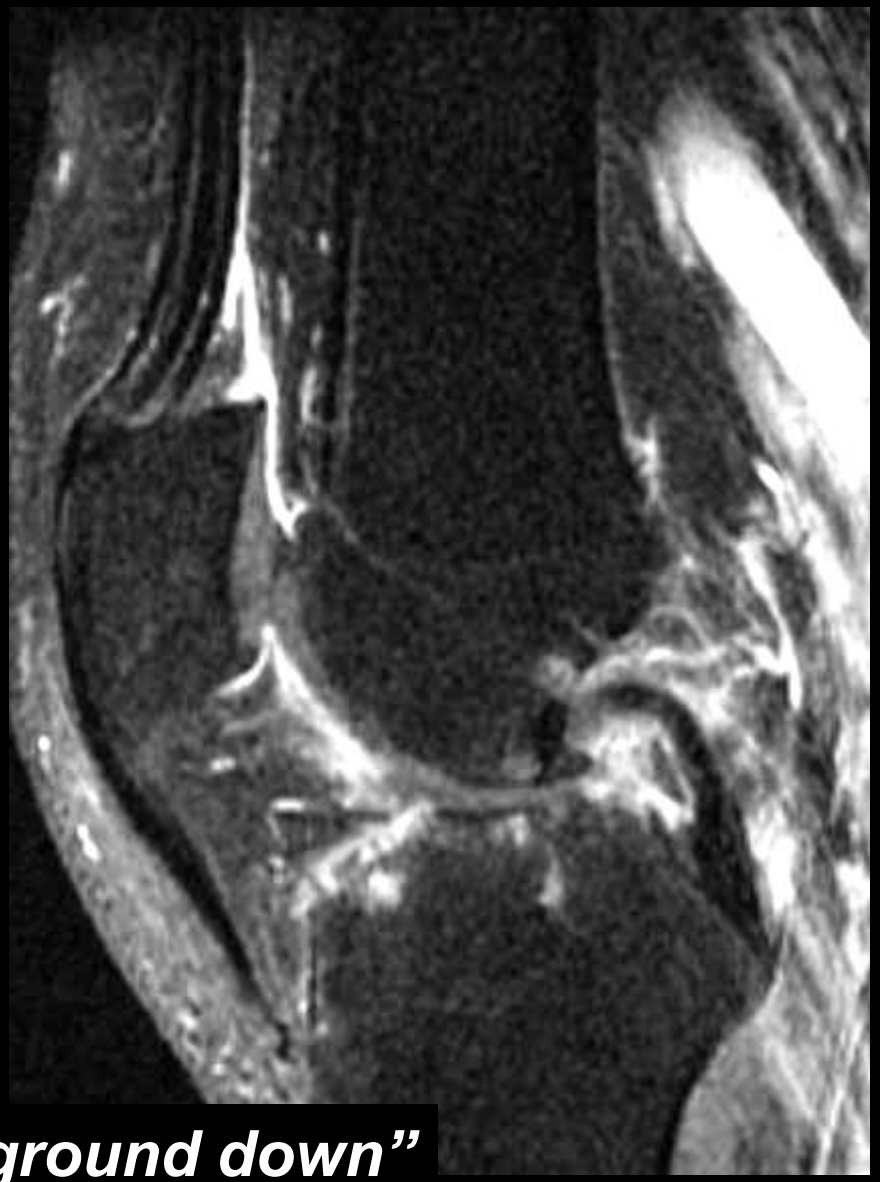


Tibial Spine Avulsion

Potential to heal

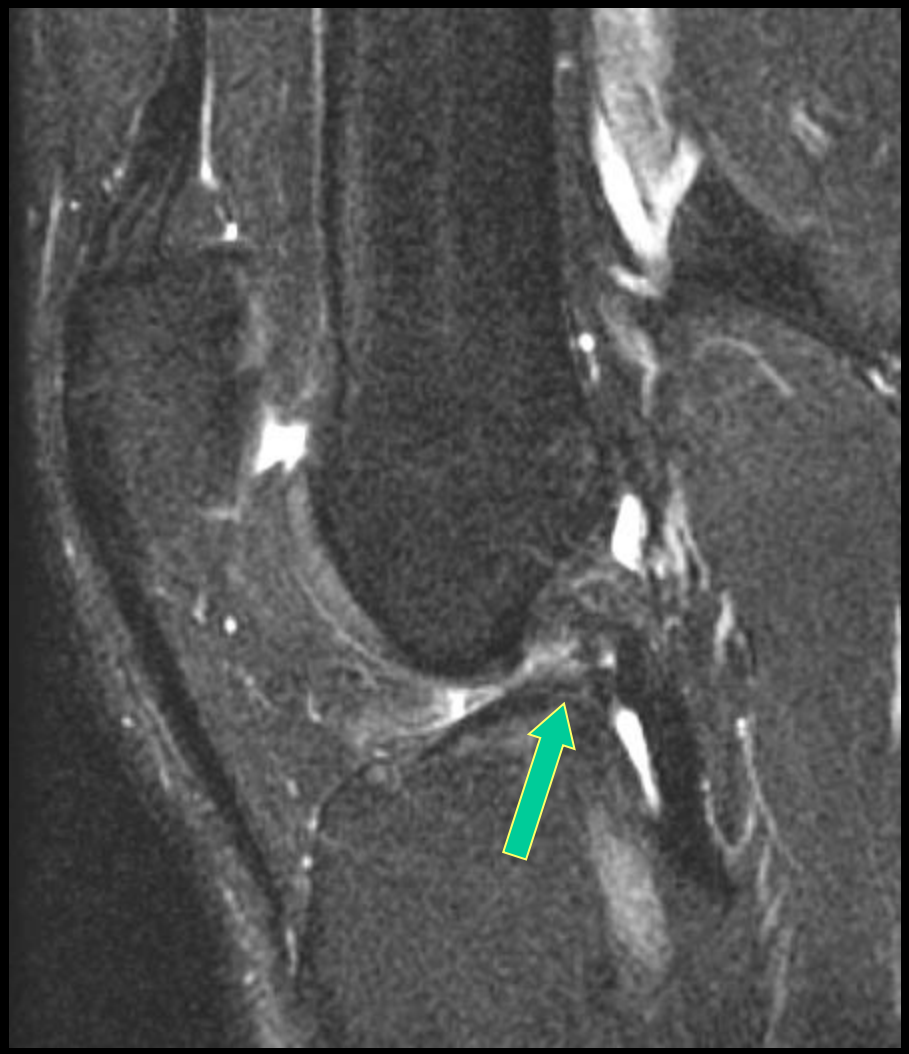
Avulsion: Tibial Insertion of ACL

Remote ACL Tear (>8wks)



Absent ACL – "ground down"

Remote ACL Tear



Patients often "re-buckle" resulting in pivot-shift bone bruises, with apparently chronic ACL tear

Fusion to PCL or meniscofemoral ligament

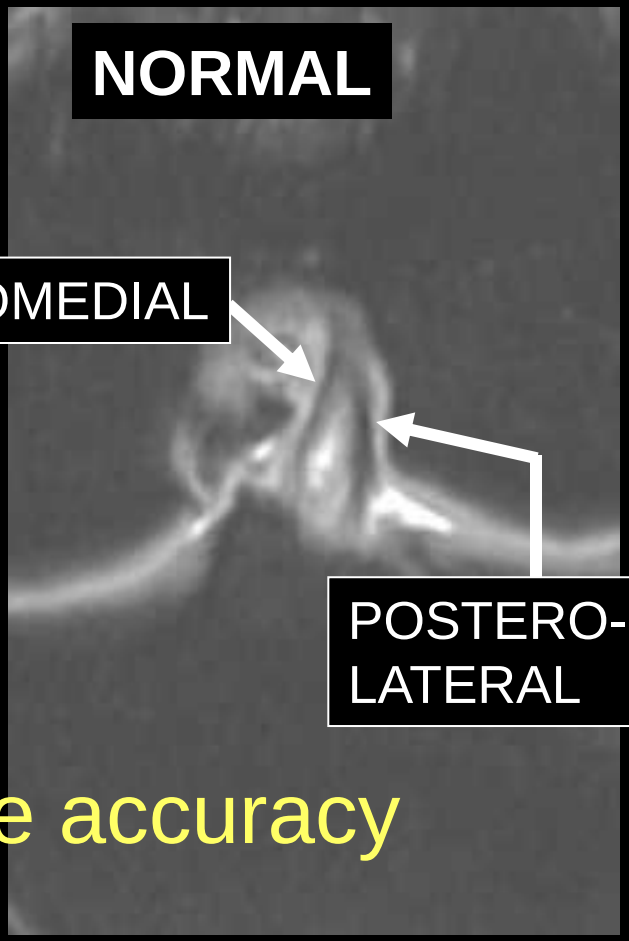
Delayed Sequela: Pivot-shift

Two years after injury

Persistent ‘dent’ Sulcus terminalis, tibial plateau

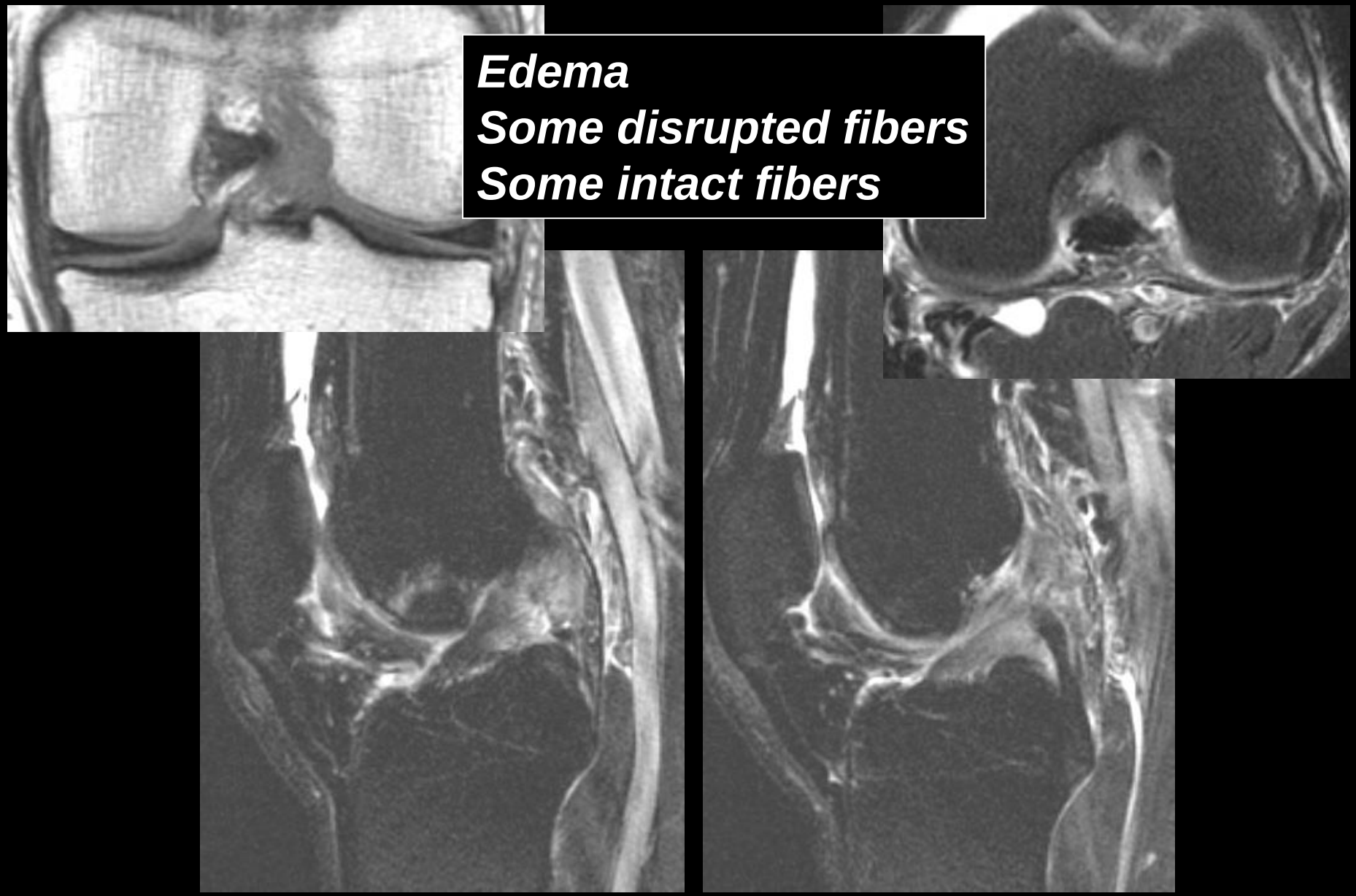
Cartilage loss posterior tibial plateau with cyst

Partial ACL Tear



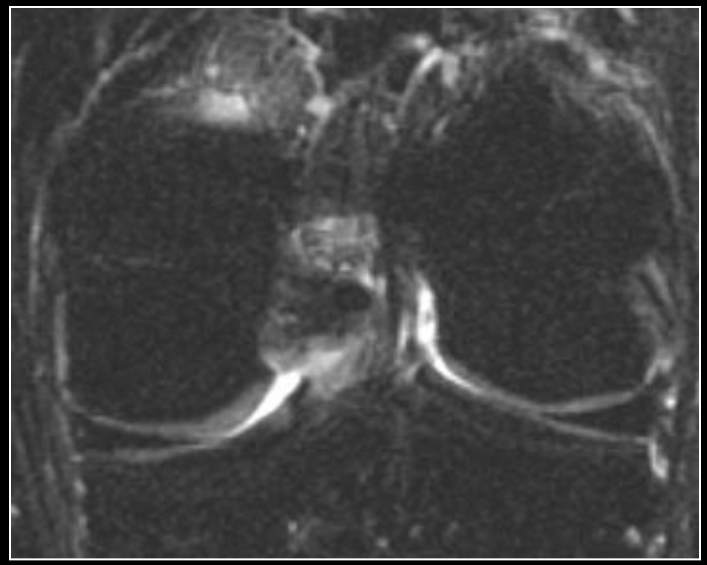
- Difficult to diagnose by MRI
- Edema of ACL
- Some fibers remain intact
- Axial, coronal planes improve accuracy
  - *Try to visualize both bundles*
- Look for secondary signs
- Correlate with Lachman test (anterior drawer)

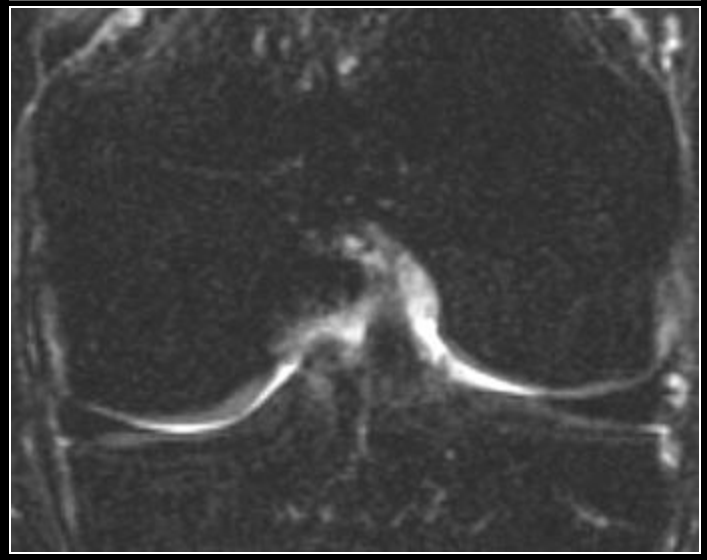
Partial ACL Tear - *Subacute*

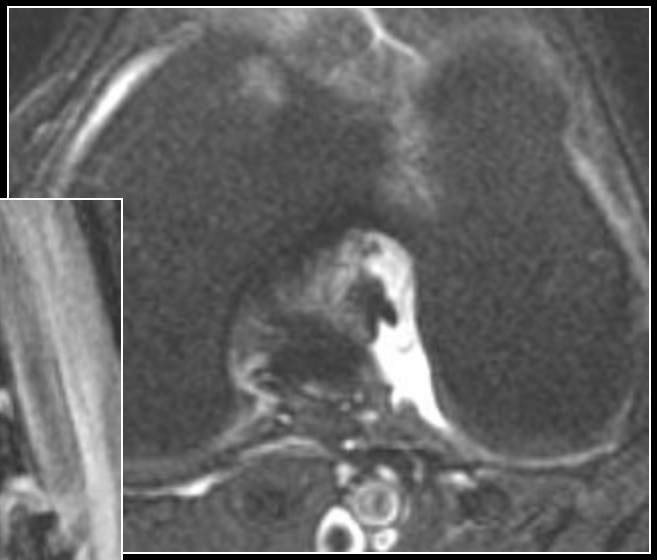


Edema
Some disrupted fibers
Some intact fibers

Partial ACL Tear – same patient, 1 year F/U







-Posterior bundle gone
-Anteromedial remains

Cruciate Ganglion Cyst

- **Criteria**
  - *Lobulated fluid*
  - *Mass effect on cruciate fibers or 'wraps around' cruciate*
  - *Fluid disproportionate to fluid in joint*
  - *Cruciate bundles intact*
- **Symptoms: pain with flexion/extension**
- **Usually no instability**

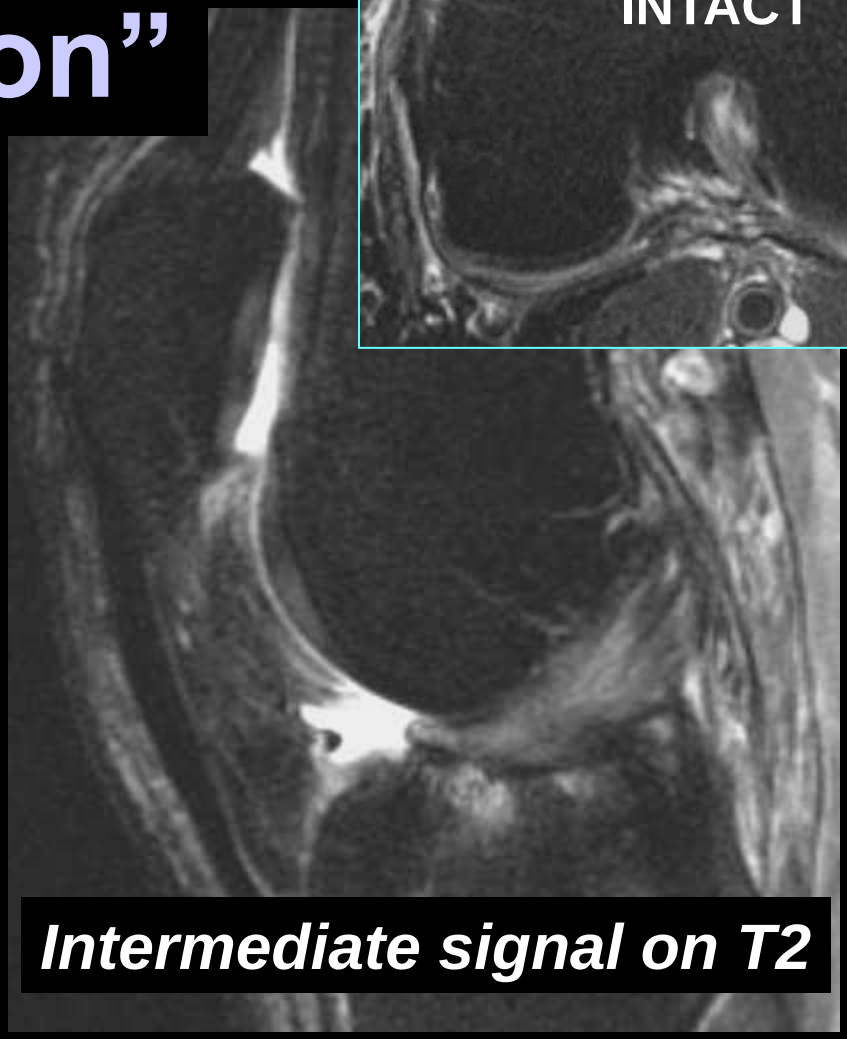
ACL Ganglion Cyst

ACL Mucoid Degeneration

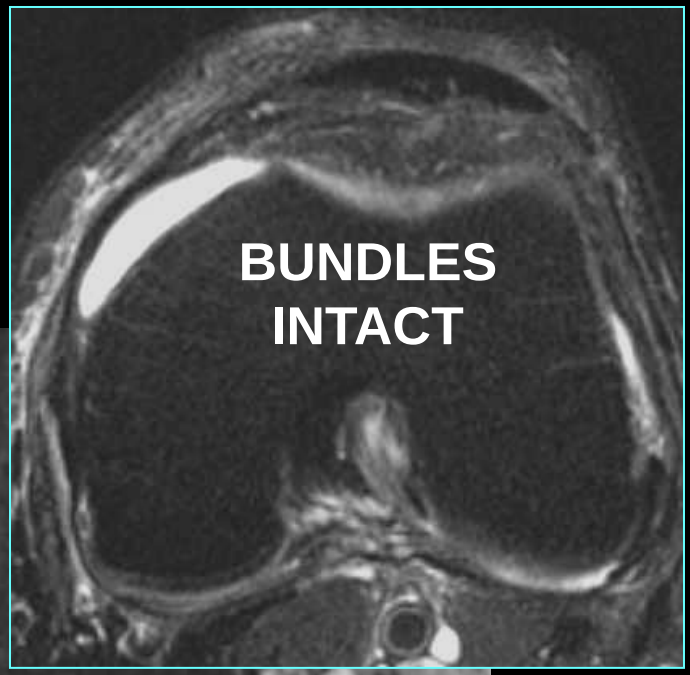
- Intact ACL poorly seen on T1 / PD
- Simulates tear
- Likely pathoetiology:
  - ACL bundles contained within sheath
  - Degeneration or synovial proliferation can cause increased signal, mass effect on sheath
- Often co-exists with ACL ganglion cyst
- Typically asymptomatic; rare instability
- Must document that BOTH BUNDLES are intact to differentiate from partial tear

ACL Mucoid Degeneration or "Synovialization"

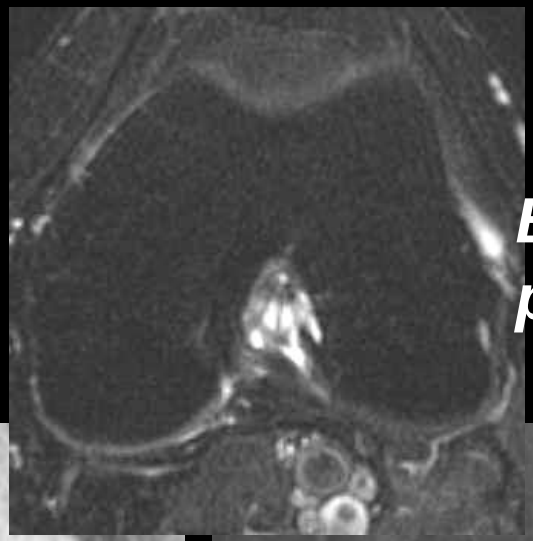
Poorly seen ACL on T1



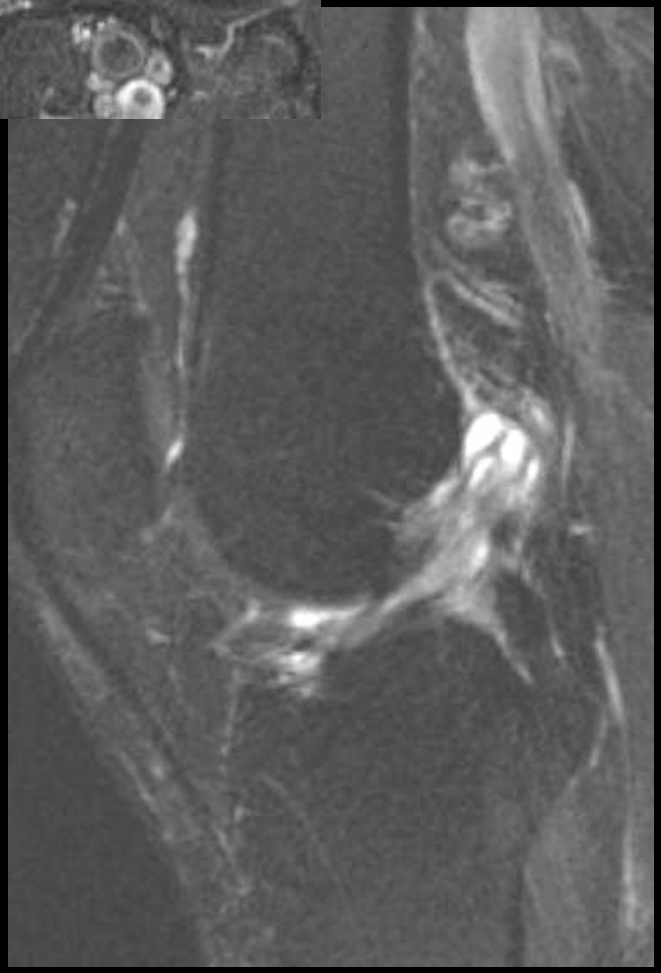
Intermediate signal on T2



ACL Mucoid Degeneration with Cyst



Bundles preserved

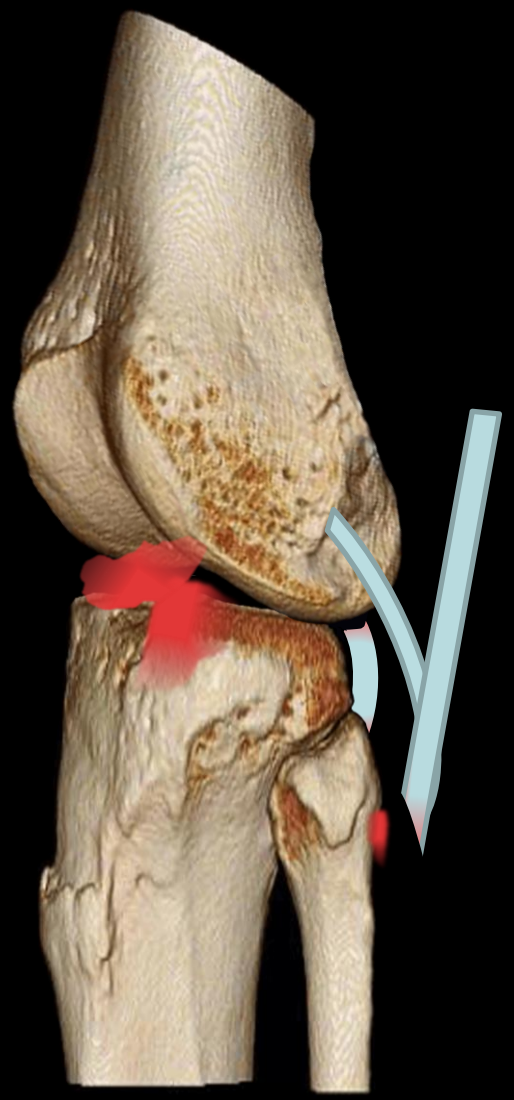


PCL Tear

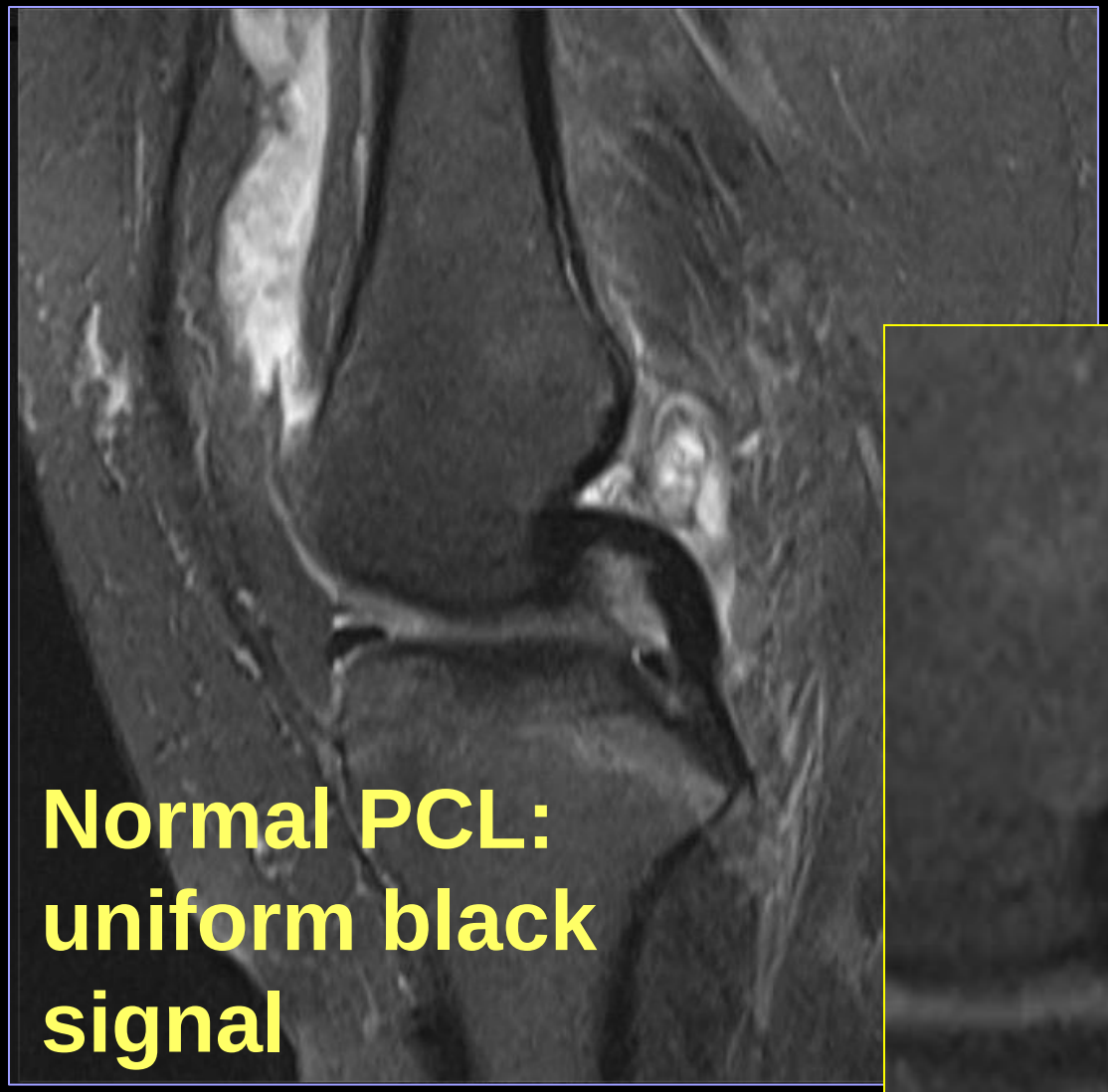
- Mechanism
  - “Dashboard” injury” – traumatic posterior drawer
  - Hyperextension
  - Dislocation (ACL also)
- Rare; 1-5% of cruciate tears
- Partial tear common (unlike ACL)
- Tear type
  - Midsubstance (genu)
  - Interstitial
  - Avulsion
- Associated injuries common
  - ACL & posterolateral corner injuries
  - Late effects: OA, esp patellofemoral

Hyperextension + Varus stress

- **Posterolateral Corner: injury +**
  - PCL injury
  - Anteromedial tibial plateau contusion or fracture
  - Medial meniscal tears



Thanks to Tetyana Gorbachova, MD, Philadelphia



Normal PCL: uniform black signal

PCL tears: Easy to miss!

PCL Tear

Partial tear at genu

Complete PCL Tear

PCL Avulsion

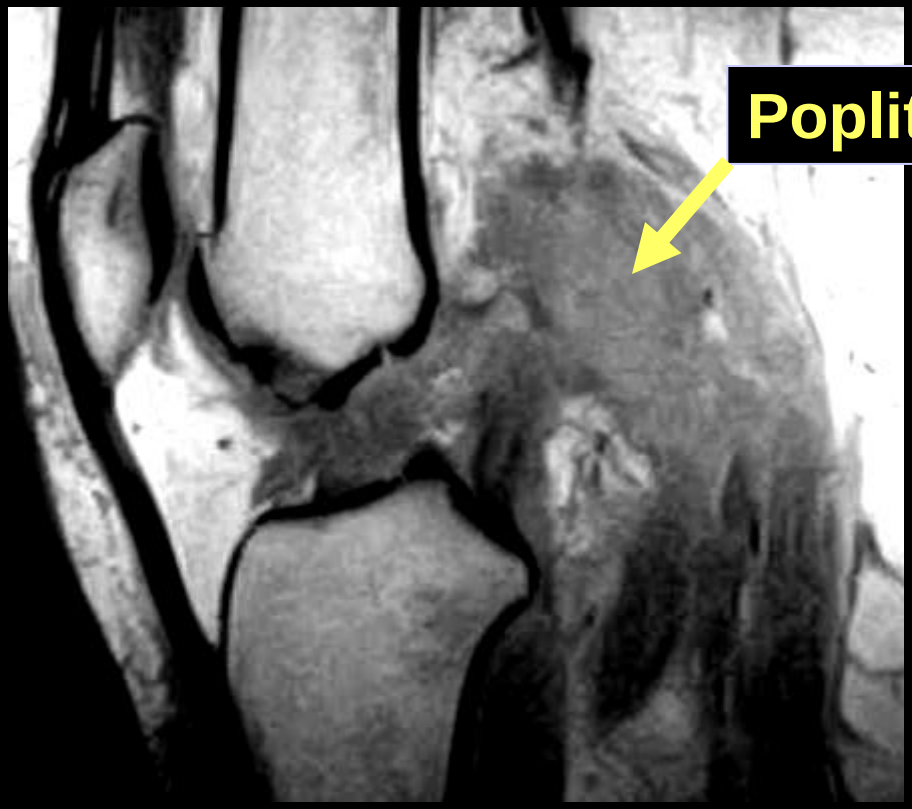
Tibiofemoral Knee Dislocation

- Relatively rare
- Motor vehicle accidents / trauma: sports
- Hyperextension injuries
- ACL and PCL tear

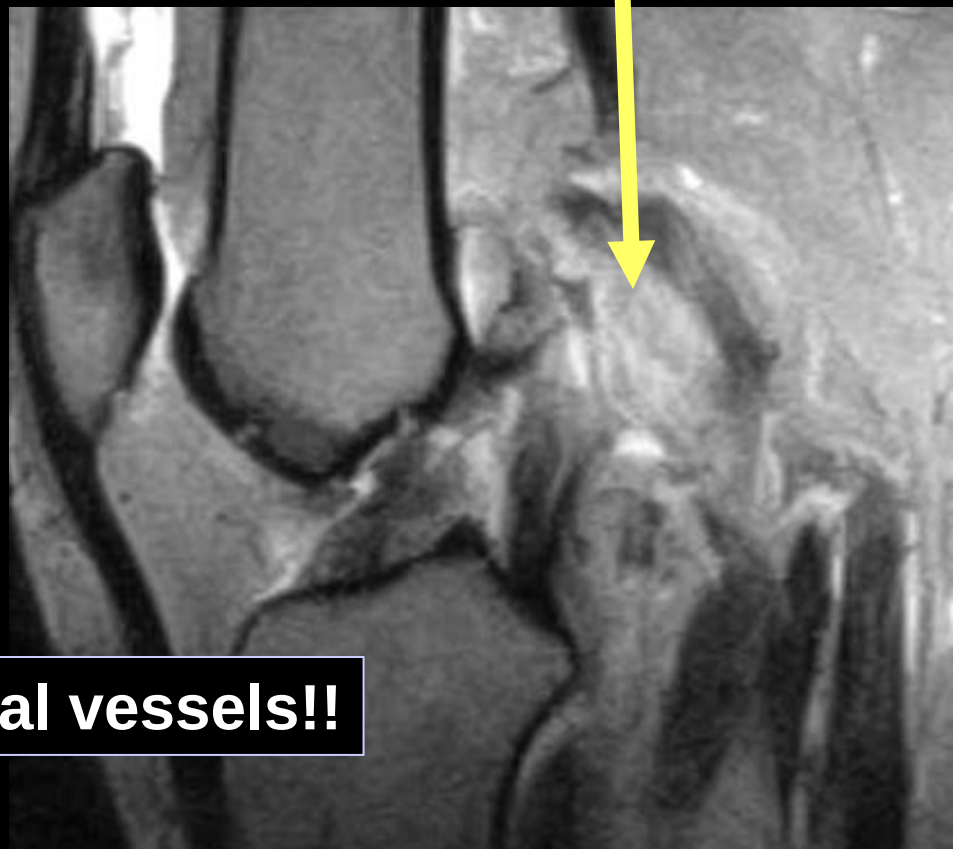
Tibiofemoral Knee Dislocation

ACL and PCL tear: think dislocation!

Tibiofemoral Knee Dislocation

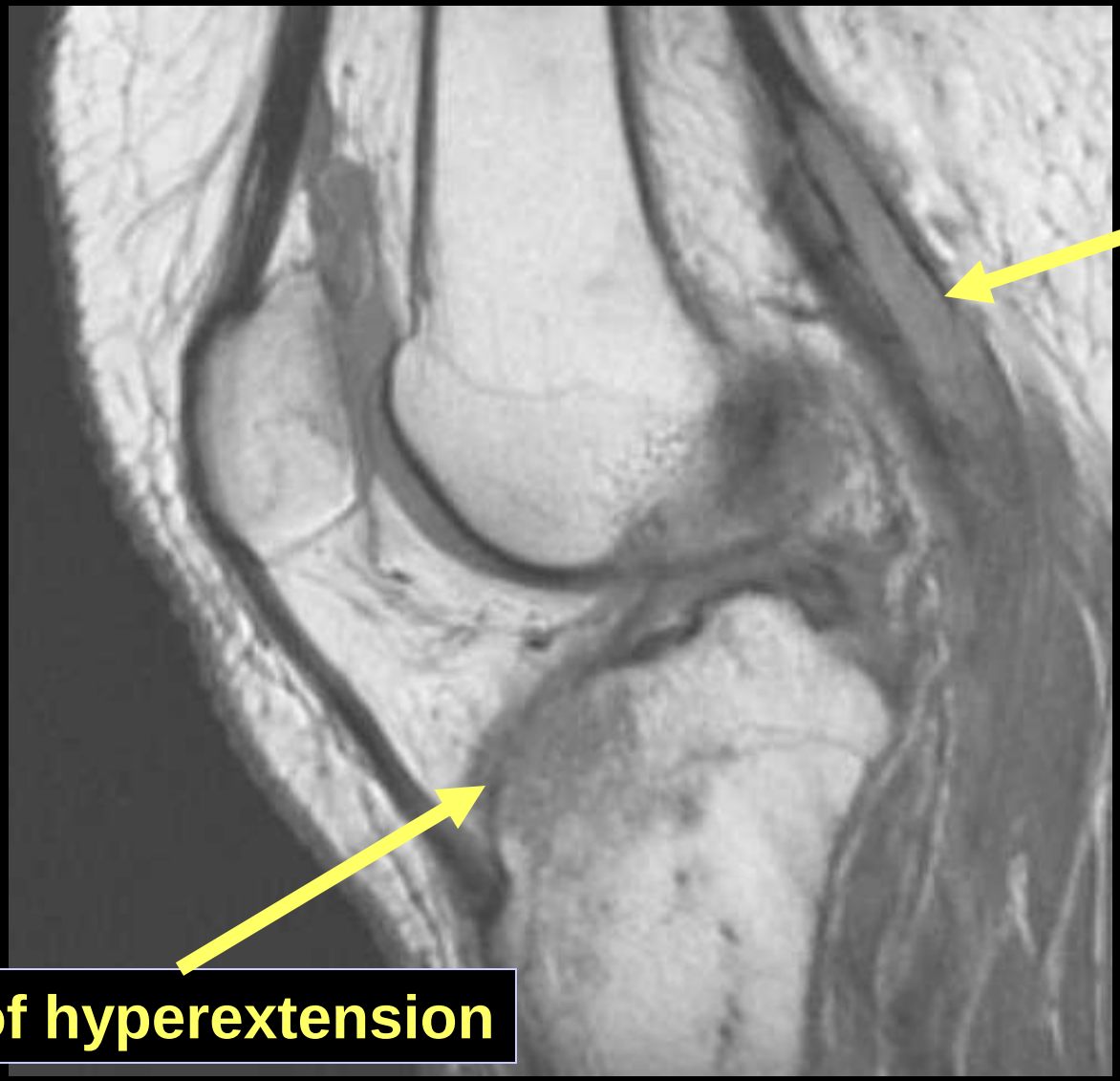


Popliteal artery pseudoaneurysm

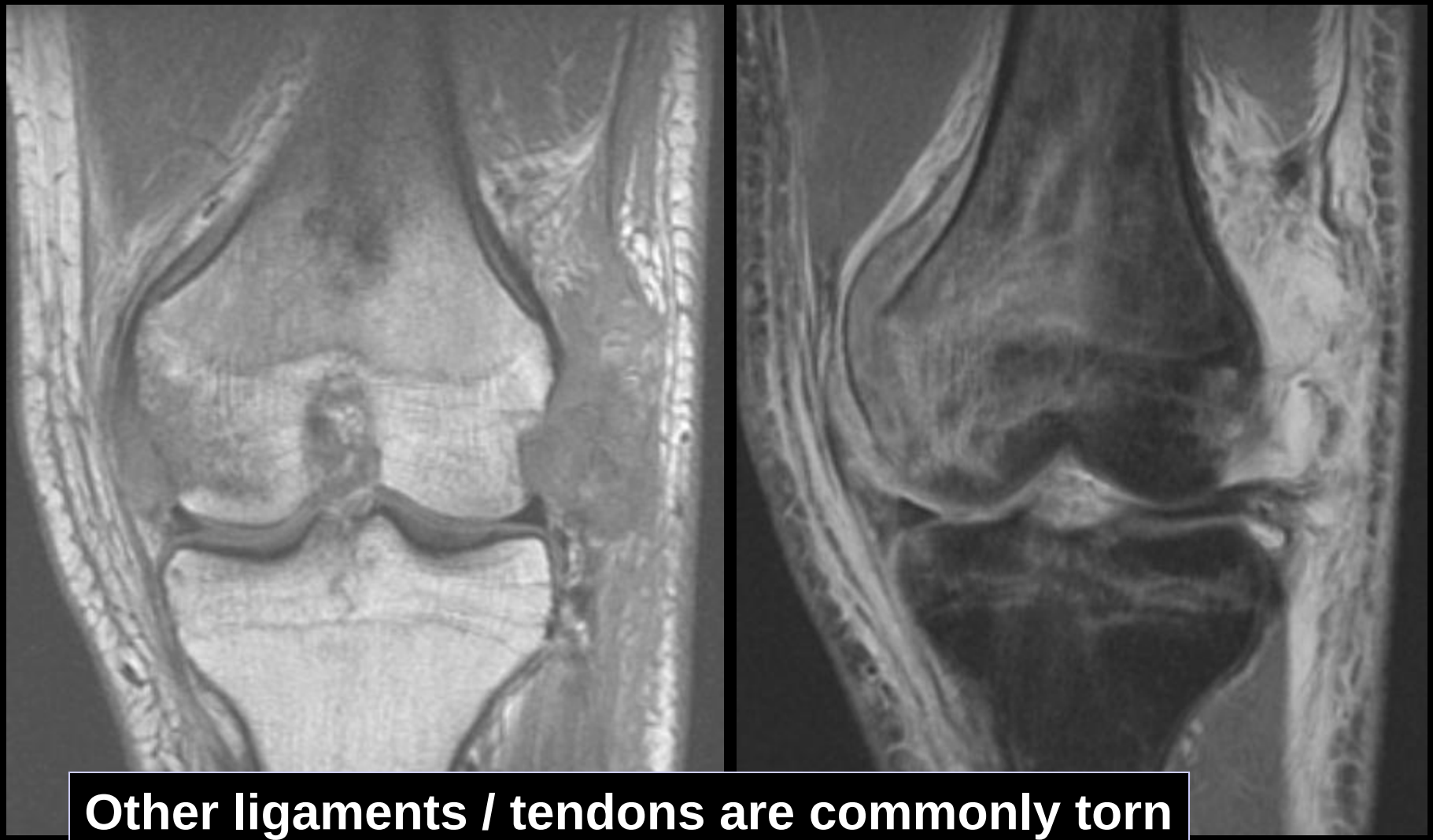


Dislocation: look at popliteal vessels!!

Tibiofemoral Knee Dislocation



Tibiofemoral Knee Dislocation



Other ligaments / tendons are commonly torn

Collateral Ligaments

Medial Collateral Ligament

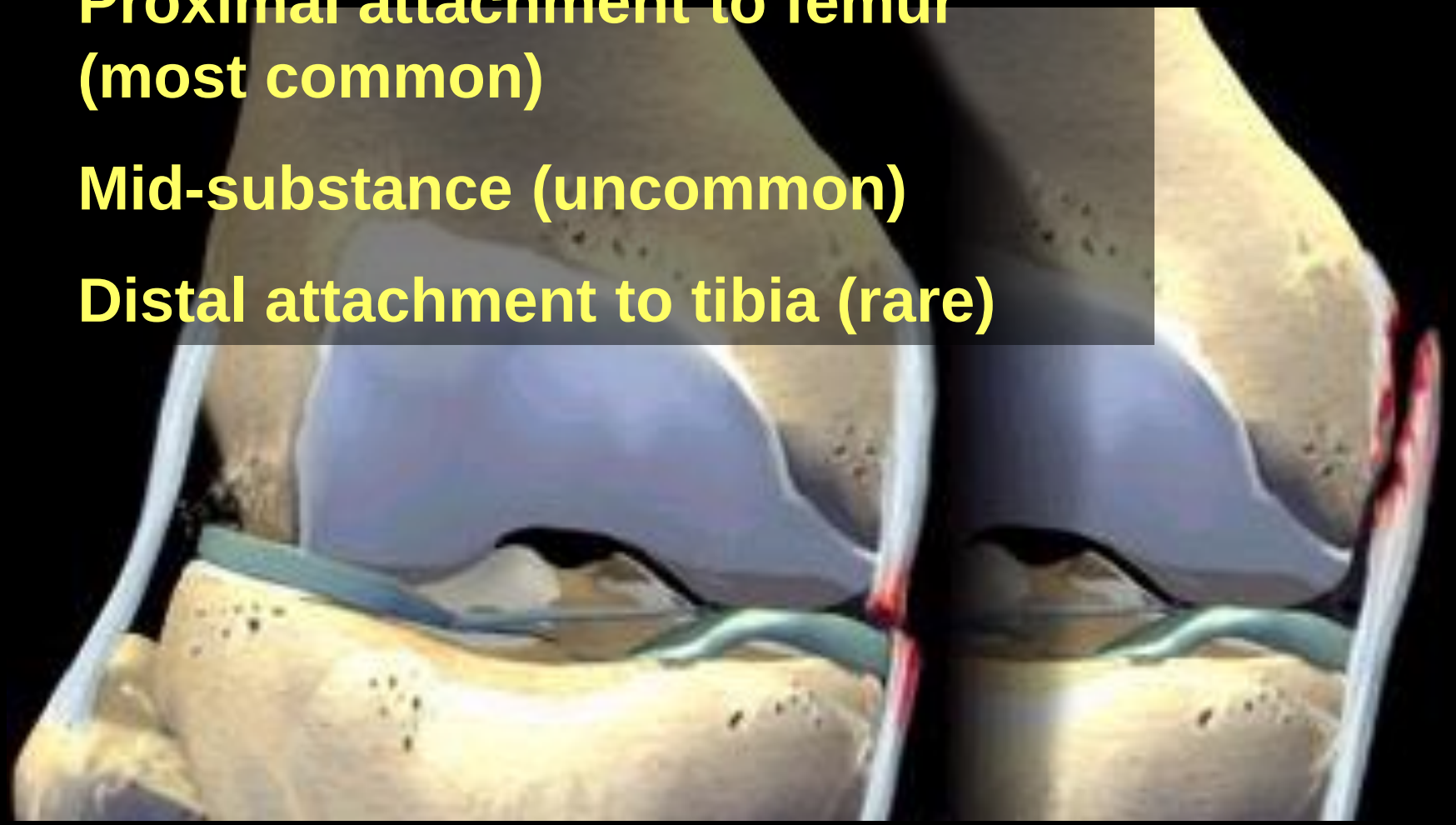
- Superficial portion (="MCL")
- Deep portion
  - *Meniscofemoral (coronary) lig*
  - *Meniscotibial lig*
  - *Very tight attachment*
- Injury from valgus stress, external rotation
- Combo injury: 95% ACL

MCL Tear: Site of Rupture

Proximal attachment to femur (most common)

Mid-substance (uncommon)

Distal attachment to tibia (rare)



MCL Sprain: Grade I

Stretching injury
Edema around intact ligament

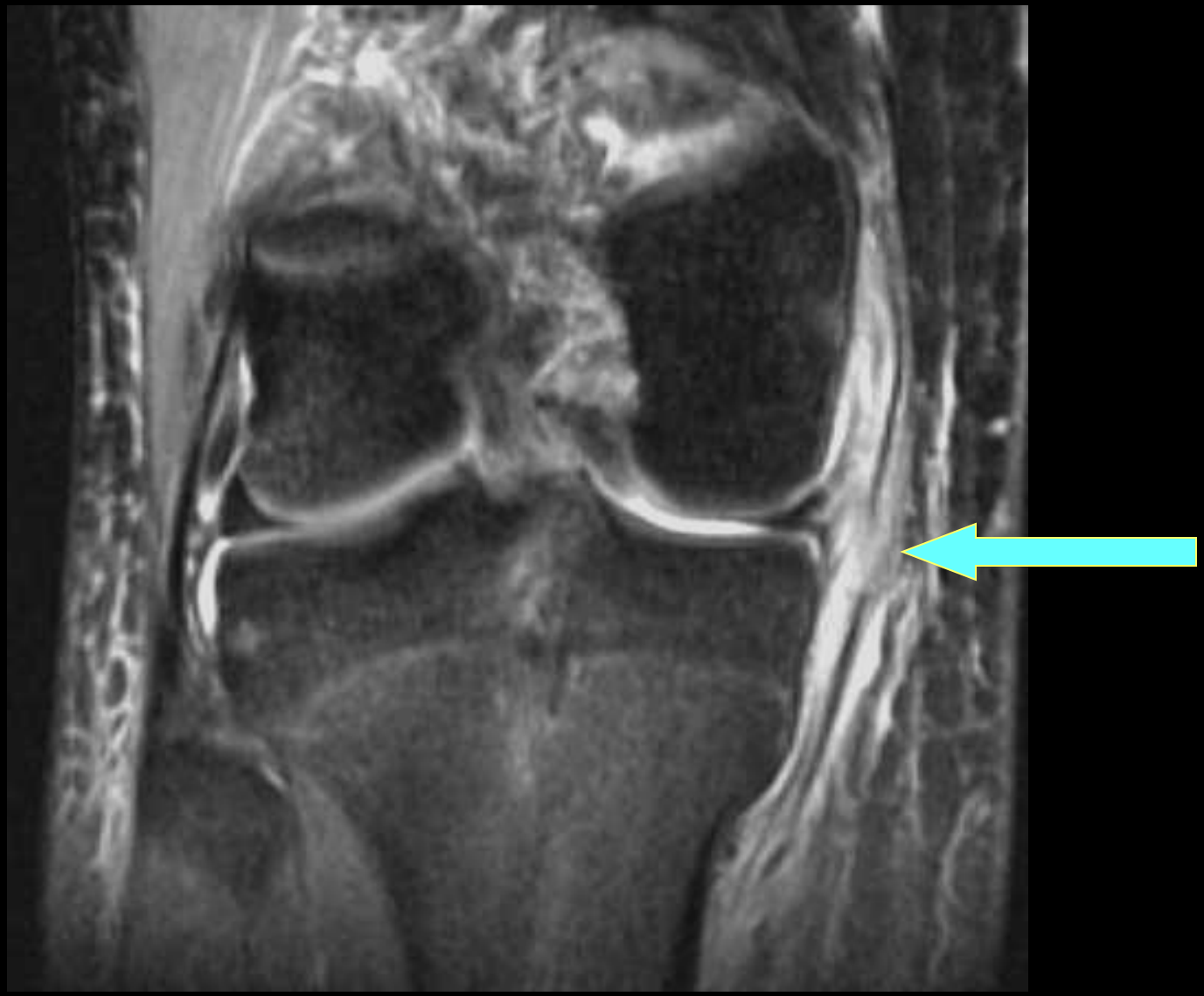
MCL Sprain: Grade II

Edema within ligament = partial tear

MCL Tear: Grade III

Complete tear

MCL Midsubstance Tear



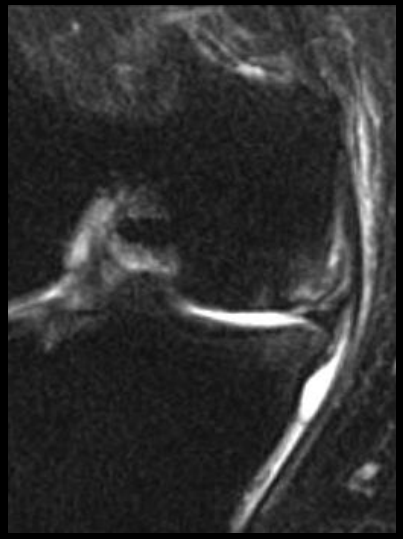
MCL: Healed Tear

Most isolated MCL injuries heal spontaneously with thickened ligament or Ca++ (Pellegrini-Steida)

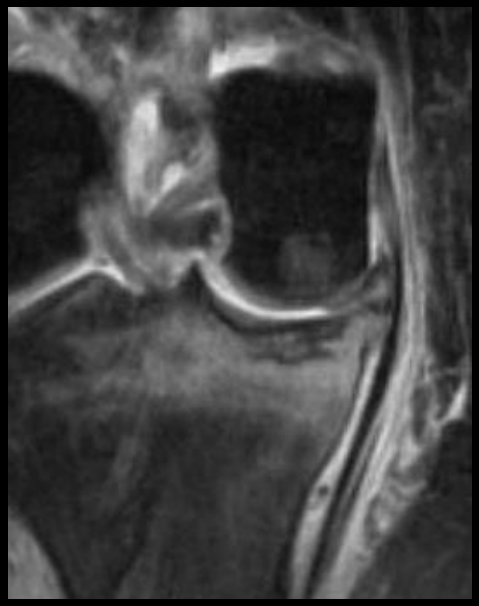
DDx: MCL Sprain

Ruptured Baker's cyst

Medial meniscal tear



Medial compartment OA



Surrounding hyperemia

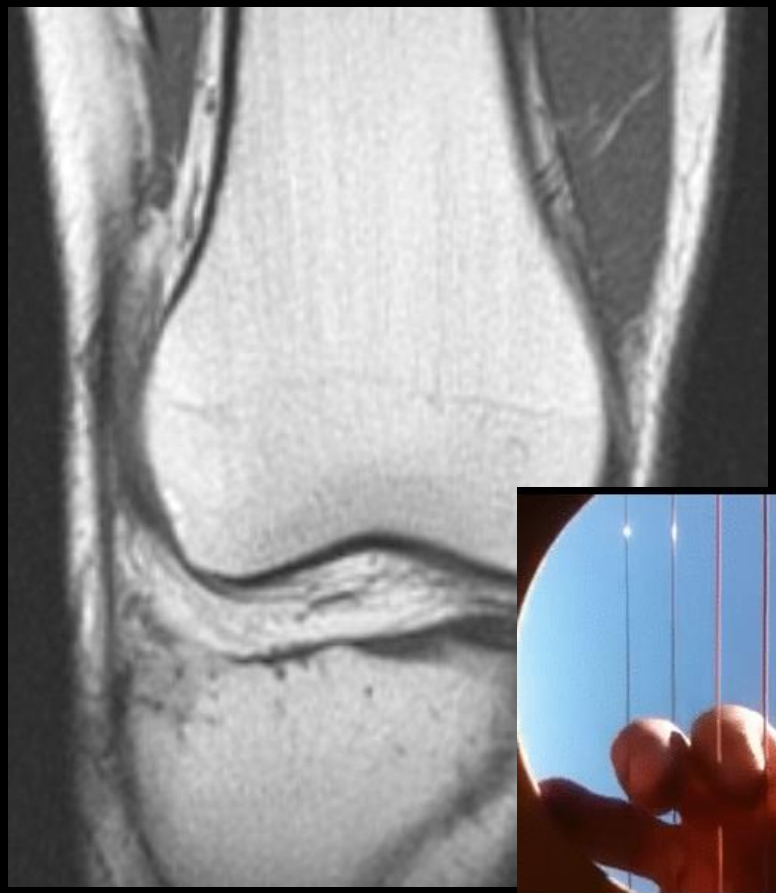
LCL Complex

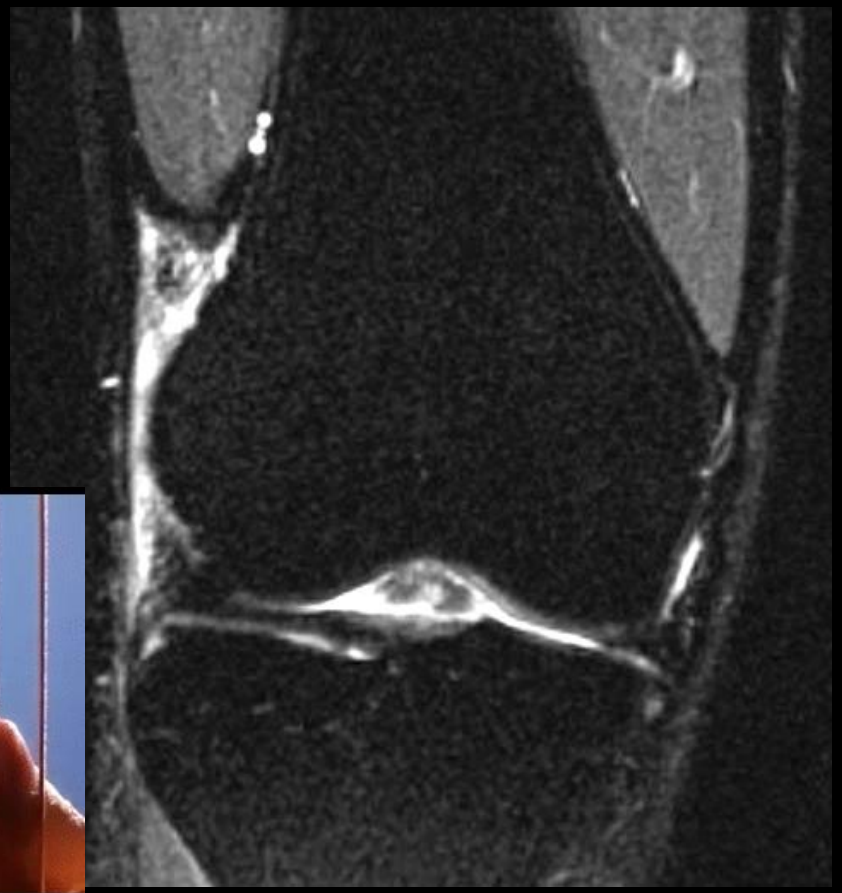
- Lateral ‘ligamentous’ complex
  - *Iliotibial band*
  - *Fibular collateral ligament (‘LCL’)*
  - *Biceps femoris*
- Other posterolateral stabilizers
  - *Arcuate ligament*
  - *Popliteus tendon*
  - *Popliteofibular ligament*
  - *Fabellofibular ligament*

LCL Complex

- Lateral ‘ligamentous’ complex
  - Iliotibial band
  - Fibular collateral ligament (‘LCL’)
  - Biceps femoris
- Association: PCL injuries
- Unlike MCL, often requires reconstruction

Iliotibial Band Friction Syndrome





- ***Runners***
- ***Friction: iliotibial band, lateral femoral condyle***
- ***Edema, pain***

Posterolateral Corner: *The "Dark Side of the Knee"*

- Complex, variable anatomy
- Inter-related static and dynamic stabilization
- No widely recognized bone marrow edema pattern *(i.e. ACL)*
- Many structures out of plane on standard MR sequences
- Often "bridesmaid" to ACL or PCL injury

Posterolateral Corner: *Who Cares?*

Orthopedists

Posterolateral corner significance:

- ACL graft force increased with varus loading, coupled varus and ext. rotation at 0 and 30° flexion – *Laprade, 1999*
  - *ACL graft failure?*

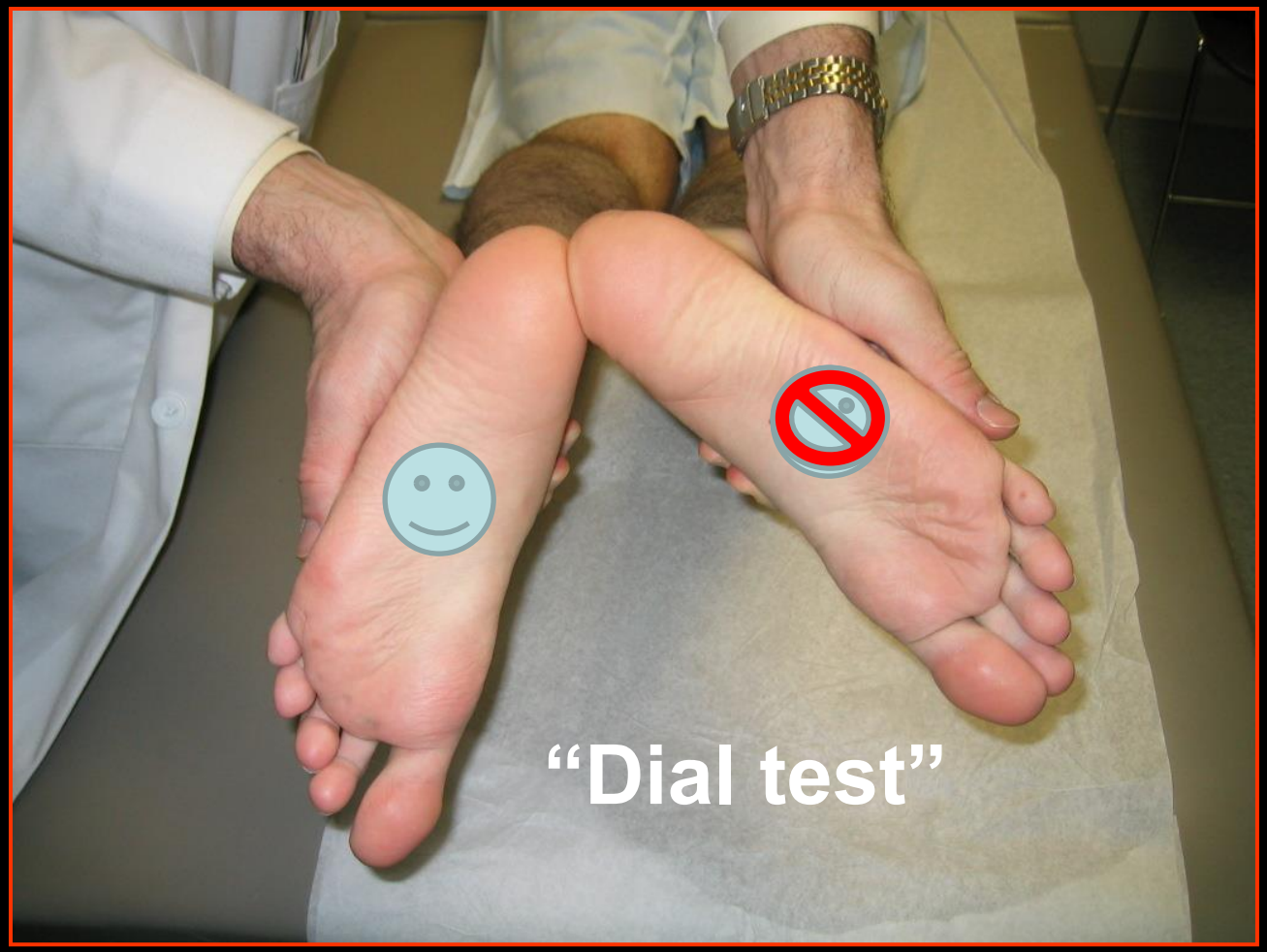
- Increased PF joint contact pressure in combined resection PCL and posterolateral complex than isolated PCL resection (reverse Maquet effect) *Skyhar, 1993*
  - *Accelerated patellofemoral osteoarthritis?*

Posterolateral Corner

Significance

- Common peroneal nerve injury (up to 30%) – foot drop
- Rotational instability
  - Instability in knee extension
  - Difficulty with stairs
  - Difficulty with “cutting” activities

Posterolateral Corner Injury Diagnosis



Posterolateral Droop / Recurvatum

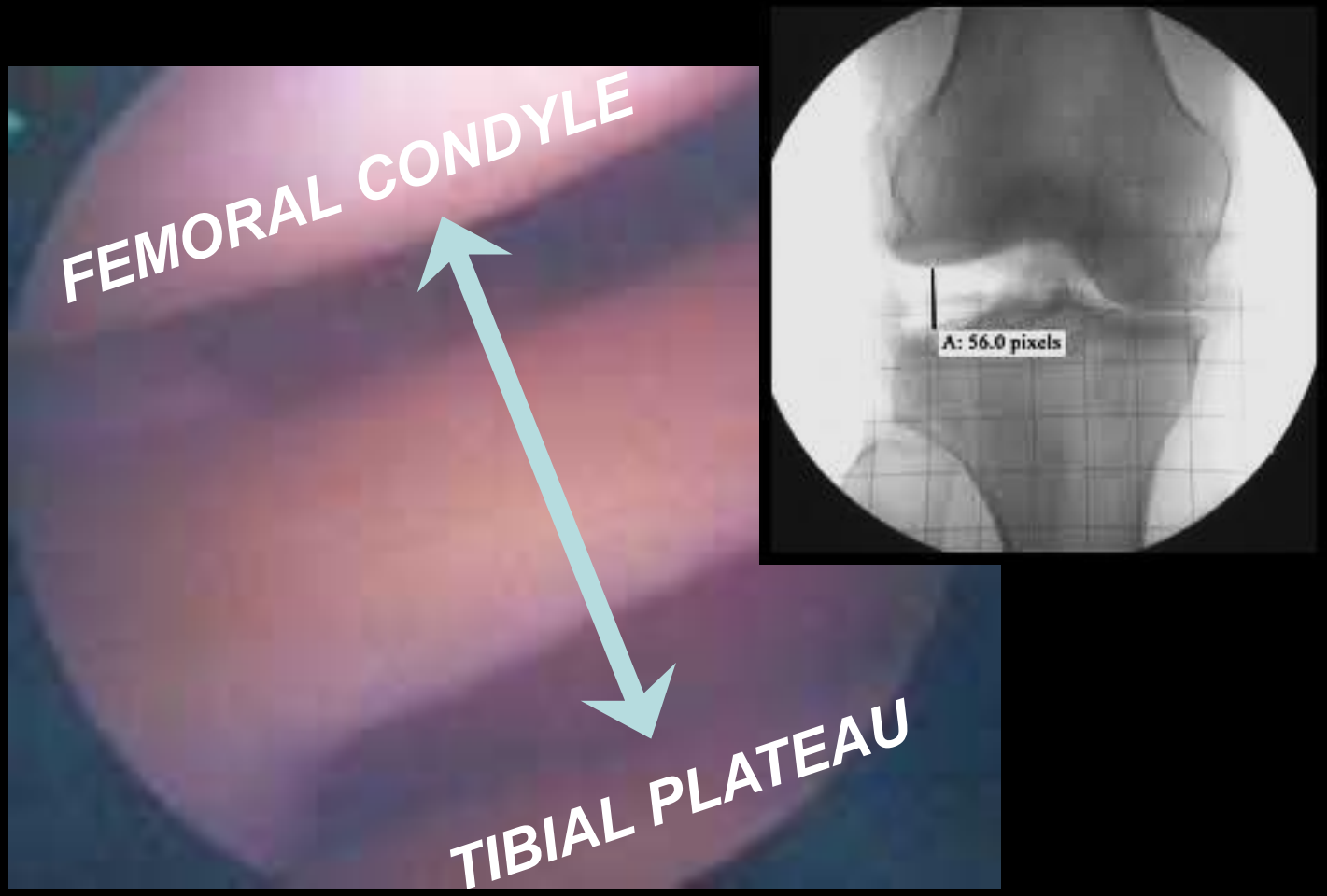
"Hughston Test"

Posterolateral Corner Injury

Genu recurvatum

Posterolateral Drawer Test

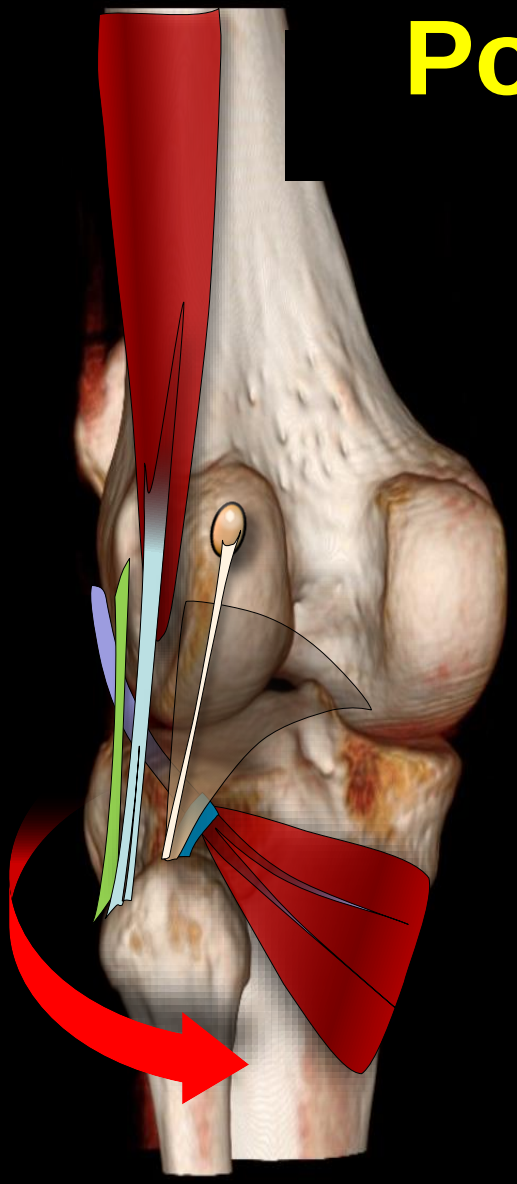
“Drive Through Sign”



Scope easily passes through lateral compartment

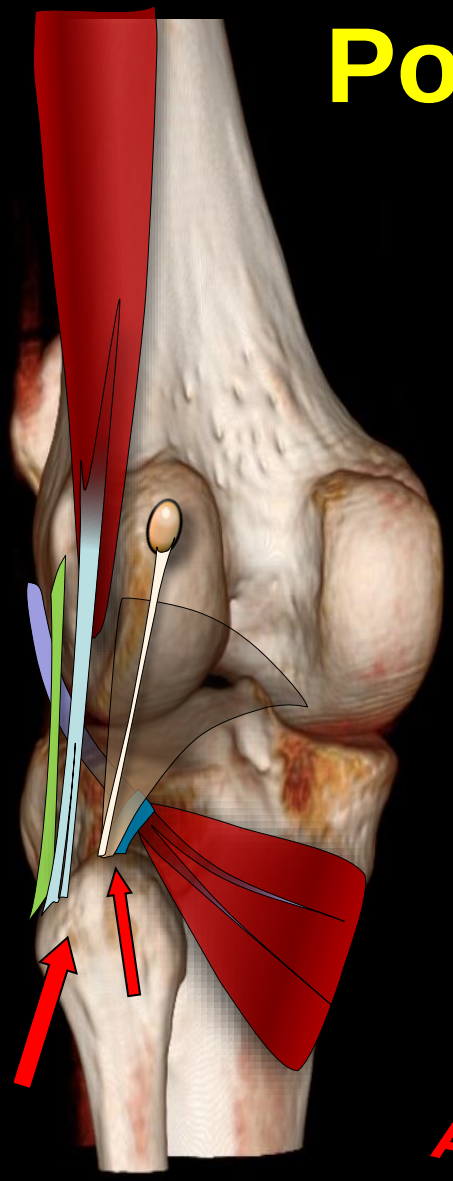
Posterolateral Corner

Function



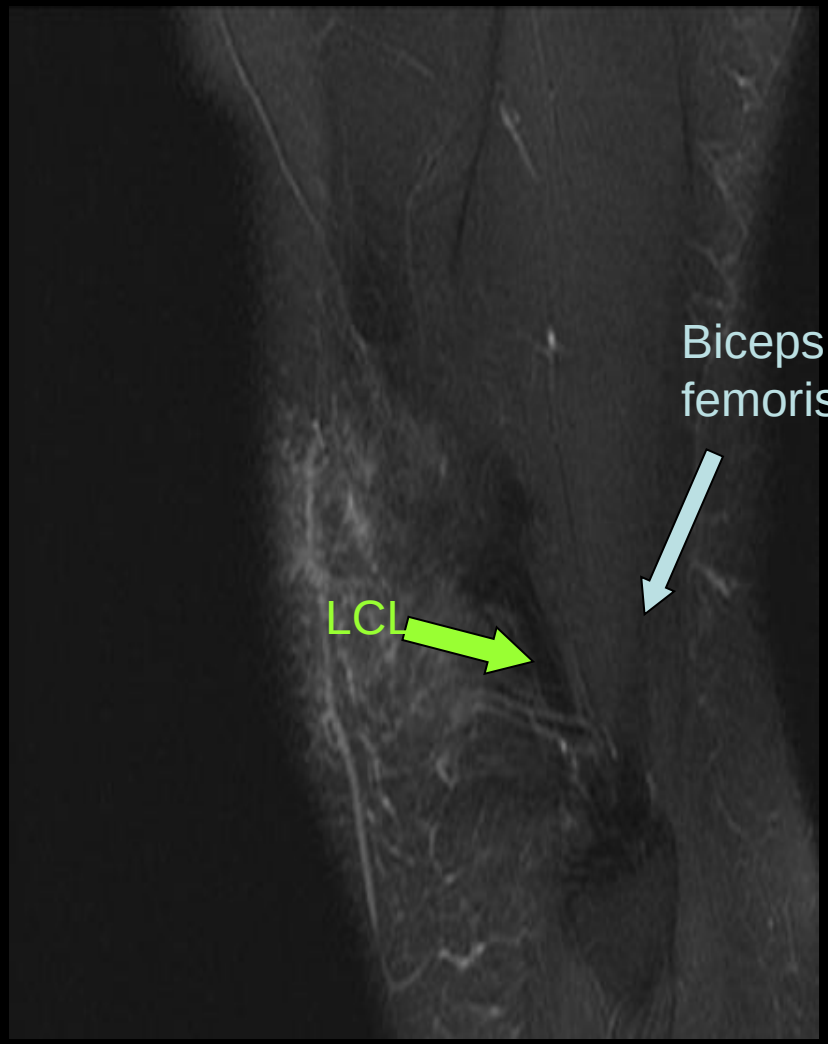
- **Intact PL corner prevents:**
  - *External rotation*
  - *Varus angulation*
  - *Posterior translation*
- Important secondary stabilizers for internal rotation in the ACL deficient knee

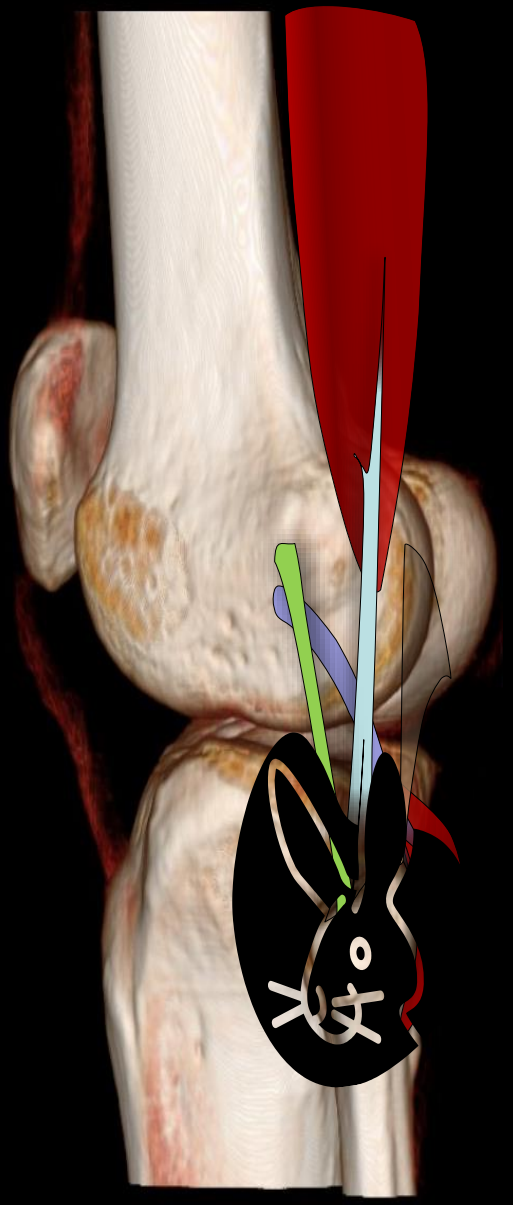
Posterolateral Corner

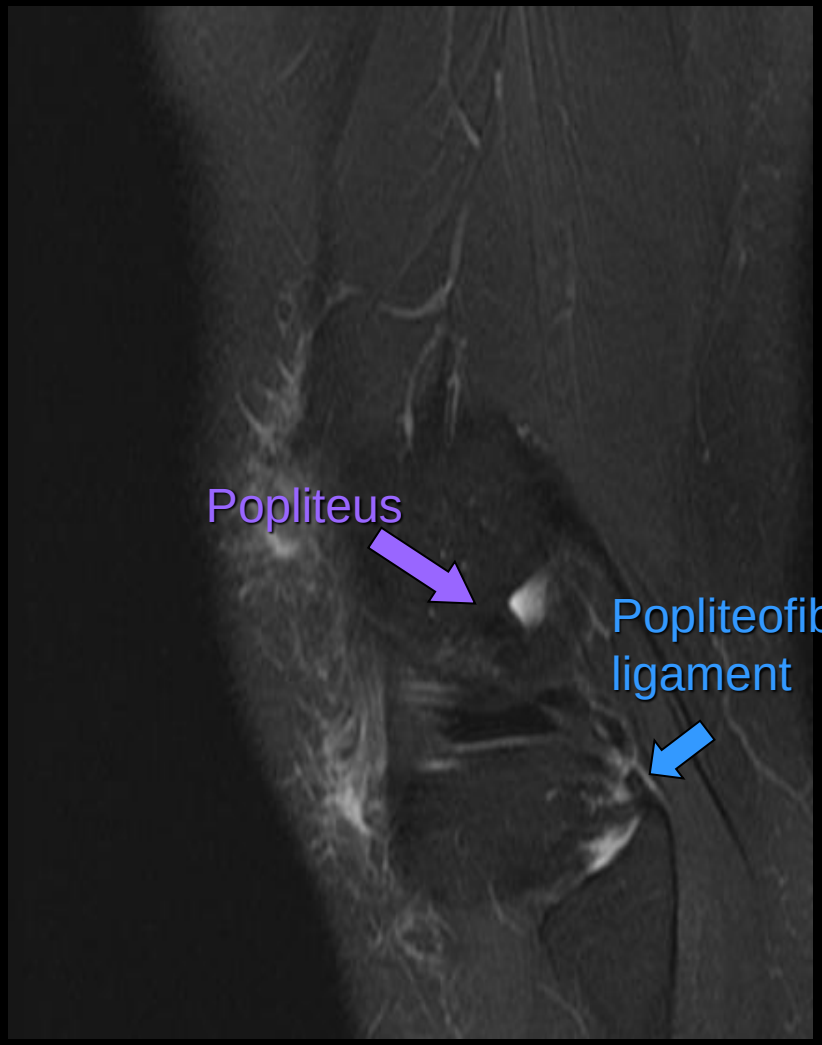


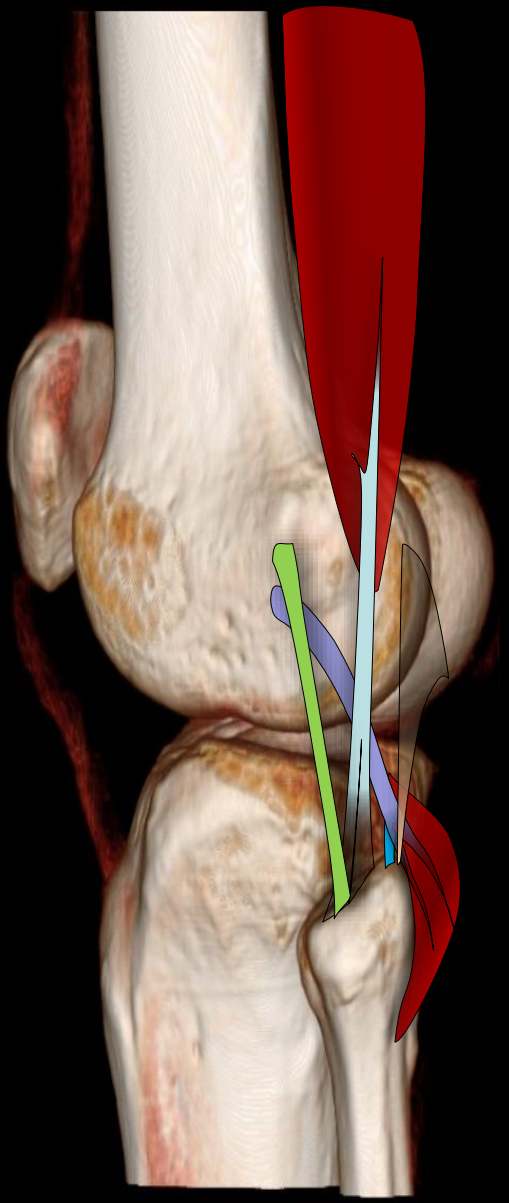
- Lateral collateral ligament
- Biceps femoris tendon
- Popliteus muscle-tendon unit
- Popliteofibular ligament
  - -can be identified in the majority of knees
- Fabellofibular ligament
  - -Links the fibular tip to the fabella
- Arcuate ligament
  - -Y-shaped, thin, of ? importance

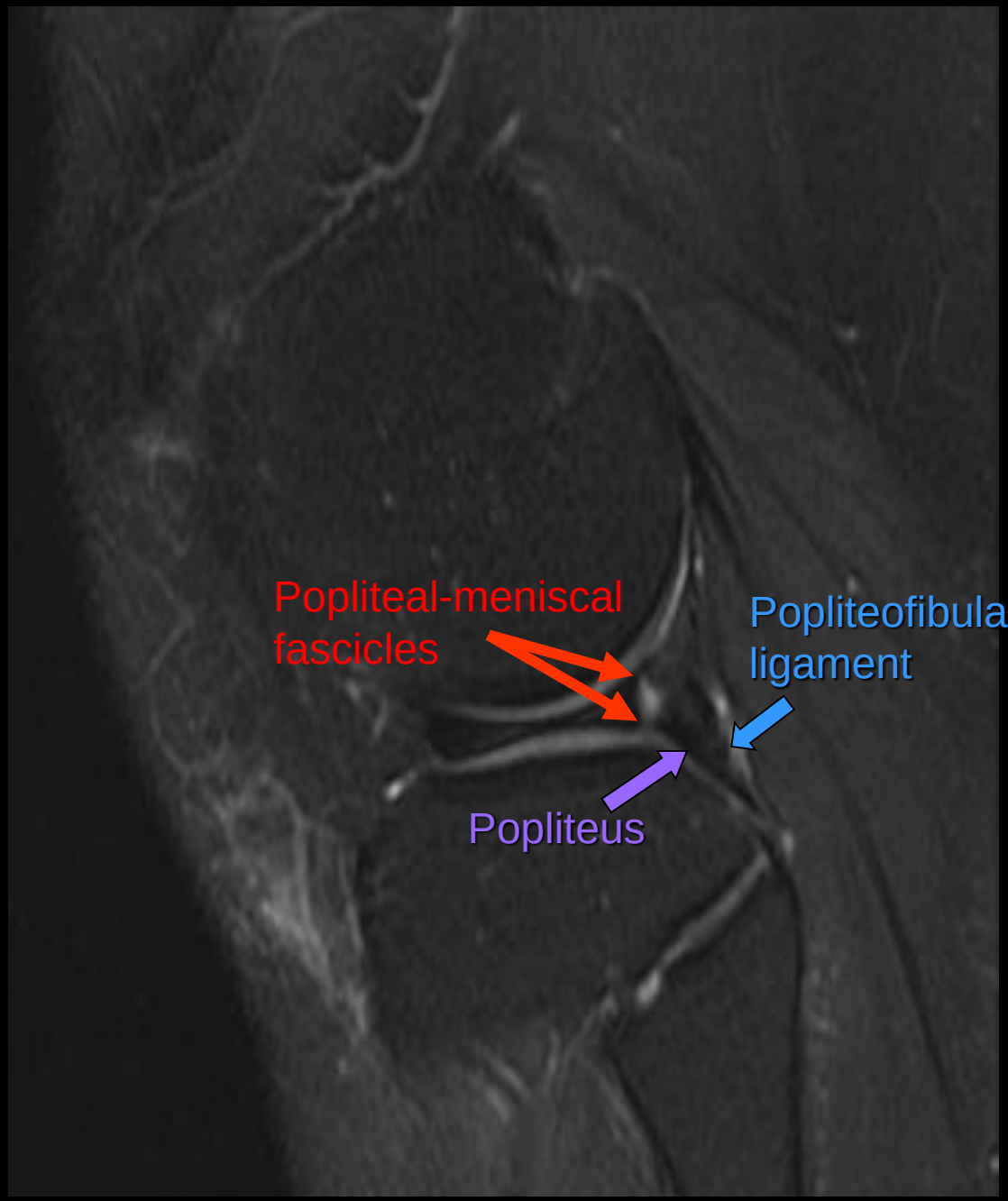
Arcuate complex

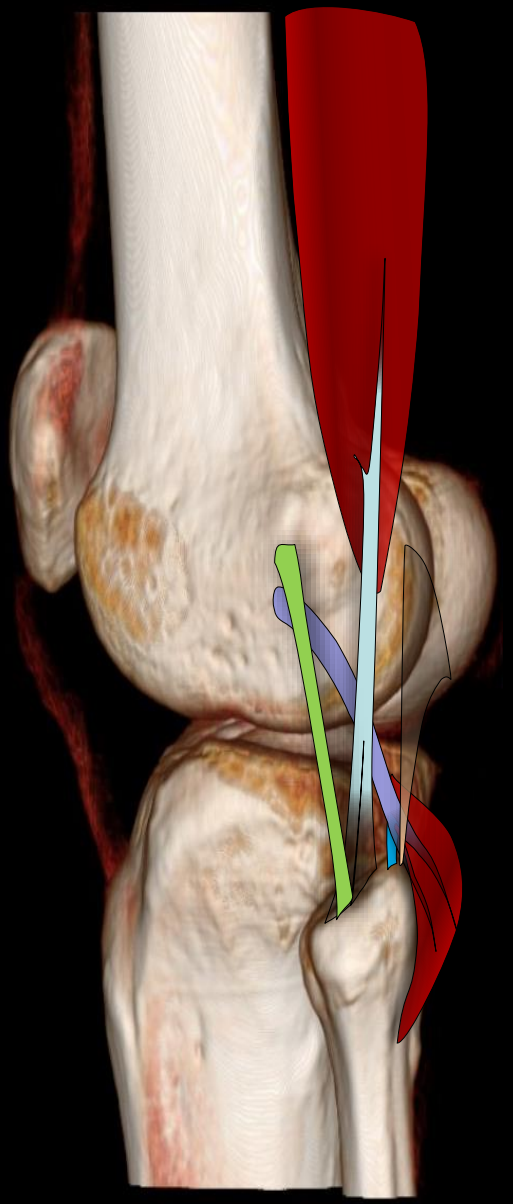

Biceps
femoris
LCL

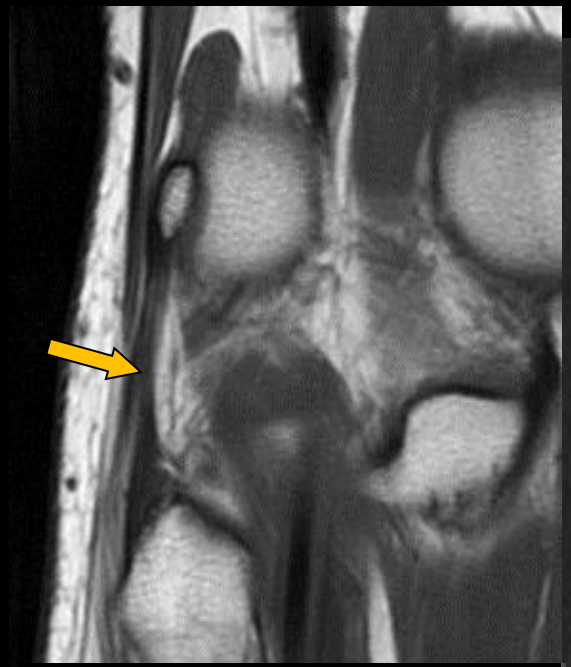



Popliteus
Popliteofibular ligament

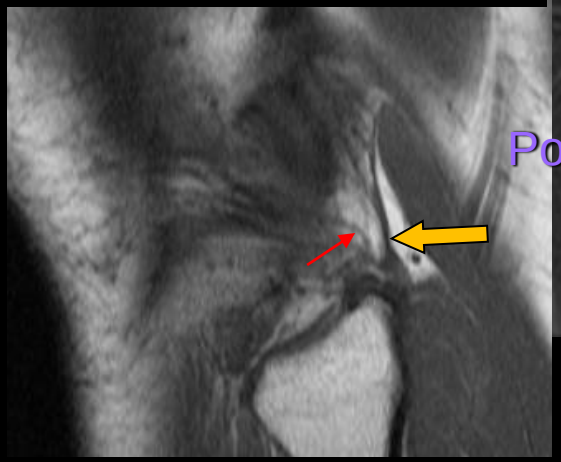



Popliteal-meniscal fascicles
Popliteofibular ligament
Popliteus

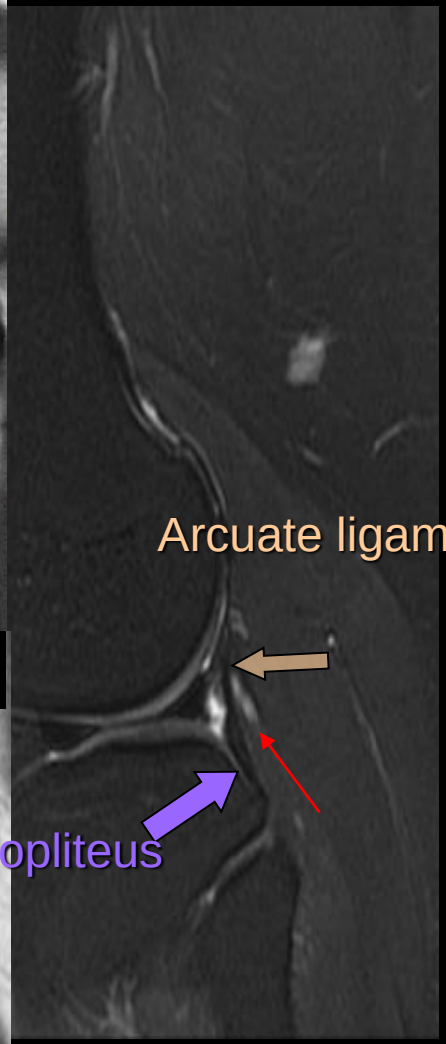




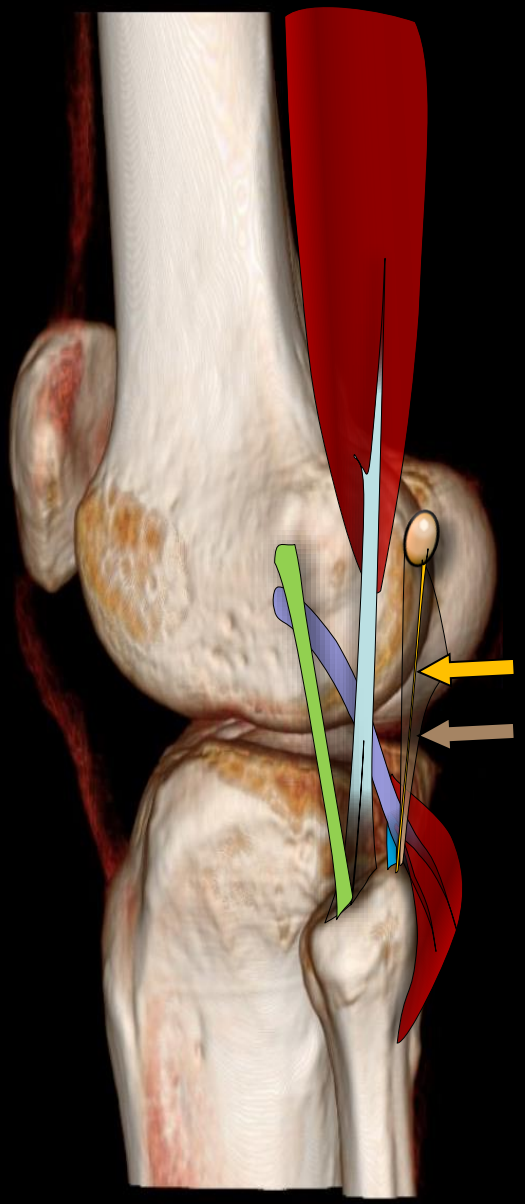
Fabellofibular ligament



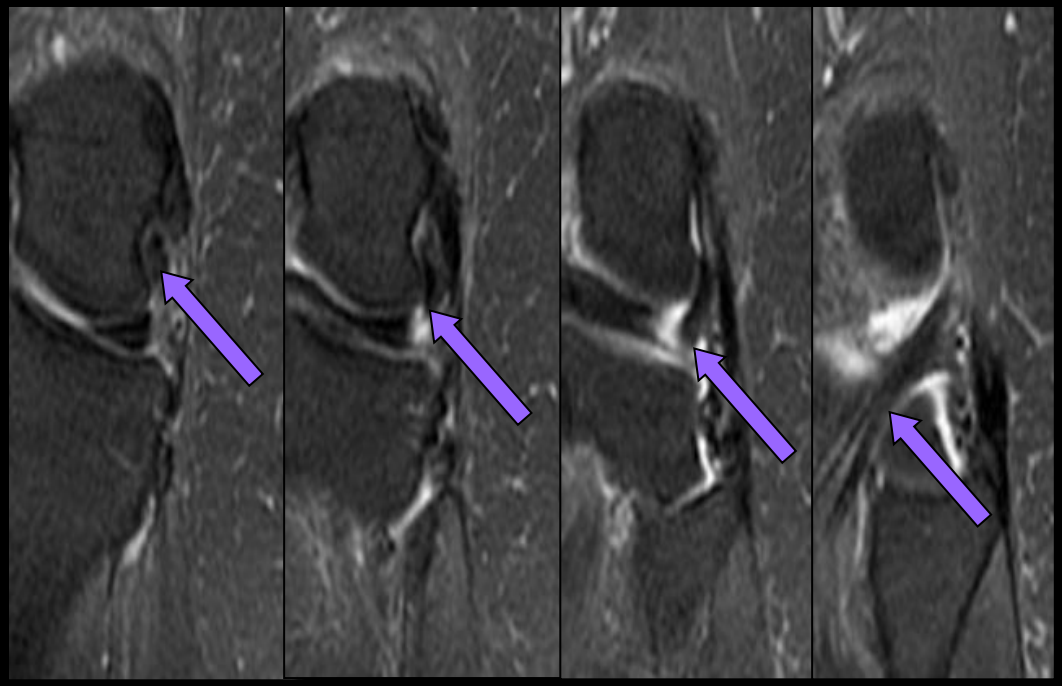
* Located superficial to the geniculate blood vessels

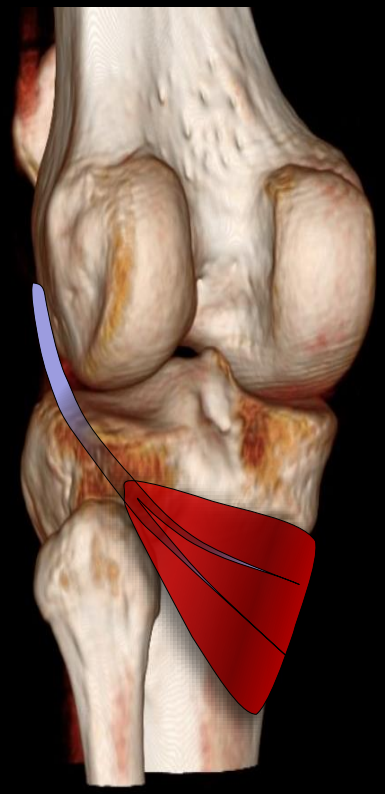


* Located deep to the geniculate blood vessels



Popliteus Tendon



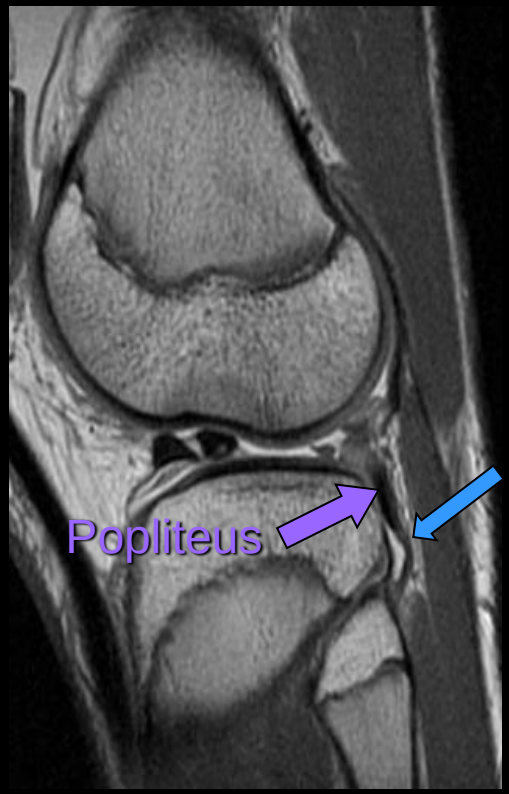


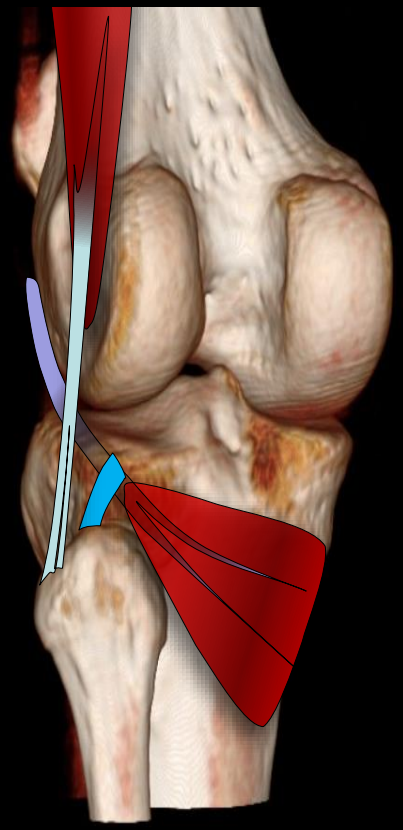
Tips:

- Follow its helicoid course from intra- to extra- articular
- Locate other structures in relation to it
- Structures are highly variable, non-visualization of FFL, PFL, especially arcuate ligament is not uncommon

Popliteofibular ligament

Seen on sagittal and coronal images, particularly when a joint effusion is present





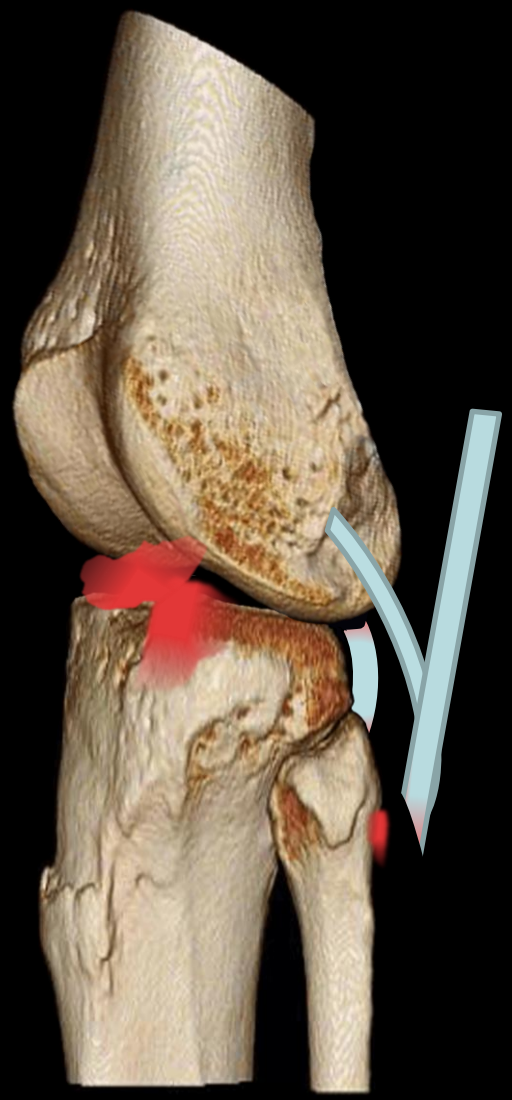
Visible as an individual structure in 90% -100% of dissected knees, but MR visualization is variable

Posterolateral Corner Injury

- **High-energy force**
  - Contact sports: American football and soccer
  - Pedestrians in traffic accidents
  - Falls
  - Knee dislocation
- **Mechanism: *Direct or Indirect***
  - Varus
  - Hyperextension
  - External rotation
- Isolated injuries are far less common than combined

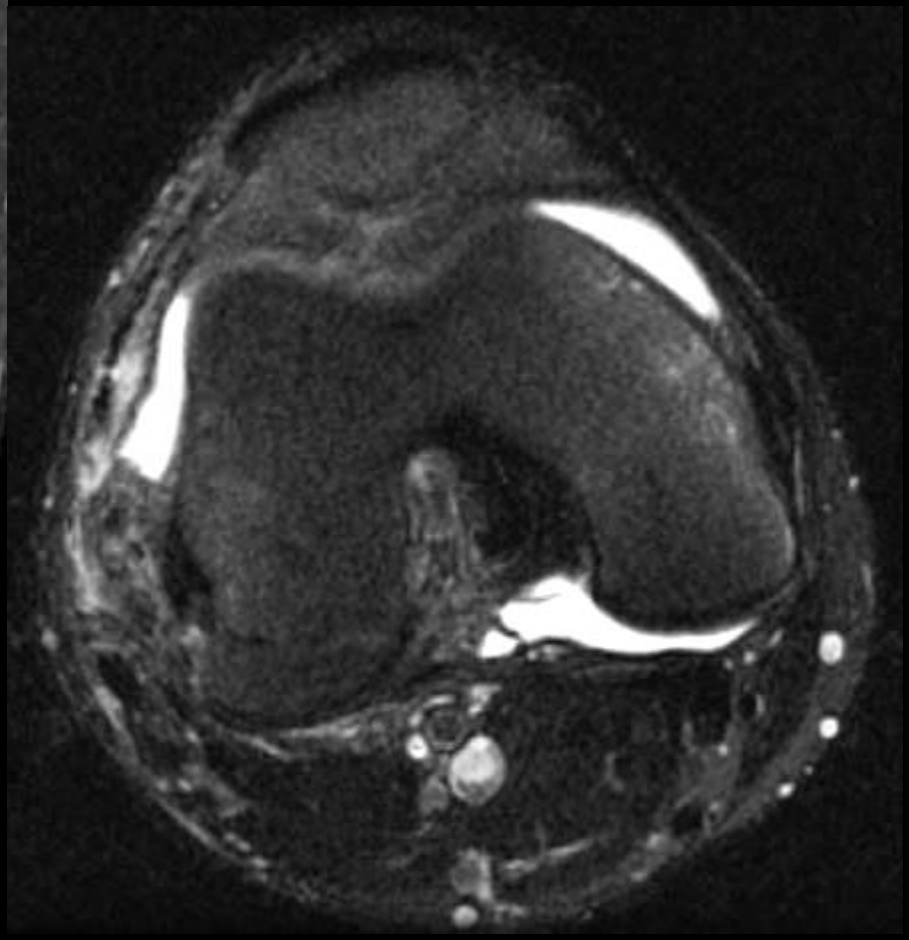
Hyperextension + Varus Stress

- **Posterolateral Corner: injury +**
  - PCL injury
  - Anteromedial tibial plateau contusion or fracture
  - Medial meniscal tears



Thanks to Tetyana Gorbachova, MD, Philadelphia

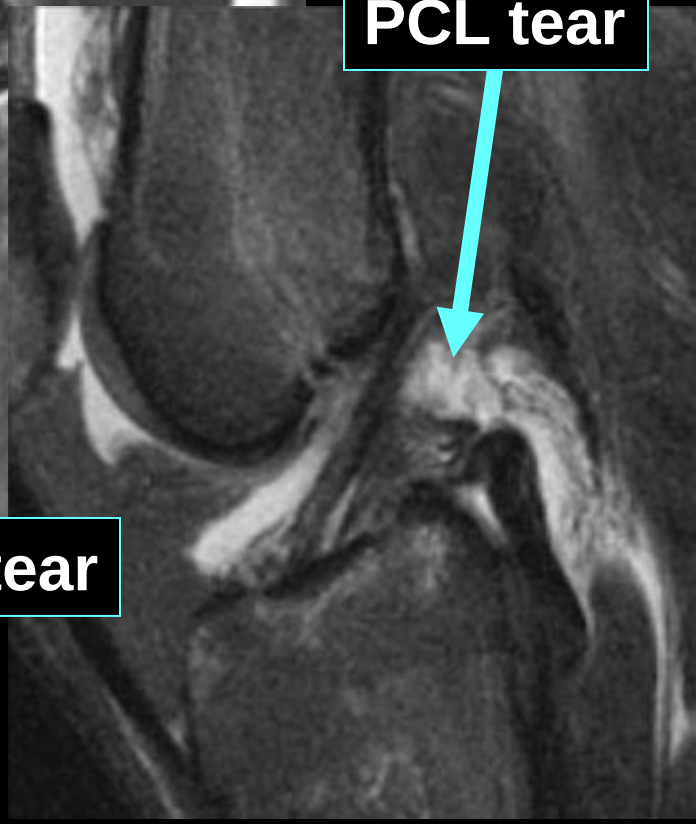
Complete Fibular Collateral Ligament Tear



Remote LCL Tear

Thickening – like old MCL injury

Biceps + FCL Tear

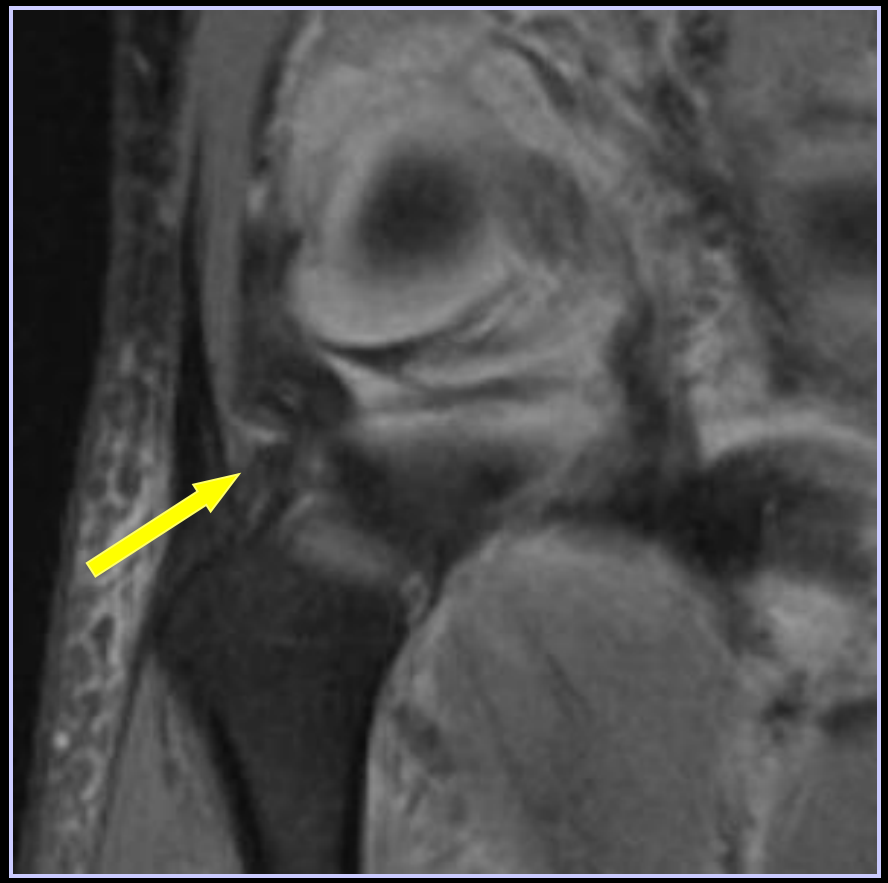


PCL tear

Arcuate ligament tear

Posterolateral Corner Injury

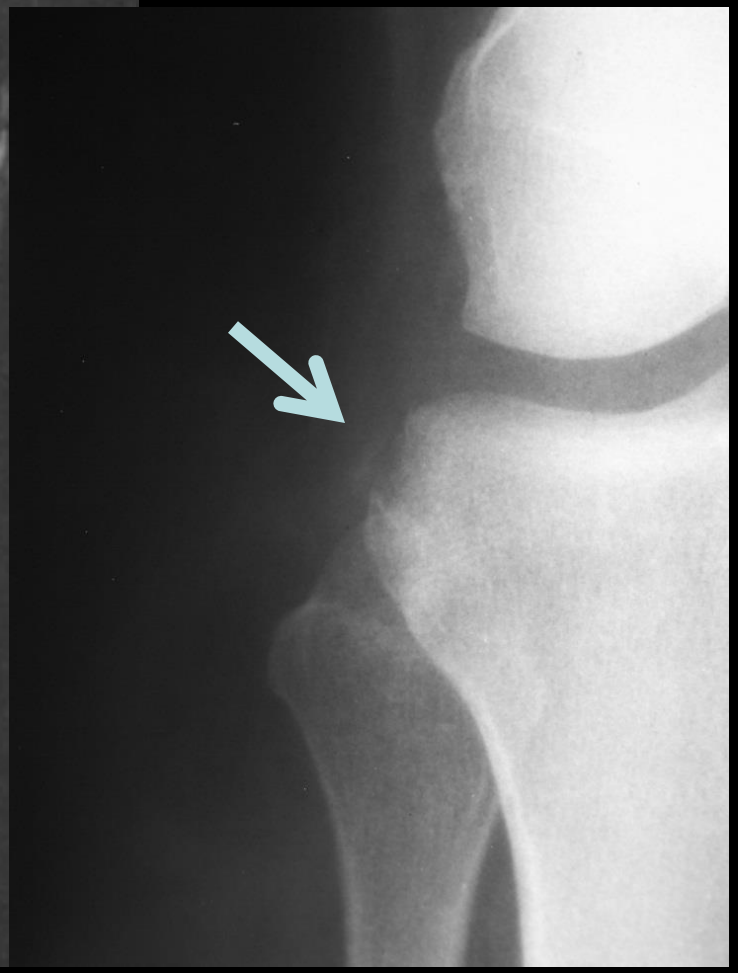
Pop-fib Ligament



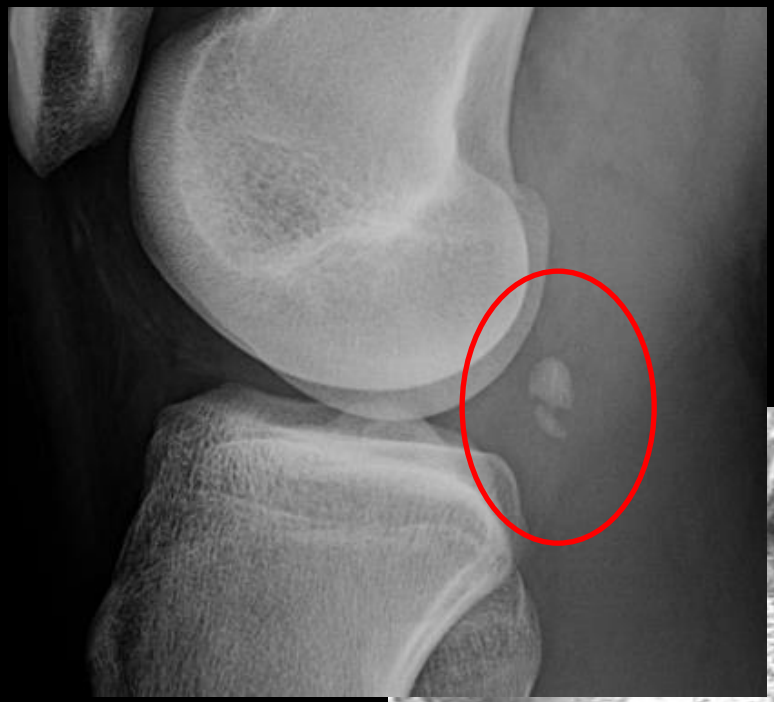
Normal

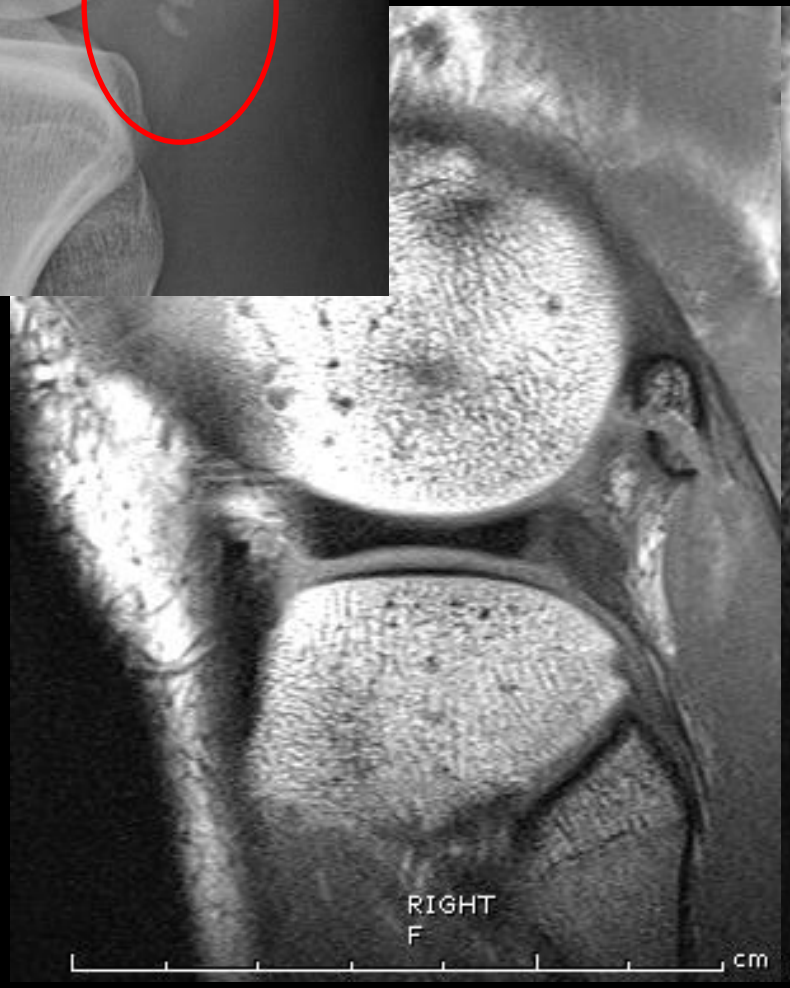
Sprain

Segond Fracture

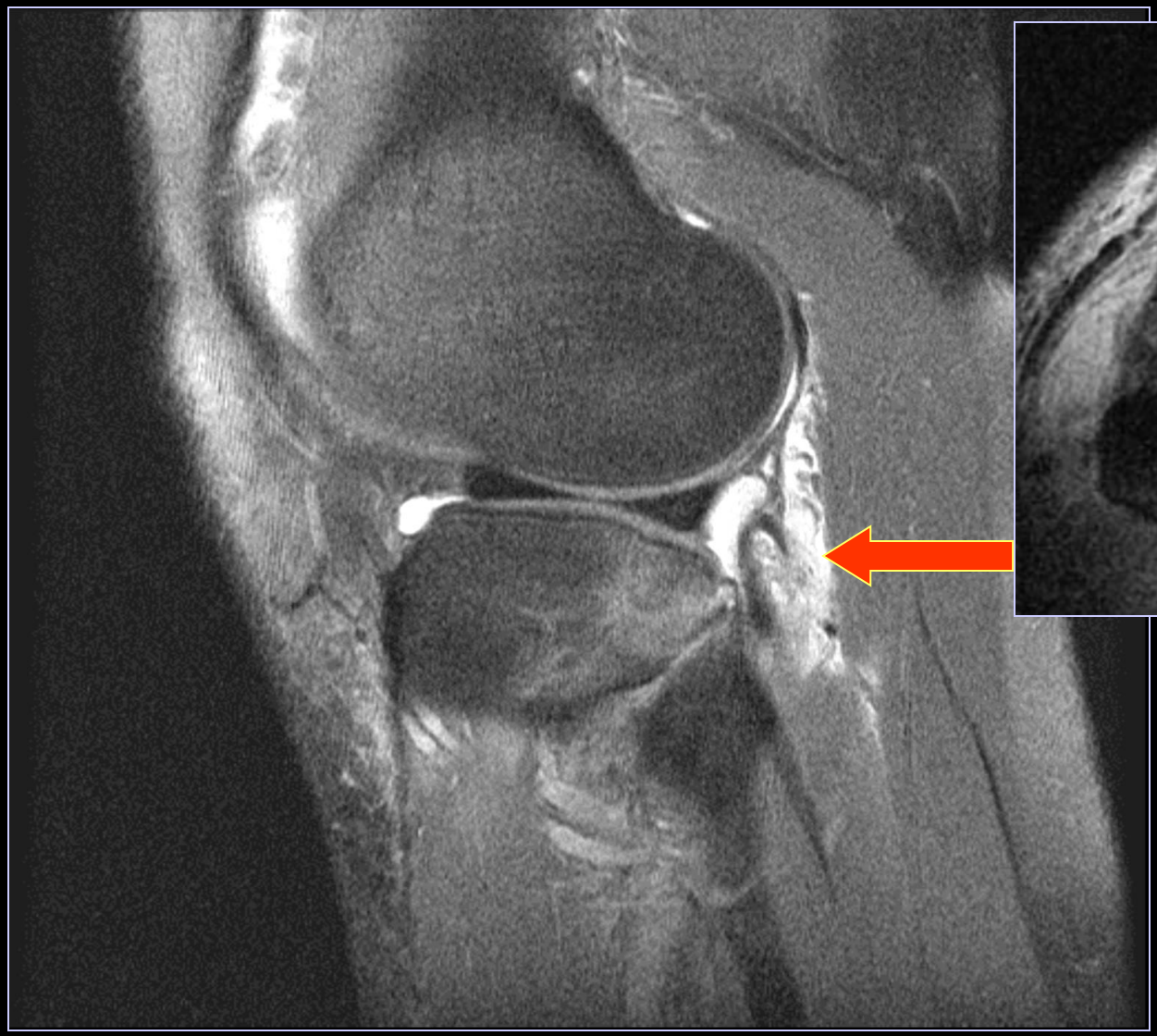


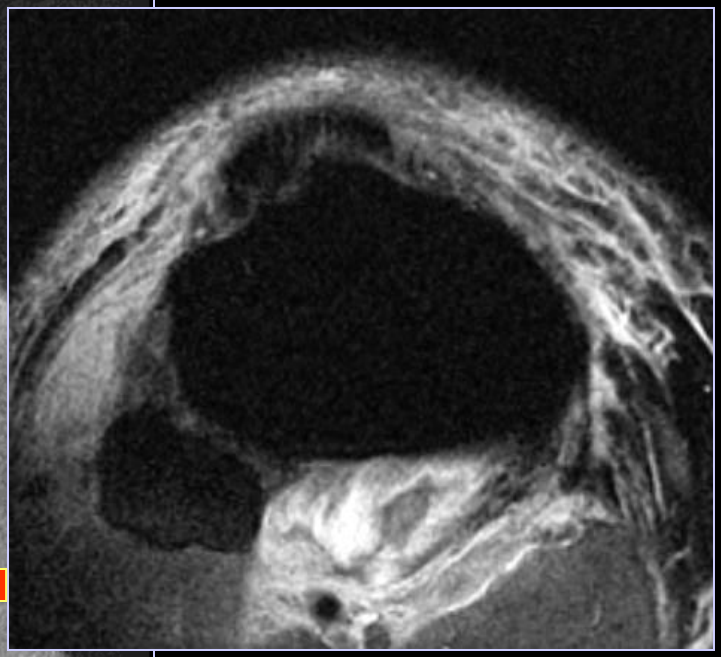
Fabella Fracture



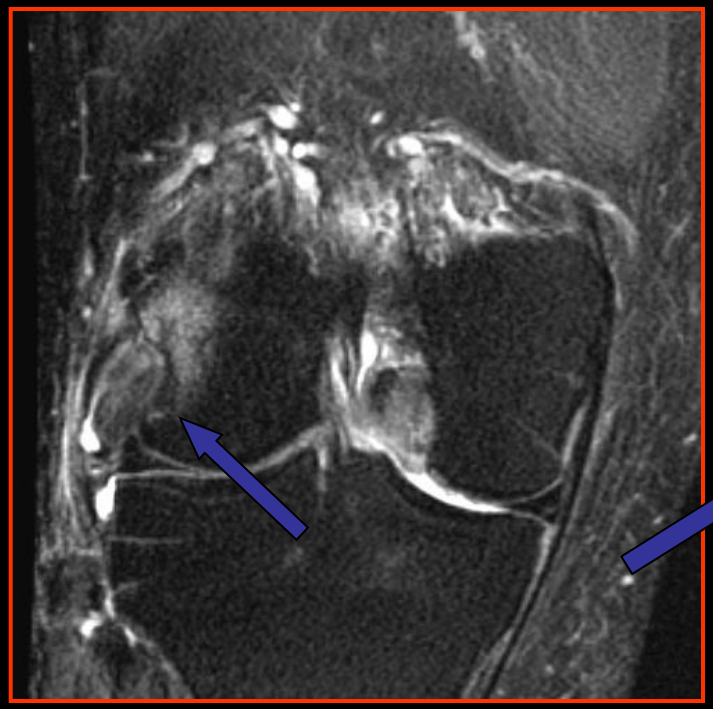


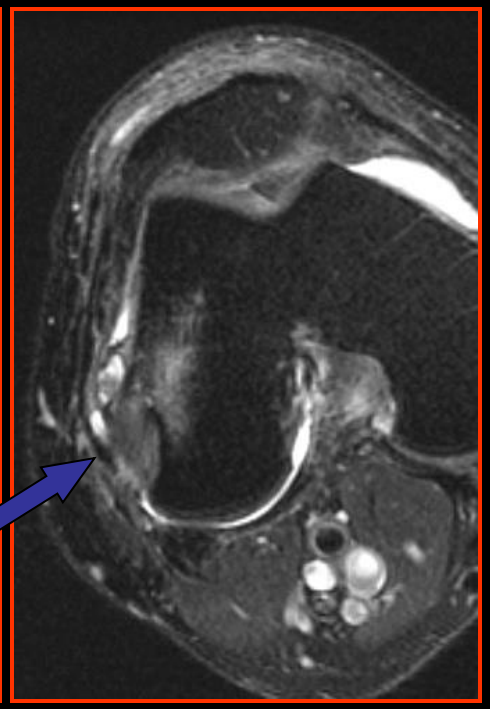
Popliteus Tear





Myotendinous junction most common





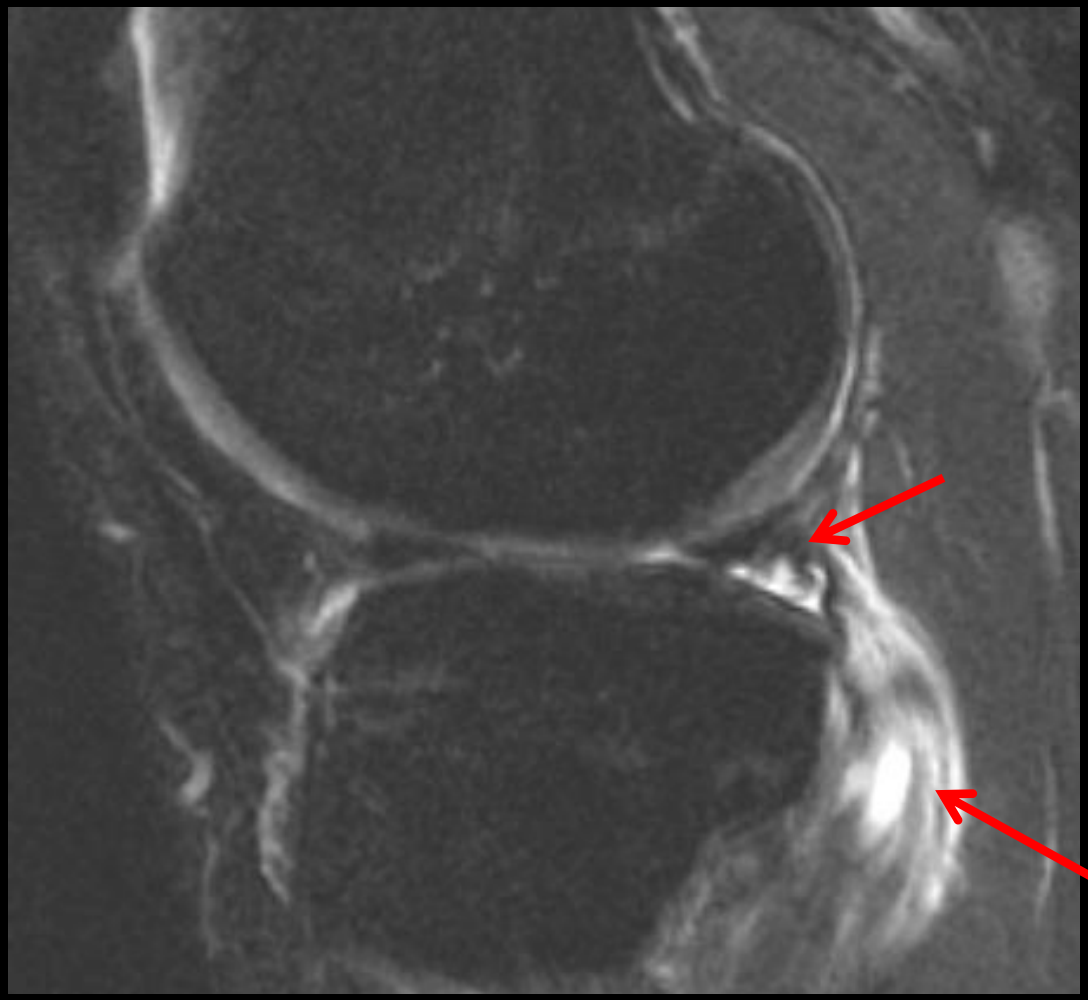
Popliteus is the *“Window to the Posterolateral Corner”*

Arcuate and pop-fib injuries

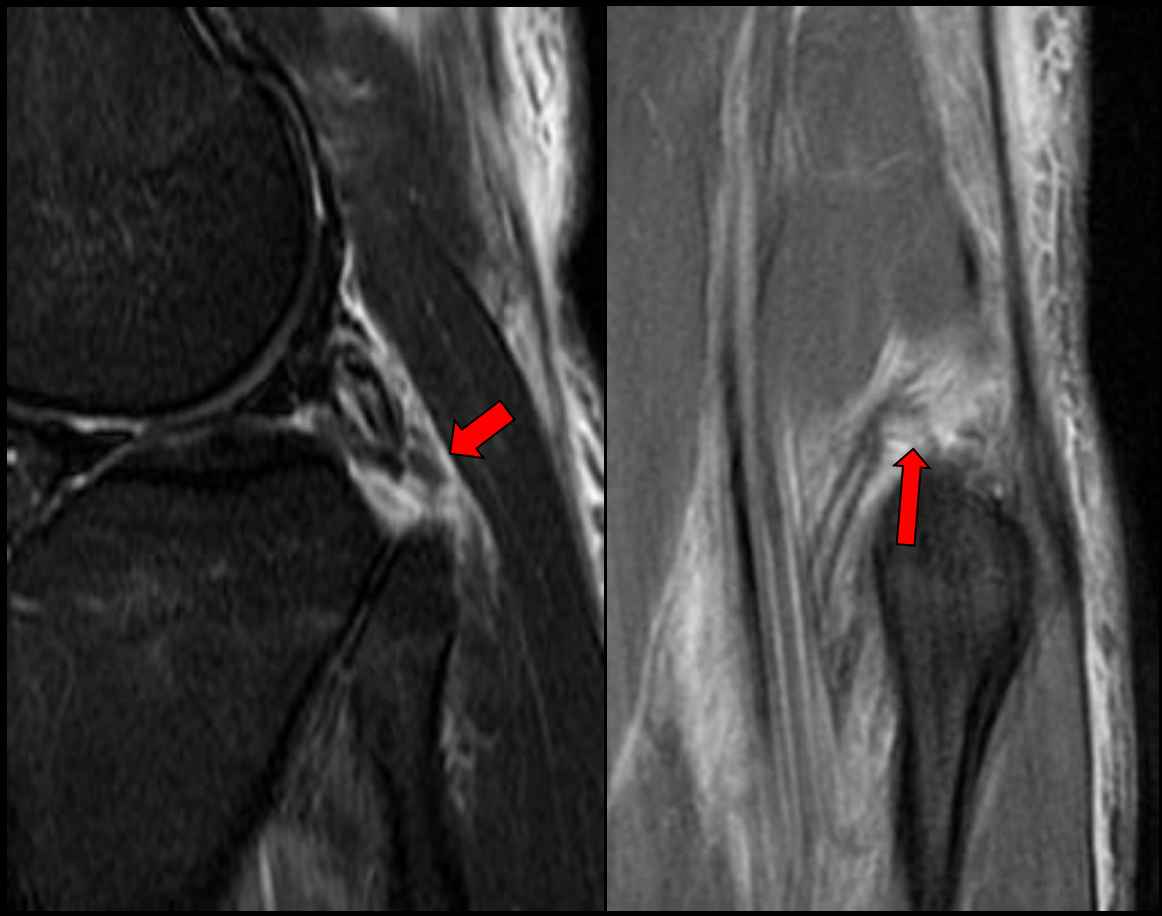
Meniscal-popliteal Fascicles

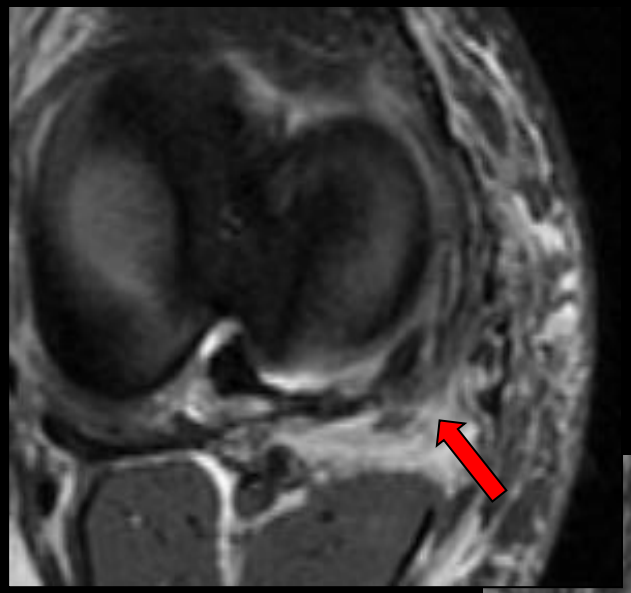
WARNING:
Highly variable!

Meniscal-popliteal Fascicle Disruption



Popliteofibular Ligament Tear

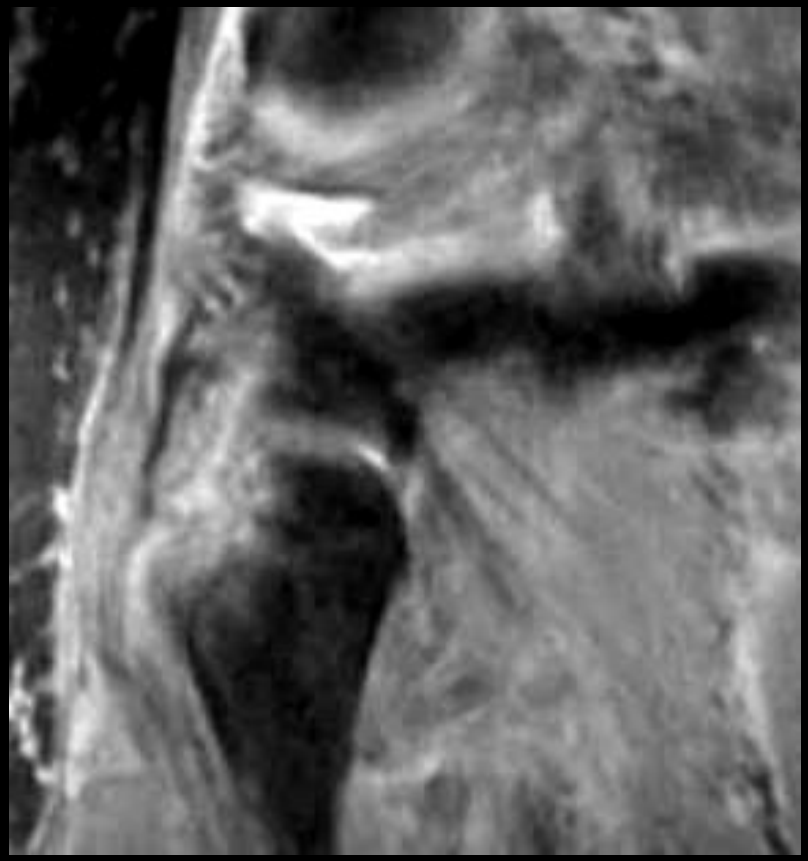




Edema superficial to myotendinous junction of popliteus

Check for fibular edema / fracture!

Fibular Avulsion



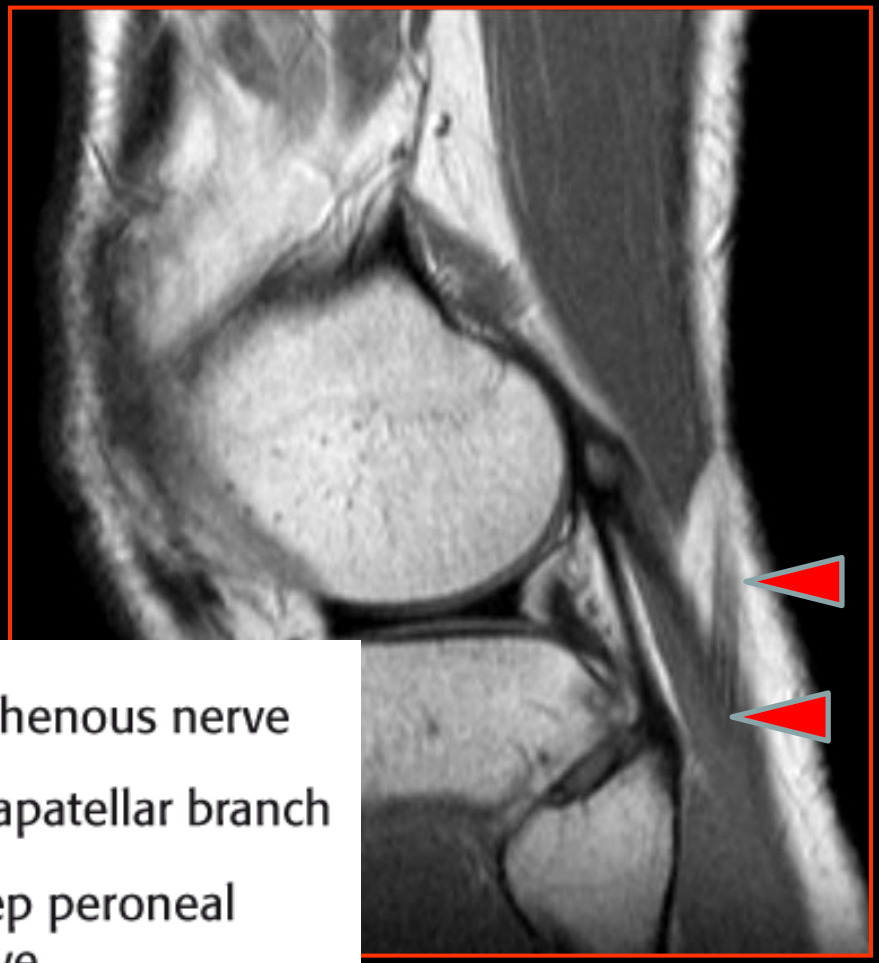
ARCUATE FRACTURE

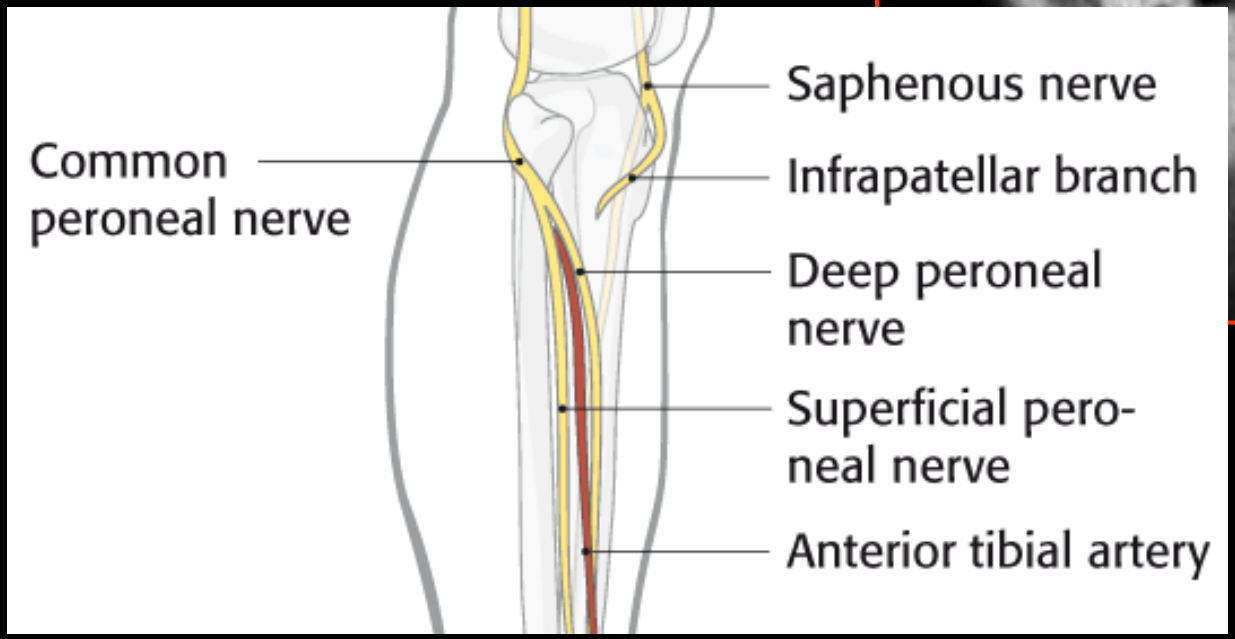
Posterolateral Corner Injury

Altered sensation to dorsum of foot and weak ankle dorsiflexion

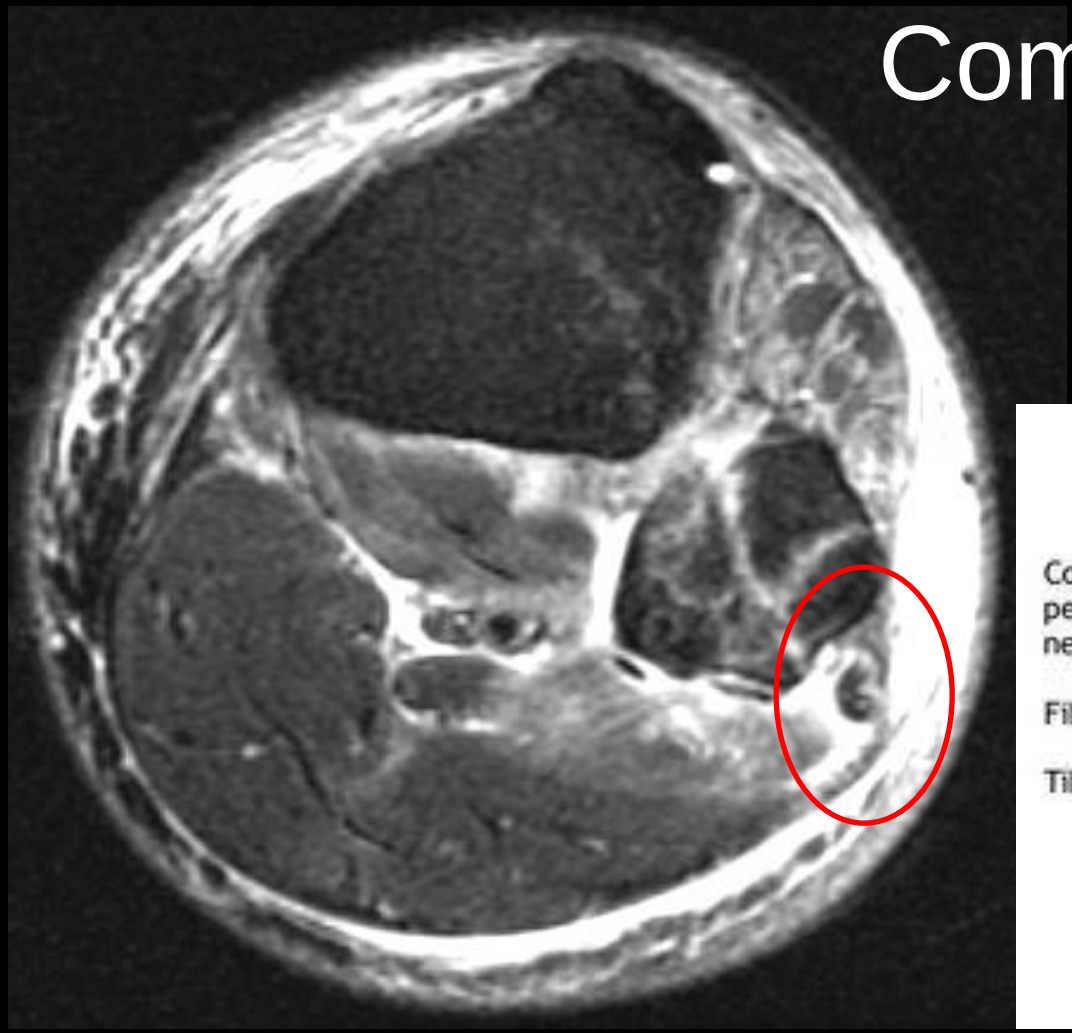
Common Peroneal N.

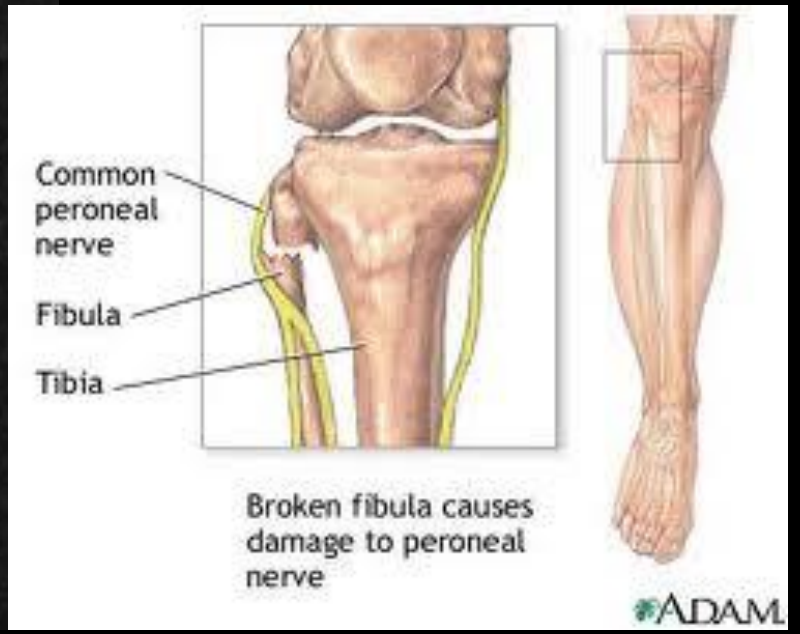
-Wraps around proximal fibula





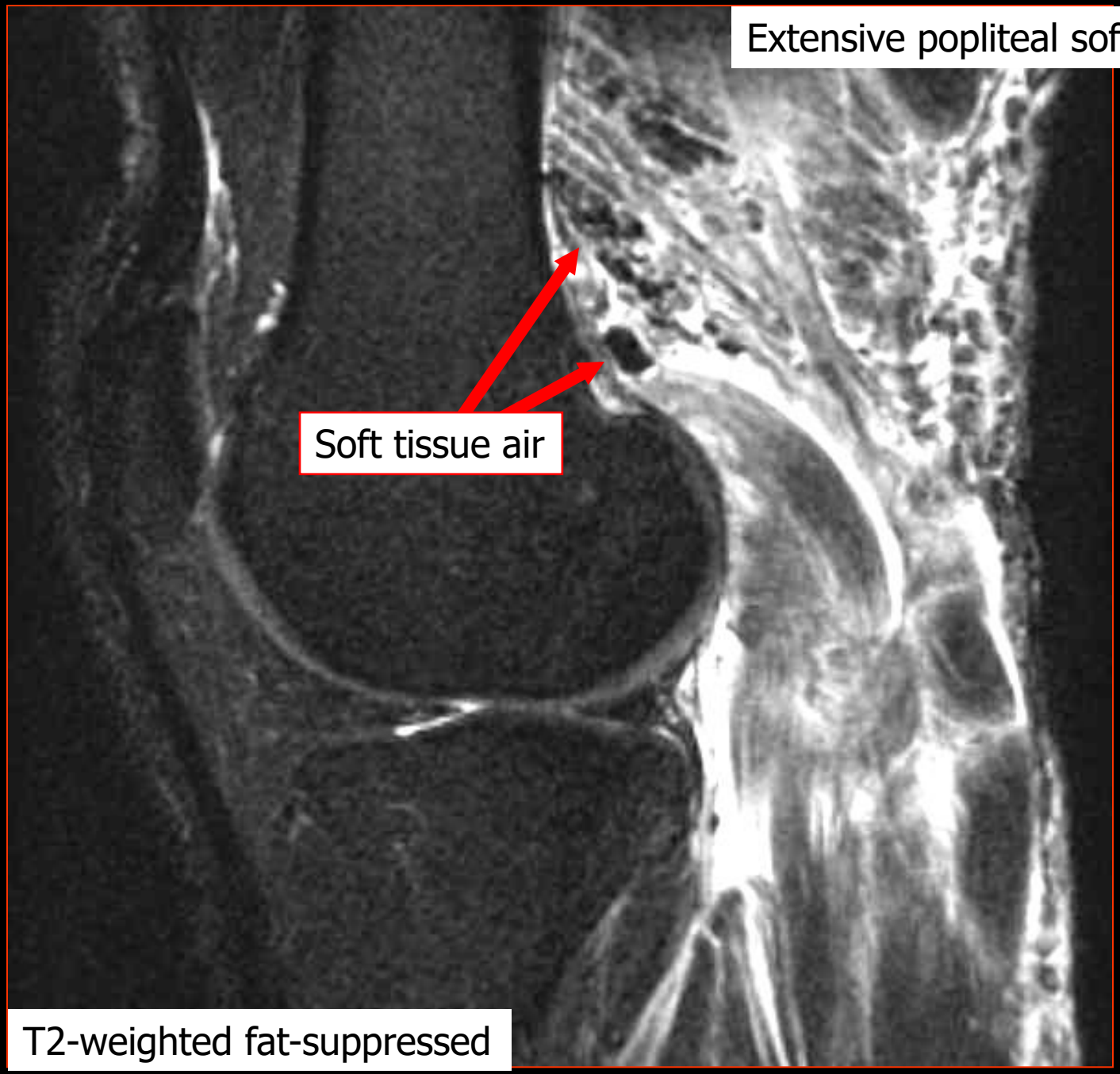
Fibular Fracture: Common Peroneal Nerve Injury

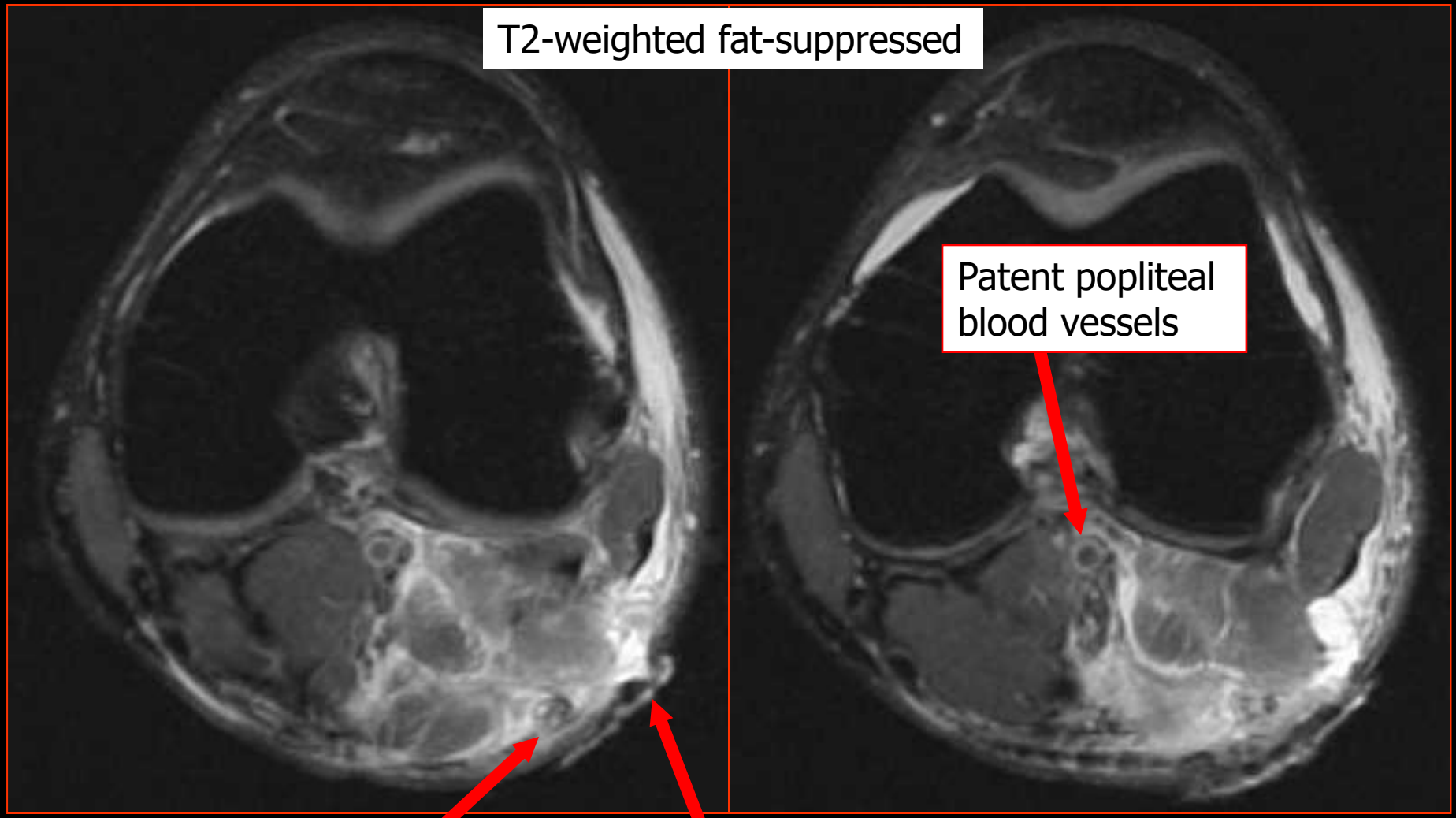




Professional football player, ‘escaping a dog’ in off season

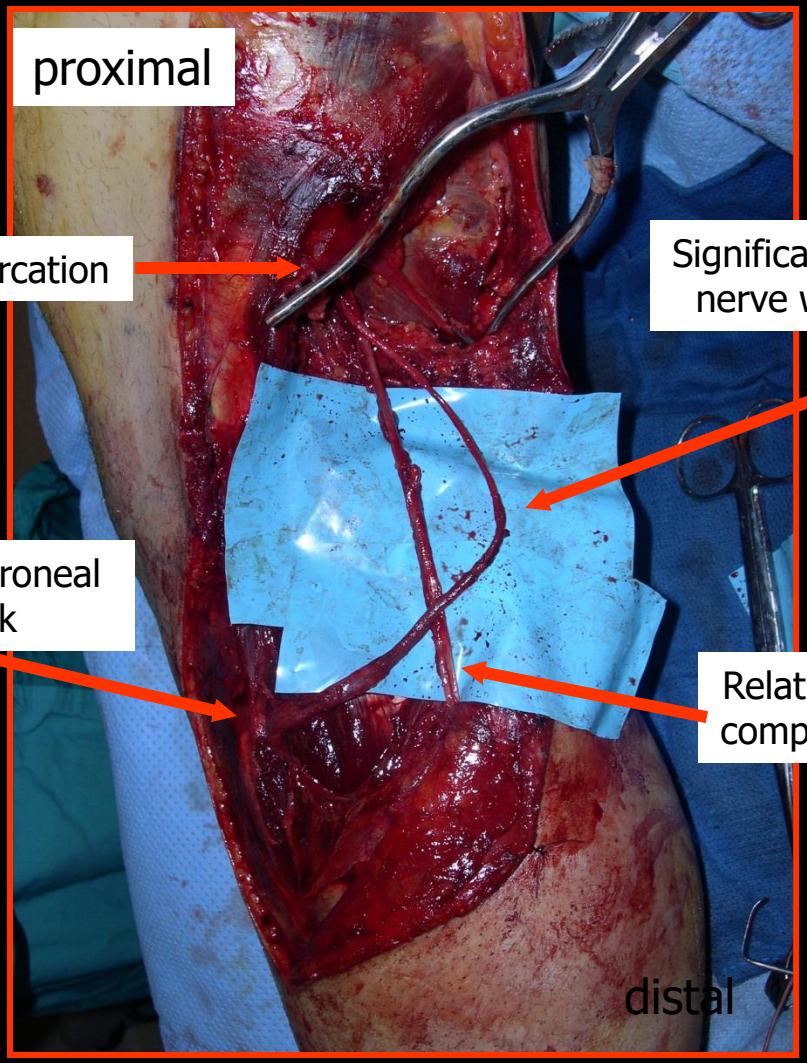
- Tried hurdling a fence
- Impaled left leg on fence
- Immediate peroneal nerve deficit
- Local ER treatment: wound sewn, no exploration


Extensive popliteal soft tissue injury
Soft tissue air
T2-weighted fat-suppressed

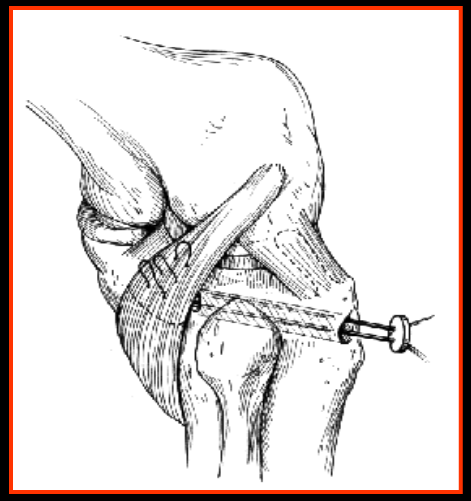

T2-weighted fat-suppressed
Patent popliteal blood vessels
Common peroneal nerve (thickened proximally)
Laceration


Oblique sagittal image
Posterolateral soft tissues
Laceration
Injured nerve
Normal nerve below fibular head

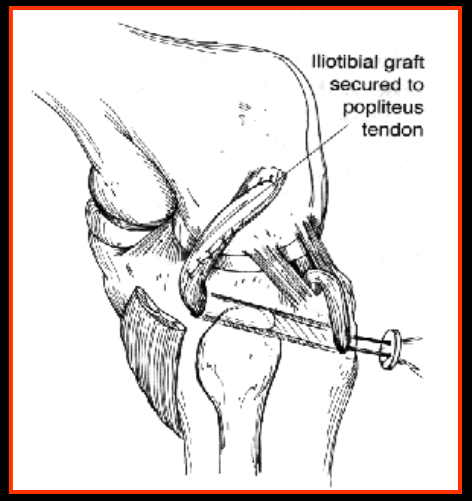
At surgery …


proximal
Sciatic Trifurcation
Significant diminution in caliber of nerve with extreme lengthening
Nearly normal caliber of peroneal nerve near fibular neck
Relatively spared sural nerve for comparison of course and caliber
distal

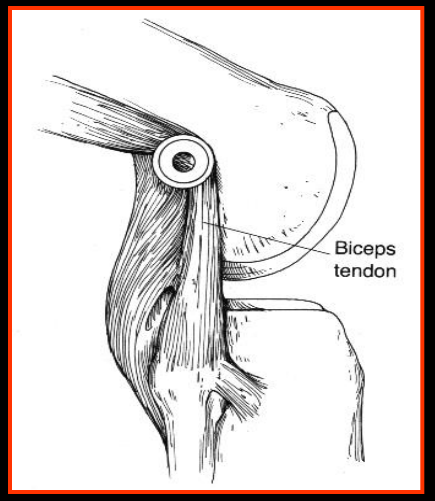
Posterolateral corner therapy: operative techniques



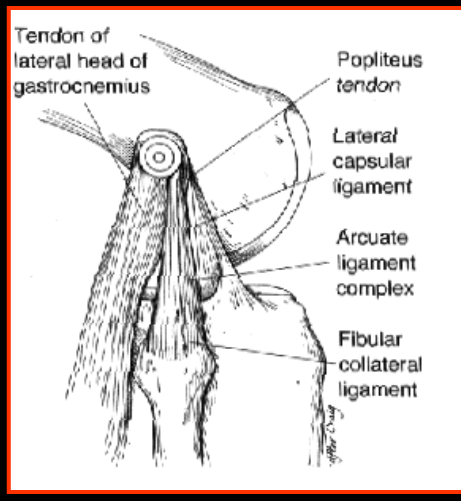
Primary repair



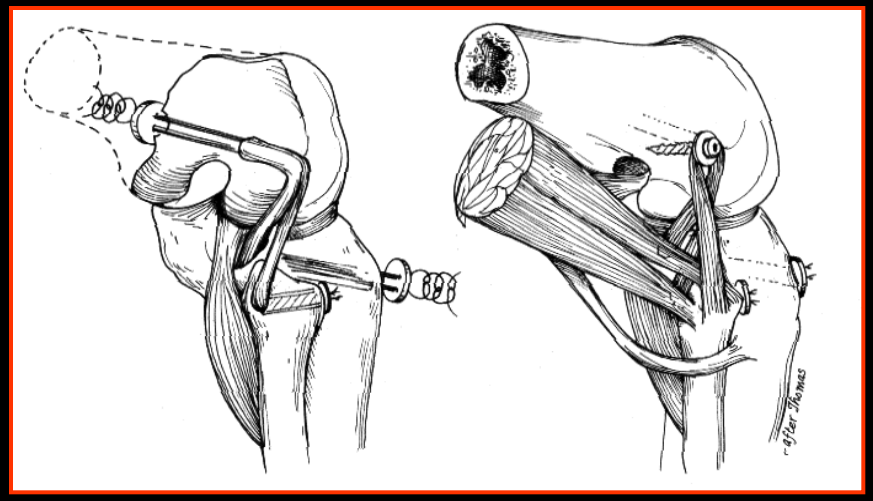
Augmentation



Biceps Tenodesis



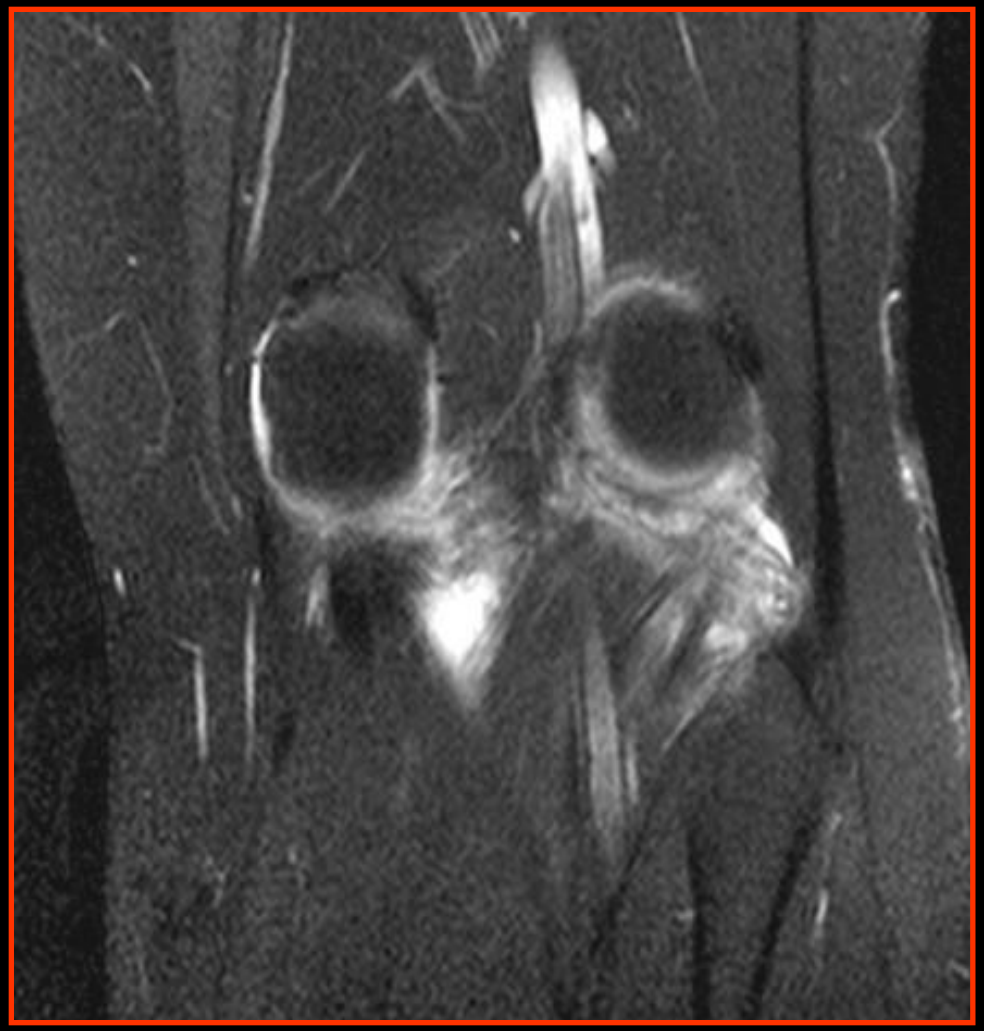
Advancement



Total Reconstruction

Take Home Points

- Look for mechanism
  - Is there cruciate injury?
  - Is there edema around the PL capsule?
- Look for integrity of main structures
  - LCL, Biceps
- Look for integrity of key *consistent* capsular structures
  - Pop-fib ligament, lateral capsular ligament



-Pivot-shift injury; PL capsular edema

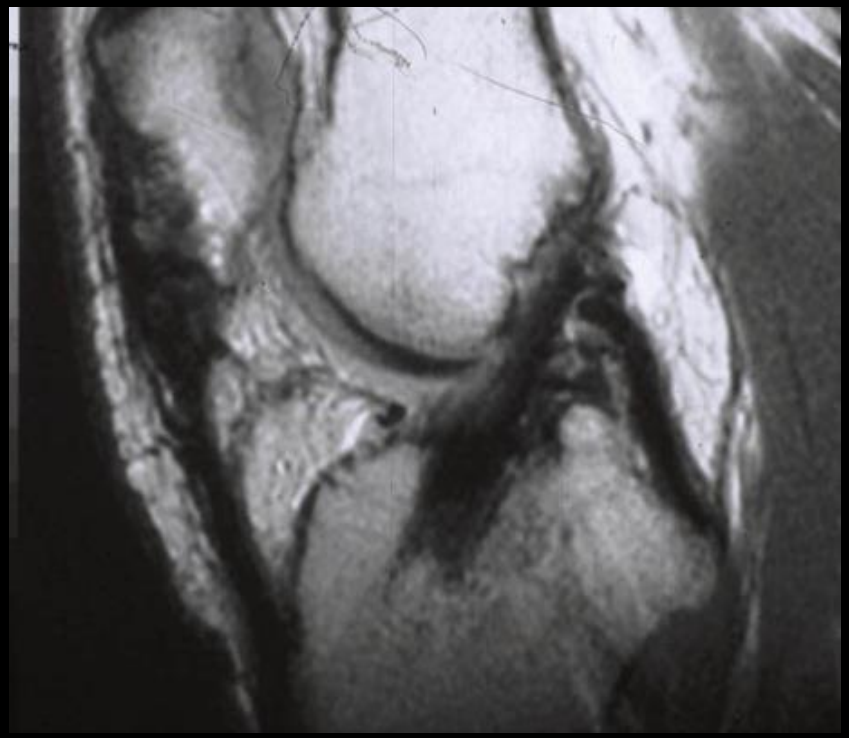
-Does NOT necessarily mean that there is a significant injury to the PL corner

Take Home Points

- Capsular / pericapsular edema ALONE
  - Very minor injury (may not report – typical for pivot-shift mechanism) DO NOT OVERCALL
- Main structure disruption
  - Major PL corner injury – report all structures that are disrupted separately
- Capsular (‘minor’) structure tear ONLY
  - MAY be a significant injury. Report concern.

Ligament Reconstruction and Repair

Anterior Cruciate Ligament Reconstruction



Common Sources of ACL Autograft

1. Bone-Patellar Tendon-Bone (BTB)
2. Hamstring (Semitendinosus and Gracilis Autograft)

MR Appearance of BTB ACL Graft

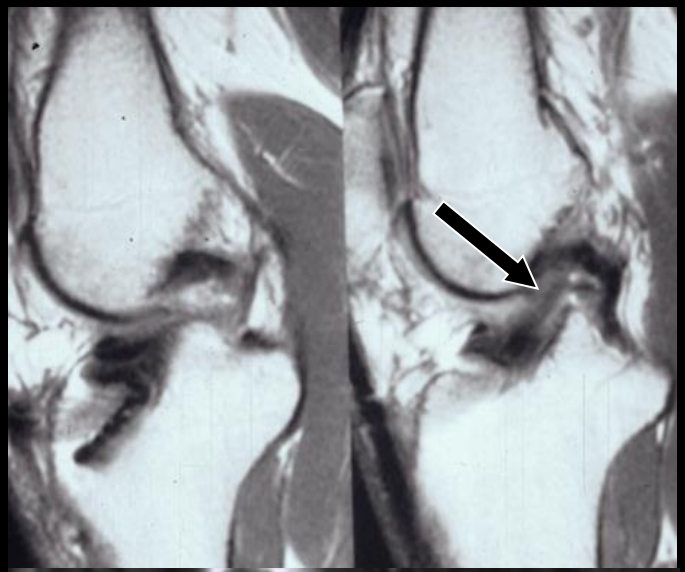
0 to 3 months

-Graft is avascular

-MR signal characteristics are identical to native patellar tendon

-Dark on T1 and T2 weighted images

MR Appearance of BTB ACL Graft



4 to 8 months

-Graft revascularization

-Increased T1 and T2 signal

-Normal graft should not have fluid signal within graft on T2-weighted images

MR Appearance of BTB ACL Graft

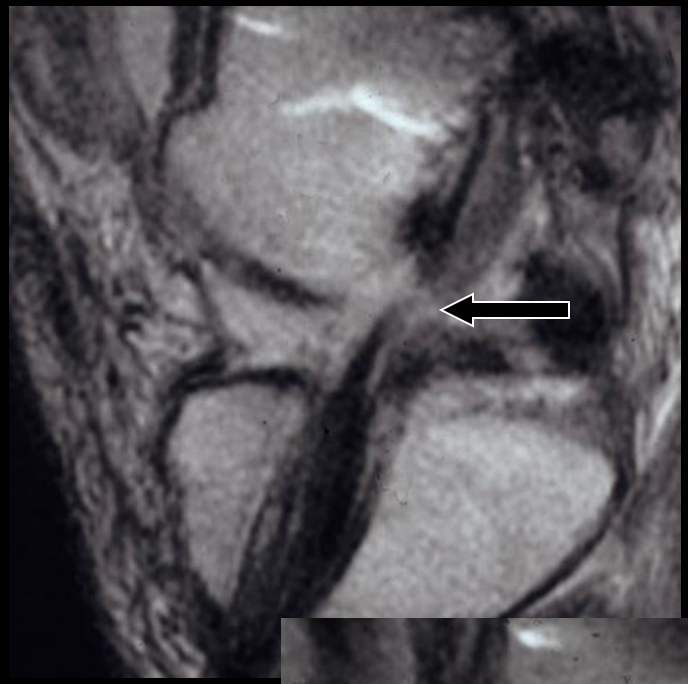
>12 months

-Ligamentization occurs

-MR appearance similar to native ACL appearance

-Dark on T1 and T2-weighted images; may have intermediate stranding in distal fibers

MR Appearance of Hamstring ACL Graft



-Hamstring graft progresses through the same stages as a BTB graft.

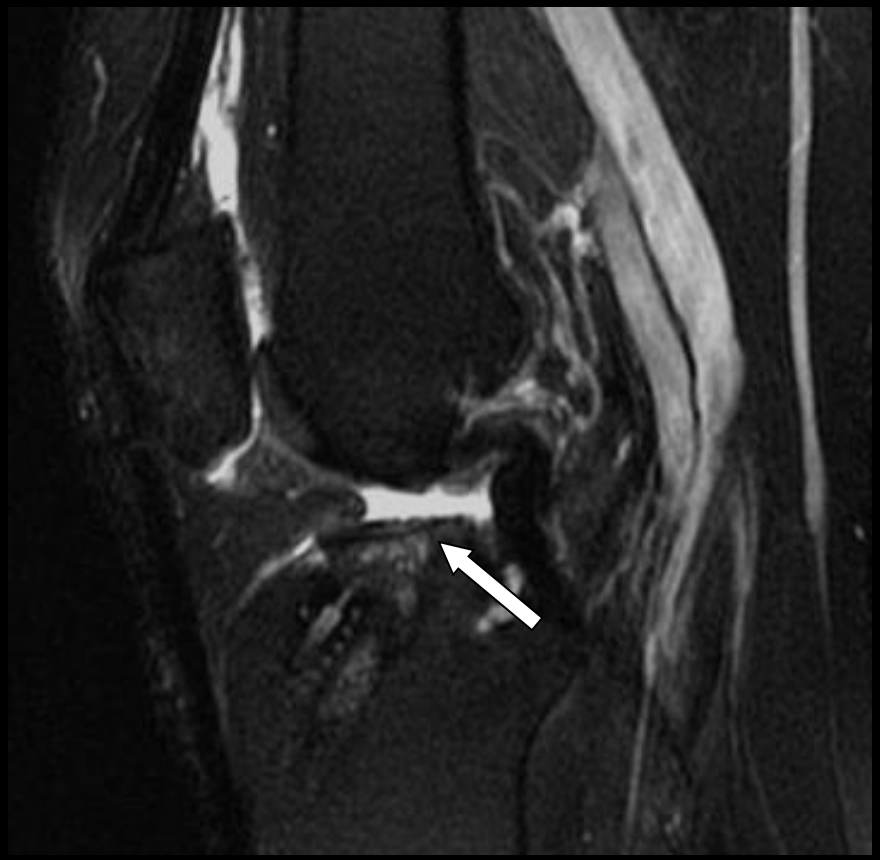
-Fluid present between separate strands of graft

MRI of the ACL Graft

Recurrent Symptoms

- **Lax Knee**
  - *Graft disruption*
  - *Stretched graft / tunnel expansion*
- **Lack of Full Extension**
  - *Graft impingement*
  - *Loose bodies*
  - *Arthrofibrosis*
- **Recurrent Trauma**
  - *Internal derangement, tear of graft*

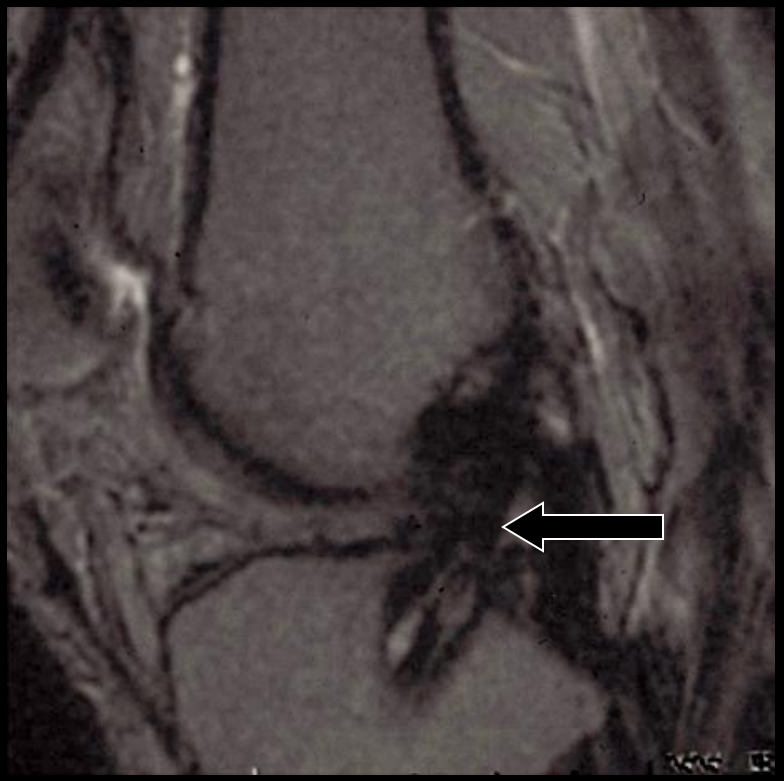
Lax Knee: Disrupted ACL Graft



-Discontinuity of fibers

-Graft fibers resorb over time

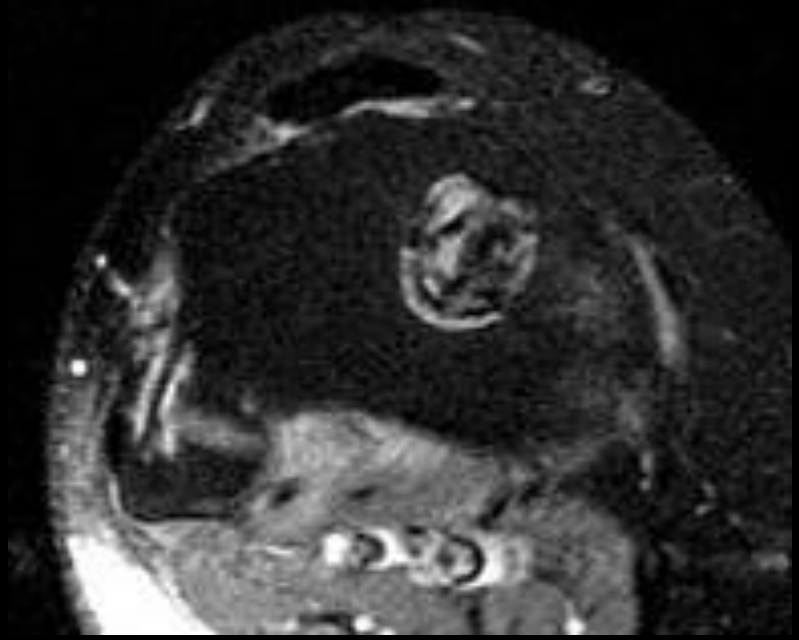
Lax Knee: Stretched Graft



-Knee lax on physical exam

-Graft intact with bowing of fibers; often associated with expansion (enlargement) of tibial or femoral tunnels

Status of the Tunnel
Tunnel Expansion



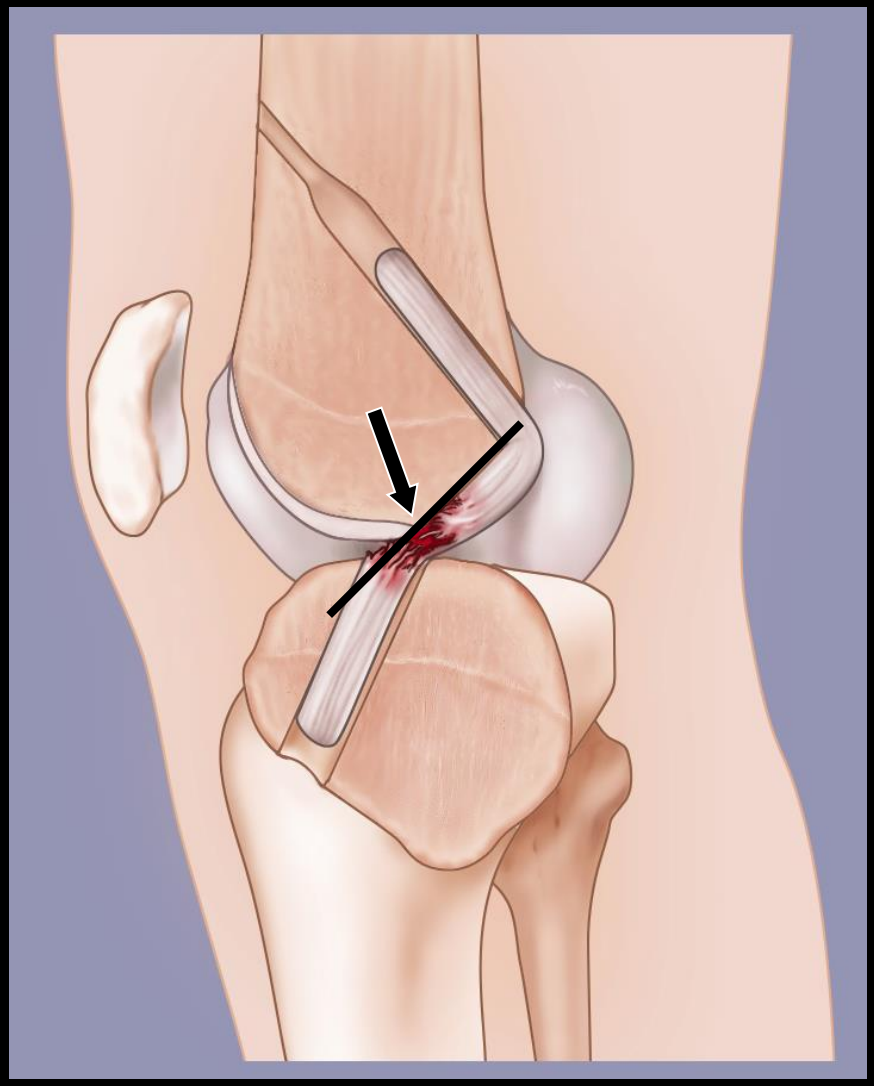
Results in graft laxity

“Windshield wiper” effect

Leads to graft impingement, tear

Femoral Tunnel Expansion

ACL Graft Impingement

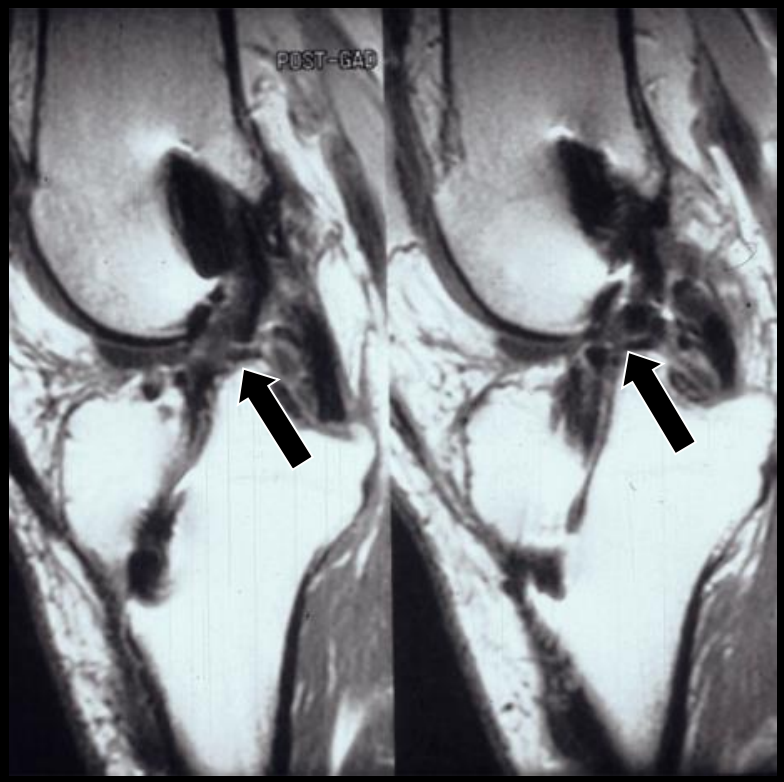


-Anterior placement of tibial tunnel or secondary to laxity

-Graft impacts roof of intercondylar notch during extension of knee

-MRI Findings
  -Anteriorly placed tibial tunnel
  -Increased signal in graft
  -Kinking of graft

Decreased ROM: Graft Impingement

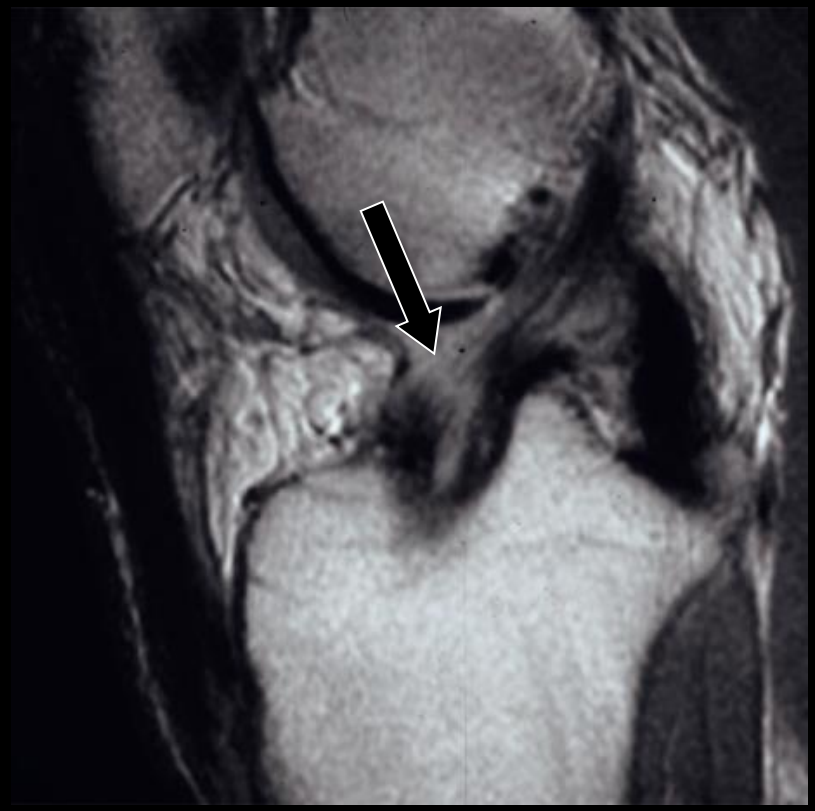


-Anterior placement of tibial tunnel

-Kinking of ACL graft

-Increased signal within graft fibers

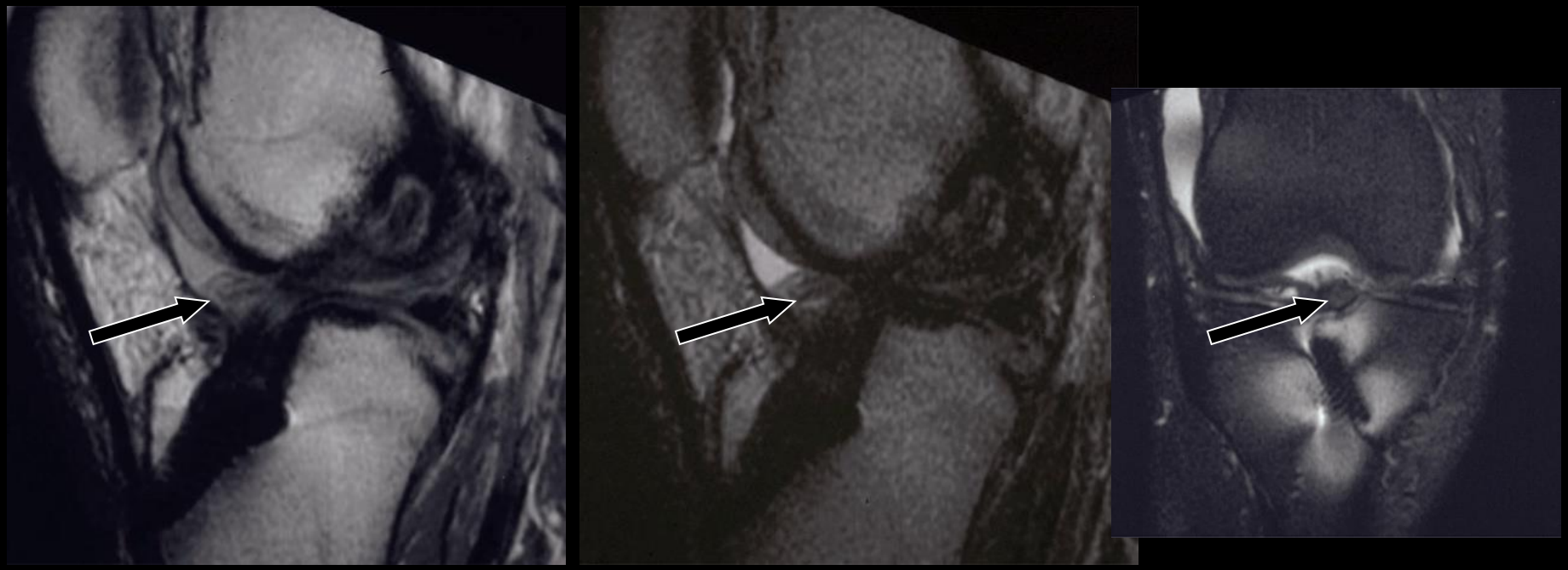
ACL Graft Impingement



-ACL kinking against roof of intercondylar notch

-Fraying of anterior graft

Decreased ROM: Arthrofibrosis

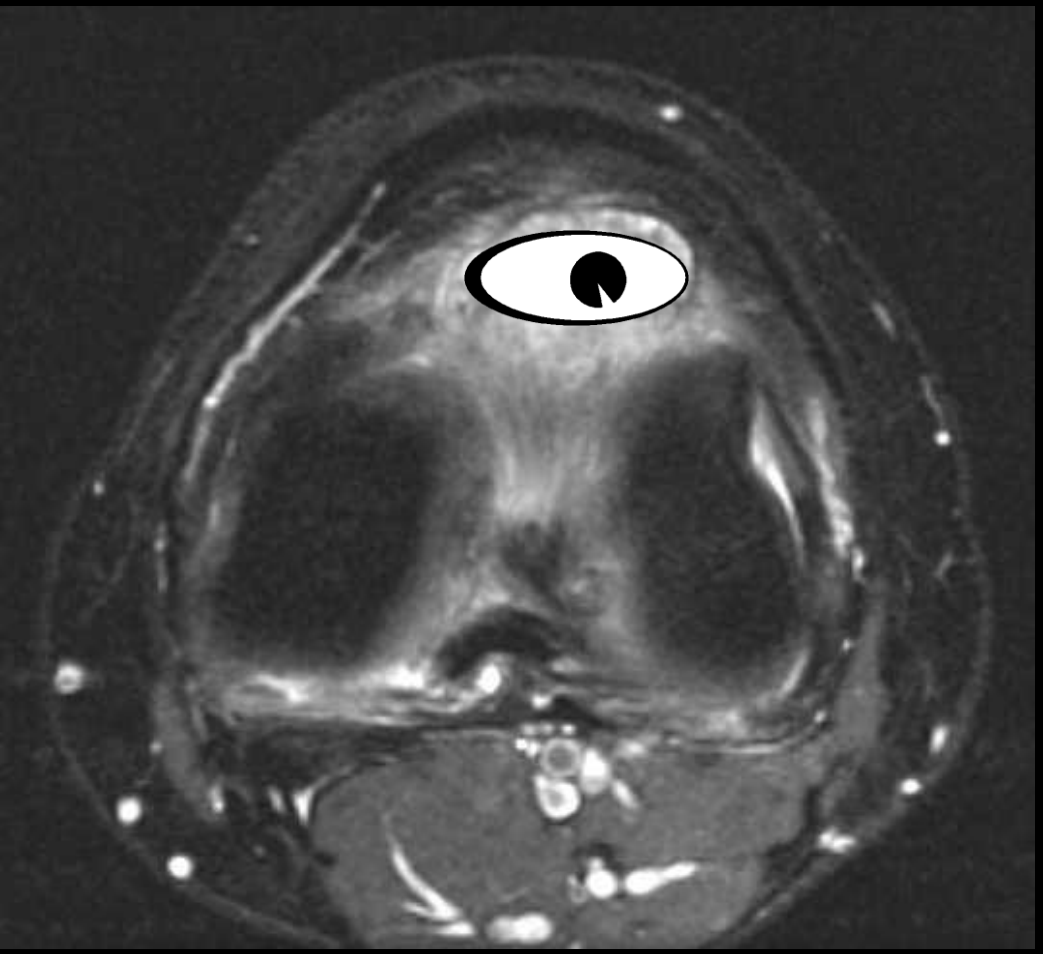


-Cyclops lesion (limits full extension of knee, anterior knee pain)

-Focal nodule of scar tissue just anterior to ACL graft

-Dark on PD and T2-weighted images

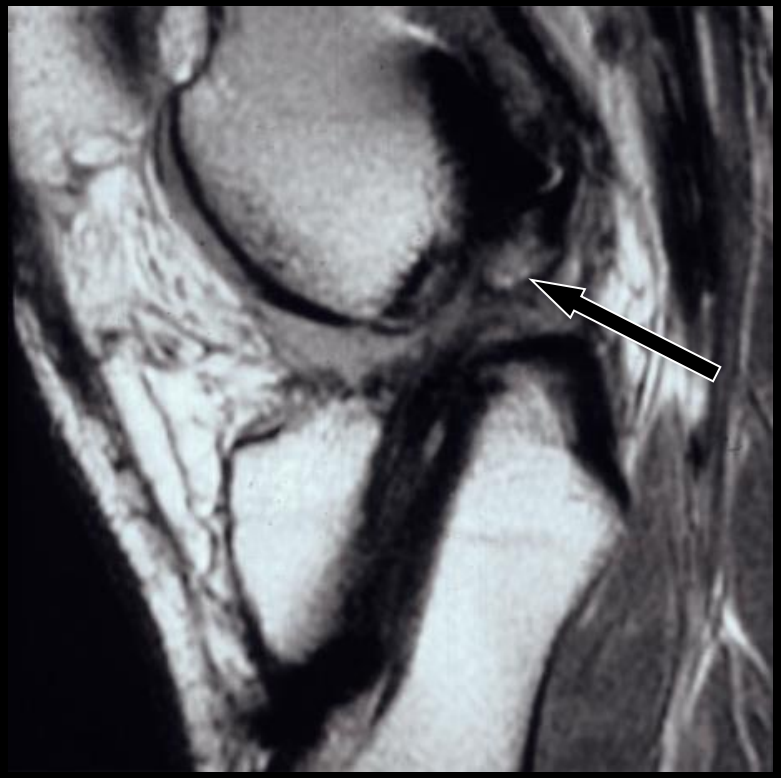
Arthrofibrosis

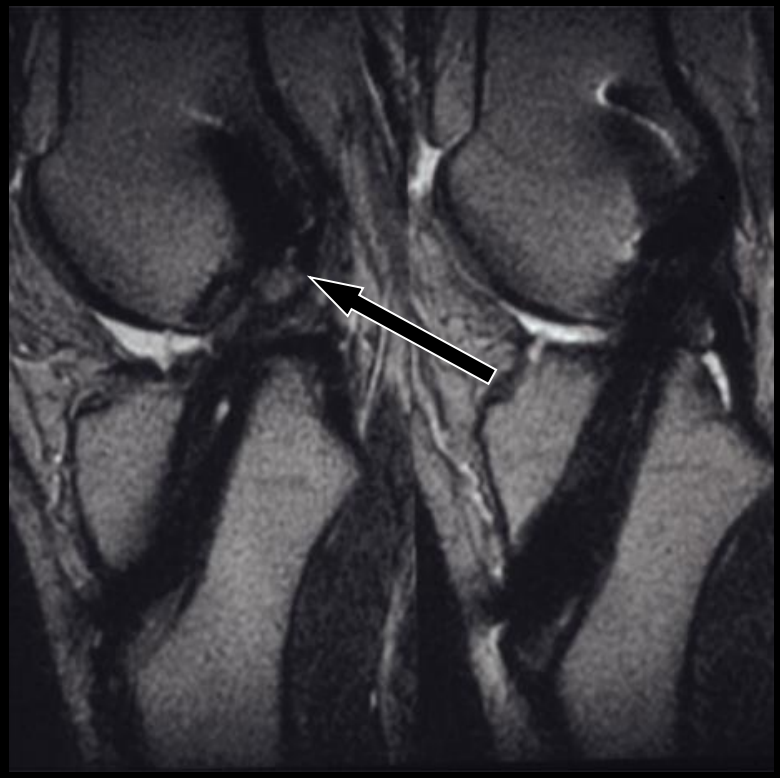


The Cyclops – by Odilon Redon (1840-1916)

(Rijksmuseum Kroller-Muller, Otterlo, the Netherlands)

Decreased ROM: Loose Bodies



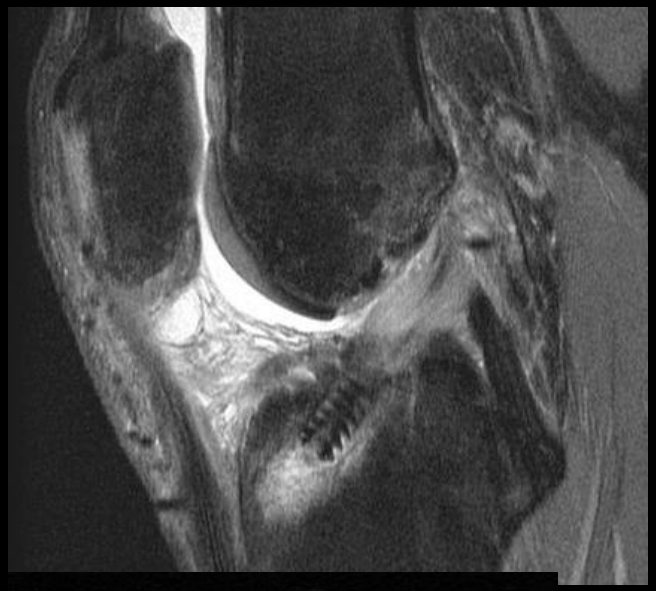


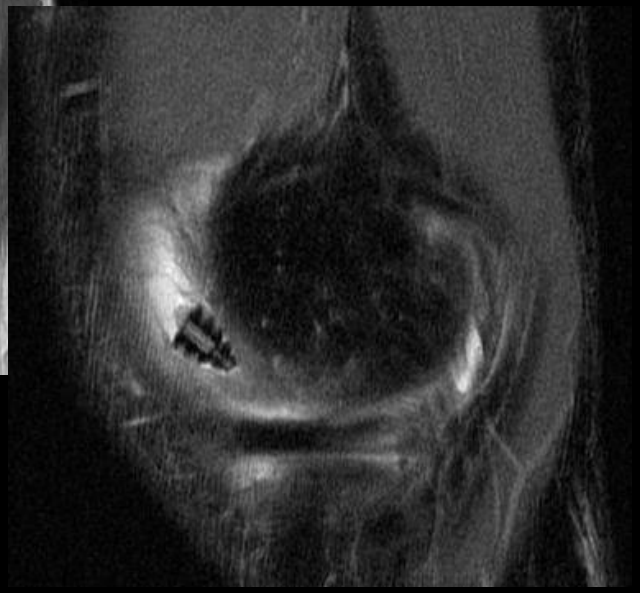
-Loss of full extension, decreased range of motion, locking

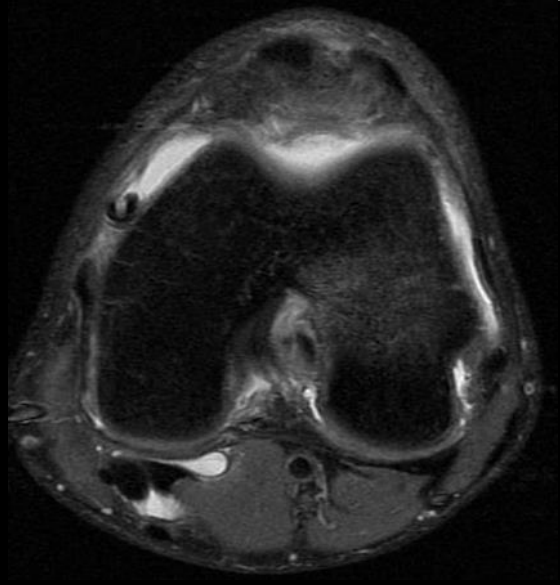
-Loose bodies can be subtle on MR imaging

-Can be cartilaginous or osseous

Decreased ROM: Foreign Body

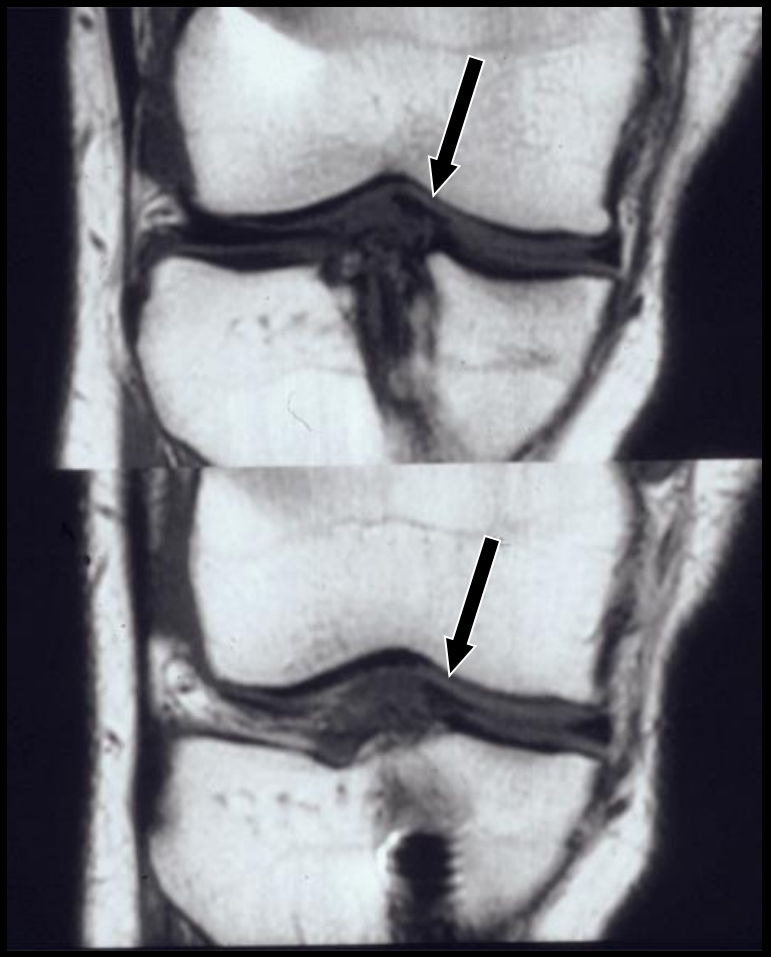






Locking and pain 6 weeks following ACL reconstruction

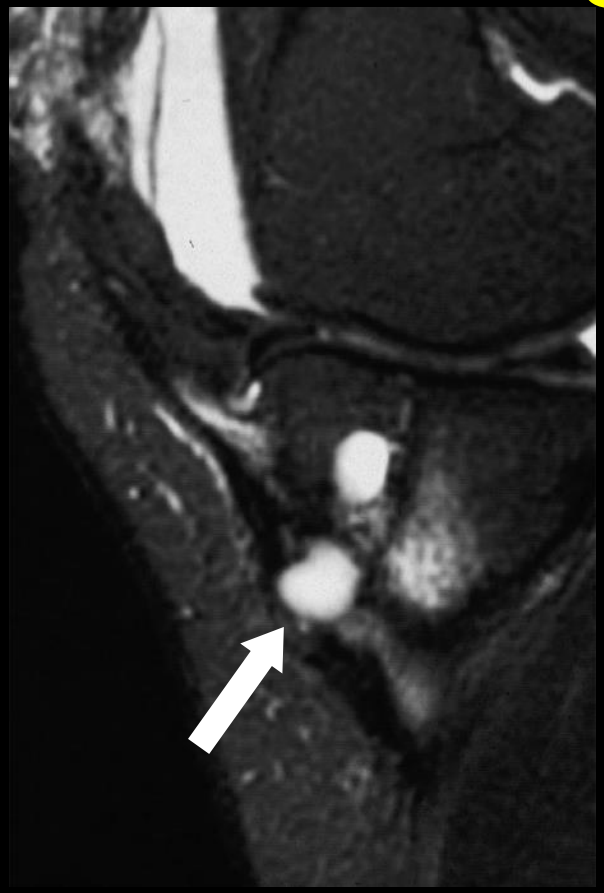
Decreased Range of Motion

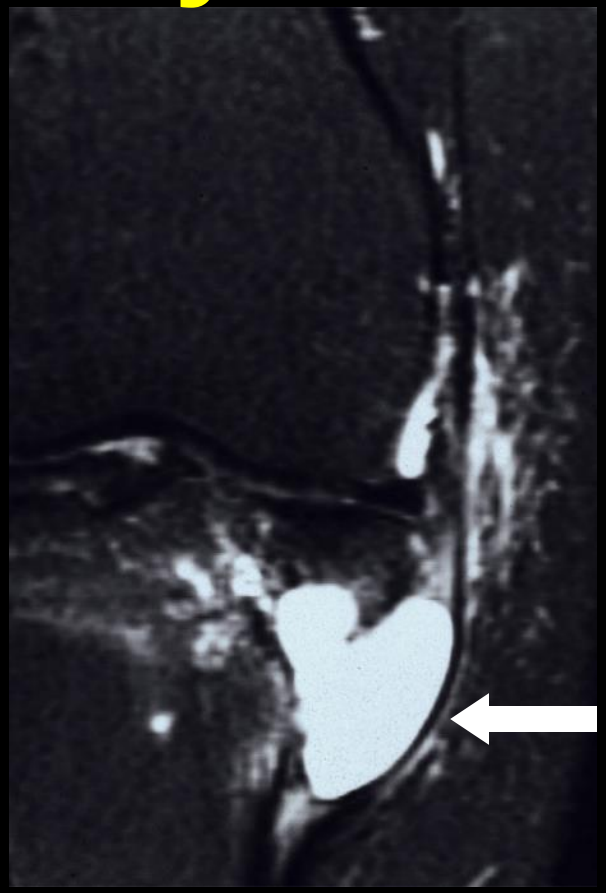


-Basketball injury following ACL reconstruction

-Bucket-handle meniscal tear with displaced fragment

Ganglion Cyst



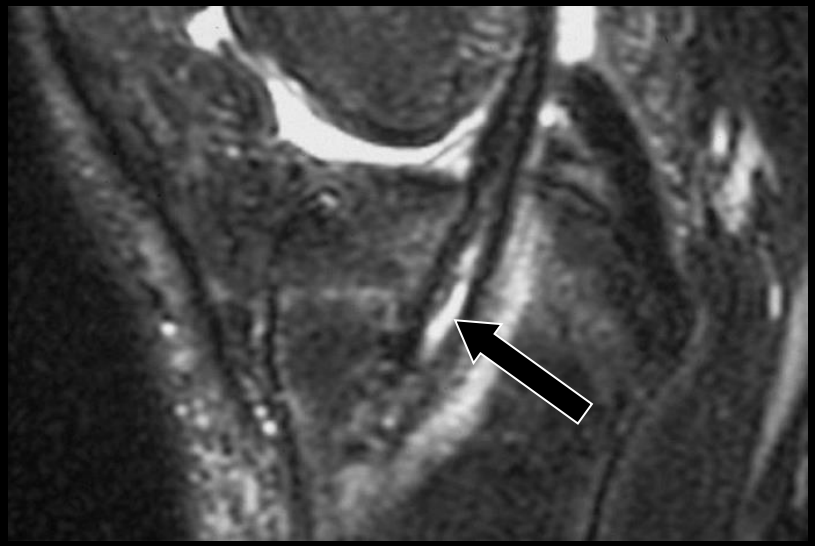


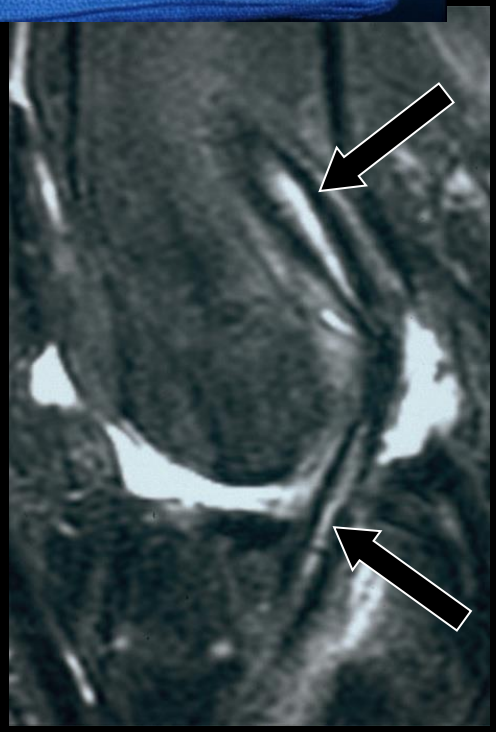
-Associated with degeneration or partial tear of graft

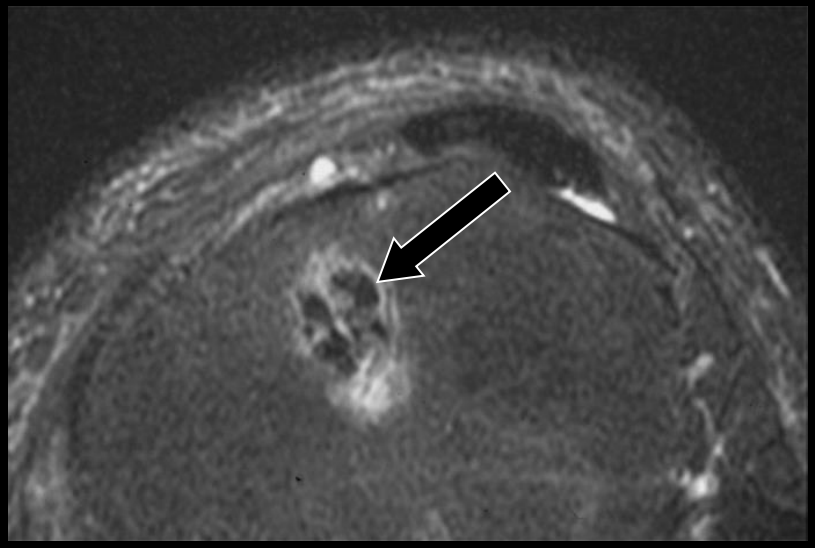
-Usually involves the tibial tunnel (presents as mass or with pain)

-More common in hamstring graft

Fluid in Tunnel of Hamstring Graft



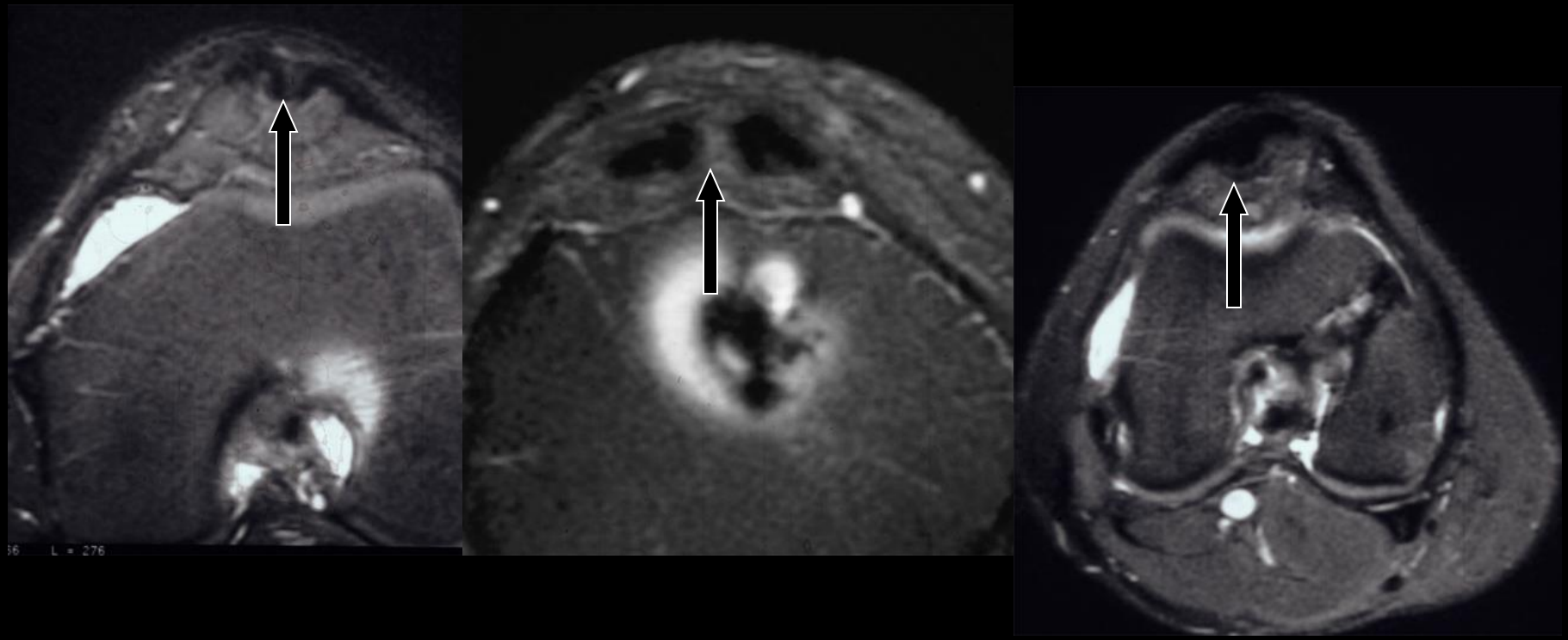




-Normal finding during first year

-Does not lead to ganglion formation

Patellar Tendon Harvest Site

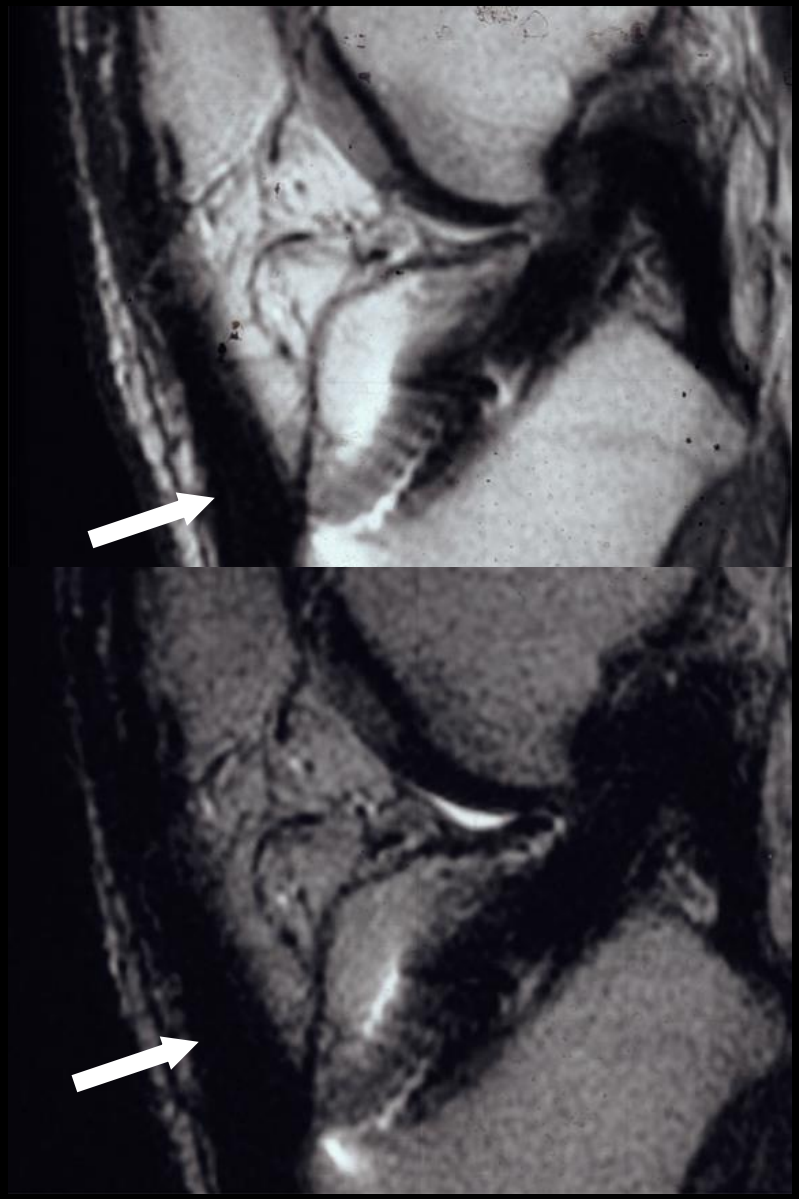


-BTB graft harvested from the middle 1/3 of the patellar tendon

-Defect seen in tendon and bone on MR imaging

-Defect fills in with tendon-like material during the first year

Harvest Site Complications



-Anterior Knee pain- common

-Patellar tendonitis

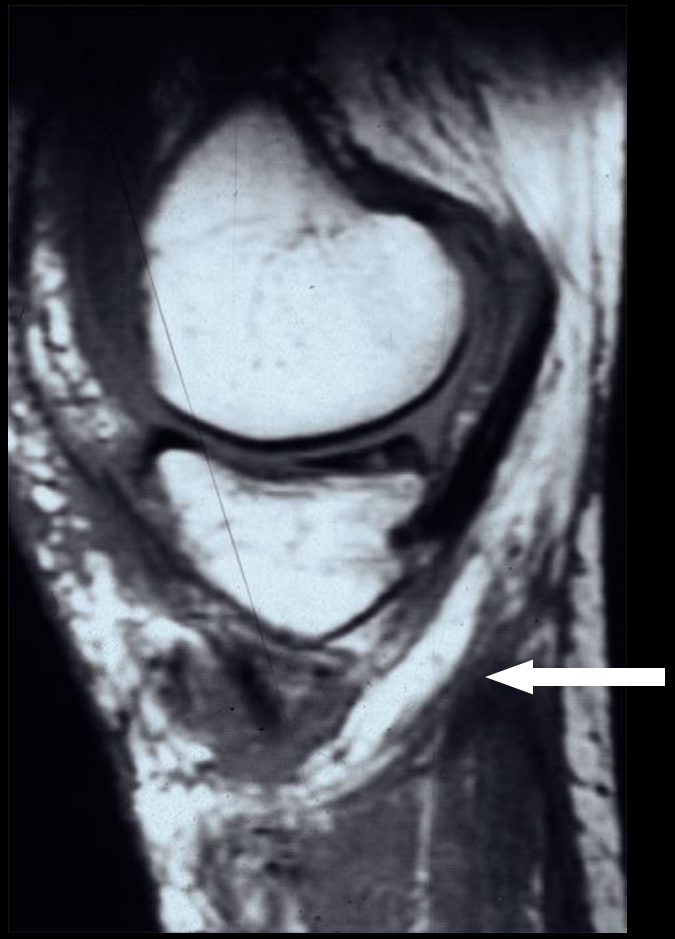
>10mm thick after one year

Harvest Site Complications

-Anterior Knee pain

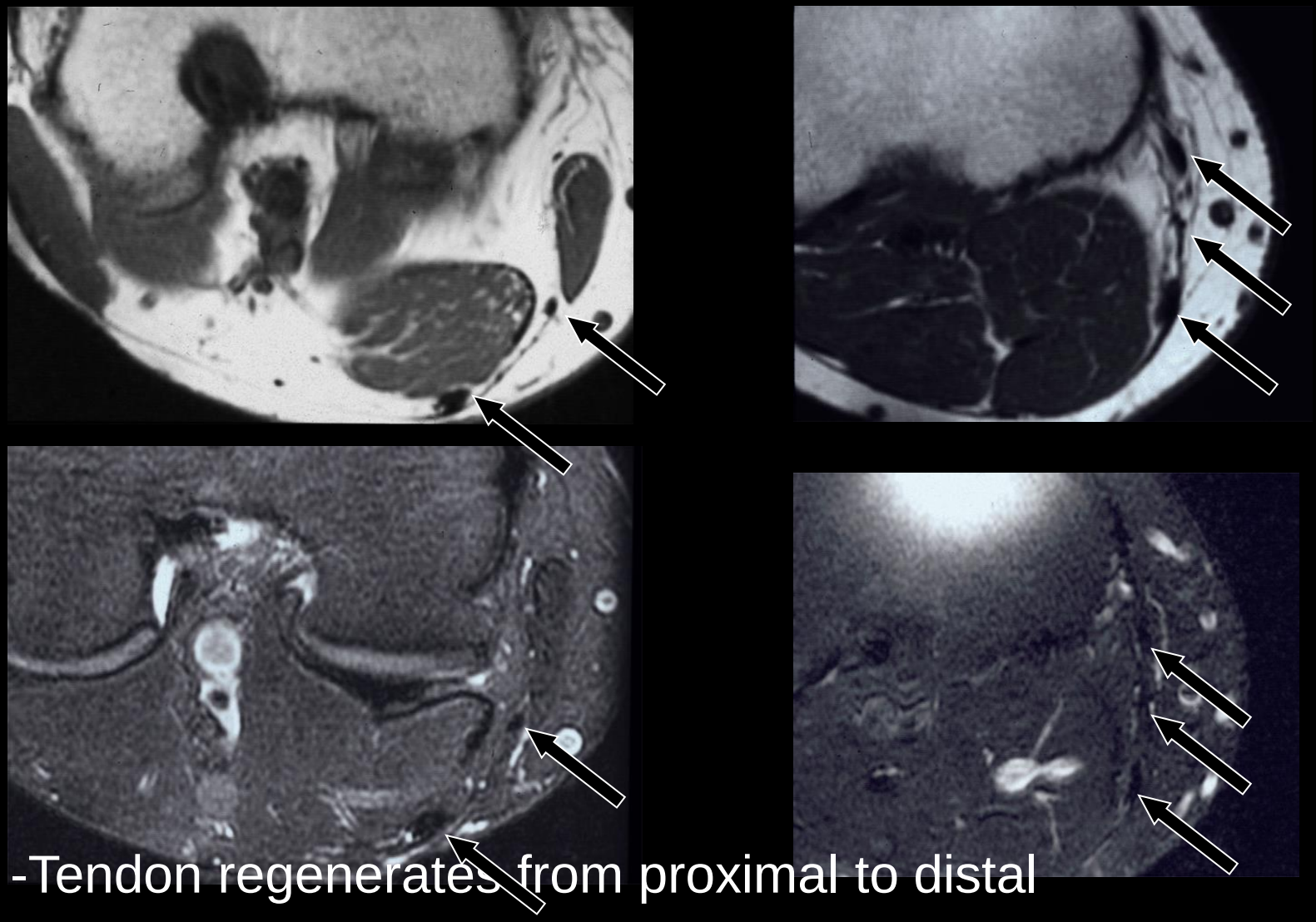
-Patellar fracture

Hamstring Tendon Harvest Site



-Immediate post-op- Fluid seen within harvest track

Hamstring Tendon Harvest Site



-Tendon regenerates from proximal to distal

-Tendon appears normal within 8 months; 80% original strength

Posterior Cruciate Ligament

-PCL twice as strong as ACL

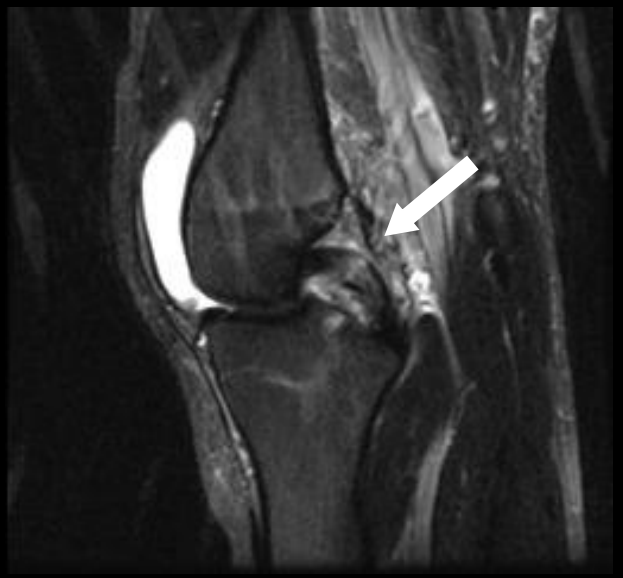
-PCL less commonly injured (usually only partially torn)

-Conservative therapy usually adequate

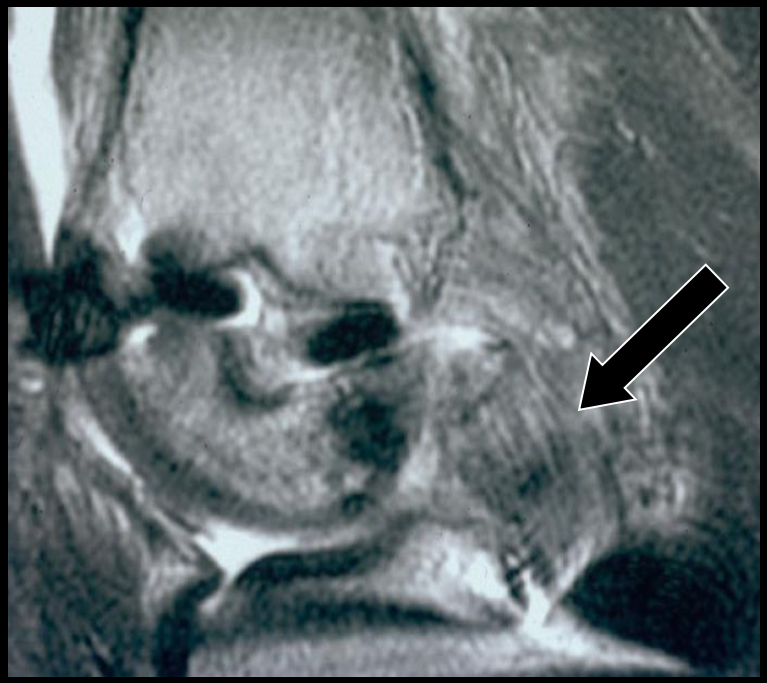
-PCL reconstruction

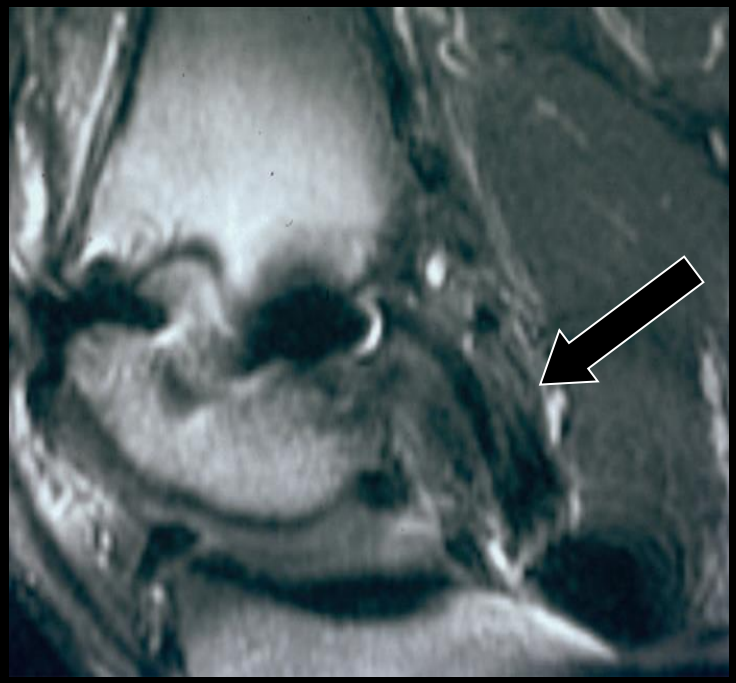
-Indicated in high performance athletes

-Indicated if significant instability/ multiple ligamentous injuries



PCL Reconstruction





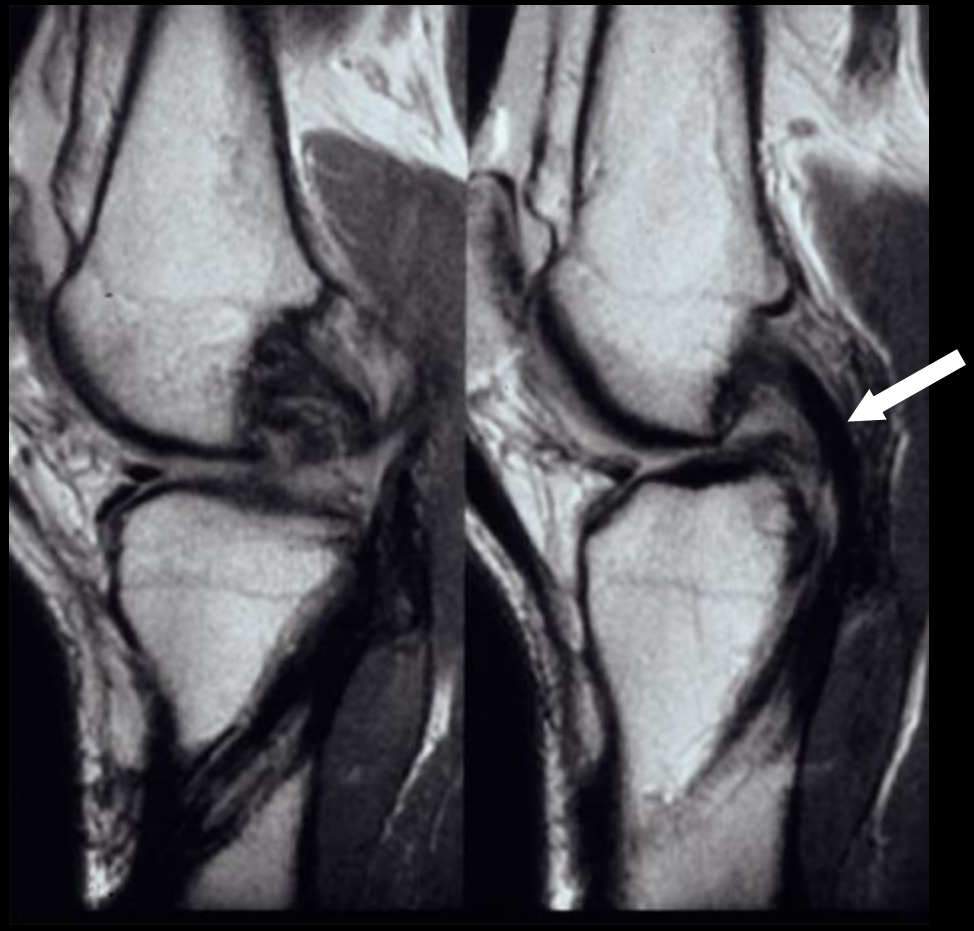
-MR appearance of PCL graft

-Initially thickened with increased signal on T1- and T2-

-Fibers become better defined by the end of the first year

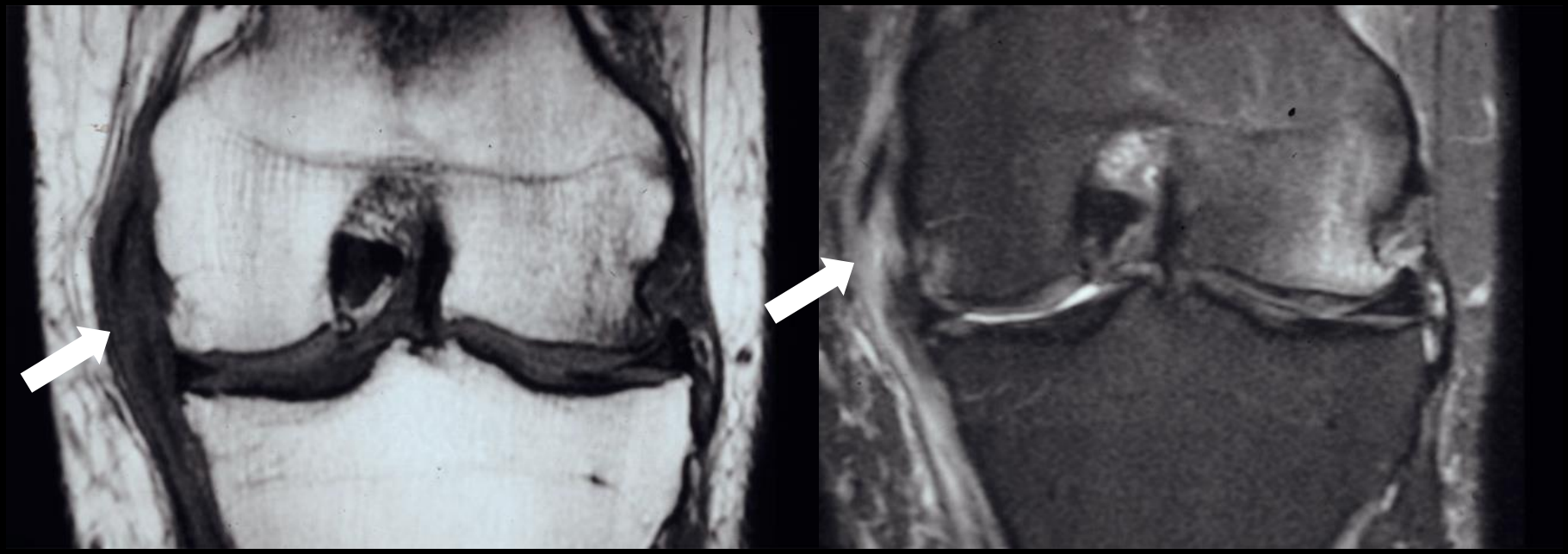
-Extensive arthrofibrosis is commonly seen

PCL Reconstruction



-By one year; fibers are well defined and dark on all pulse sequences

Collateral Ligament Injuries

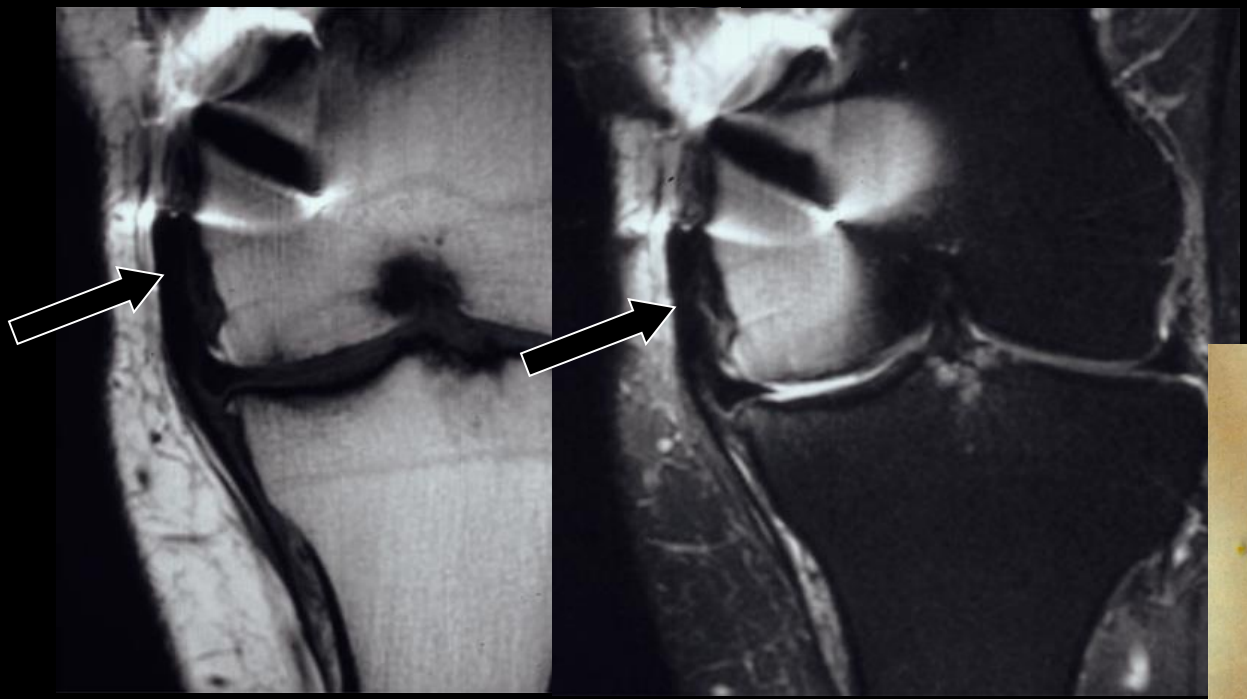


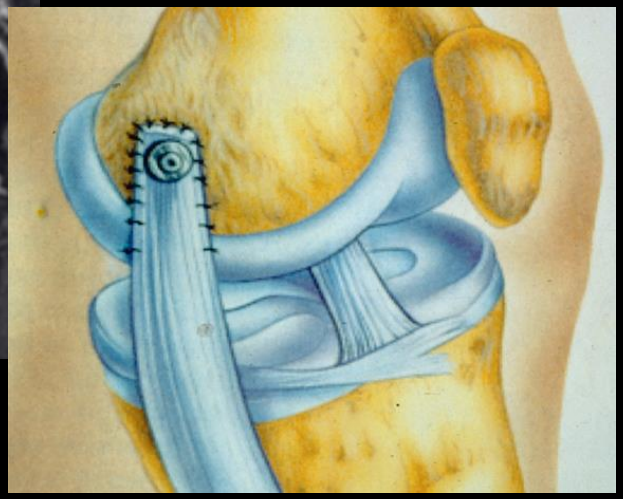
-Grade I/II sprains treated conservatively

-Grade III sprains / disruptions- when combined with other injuries

-treated with stapling or suturing

Medial Collateral Ligament Repair





-MR appearance

-Metallic artifact at repair site

-Persistent thickening of repaired ligament

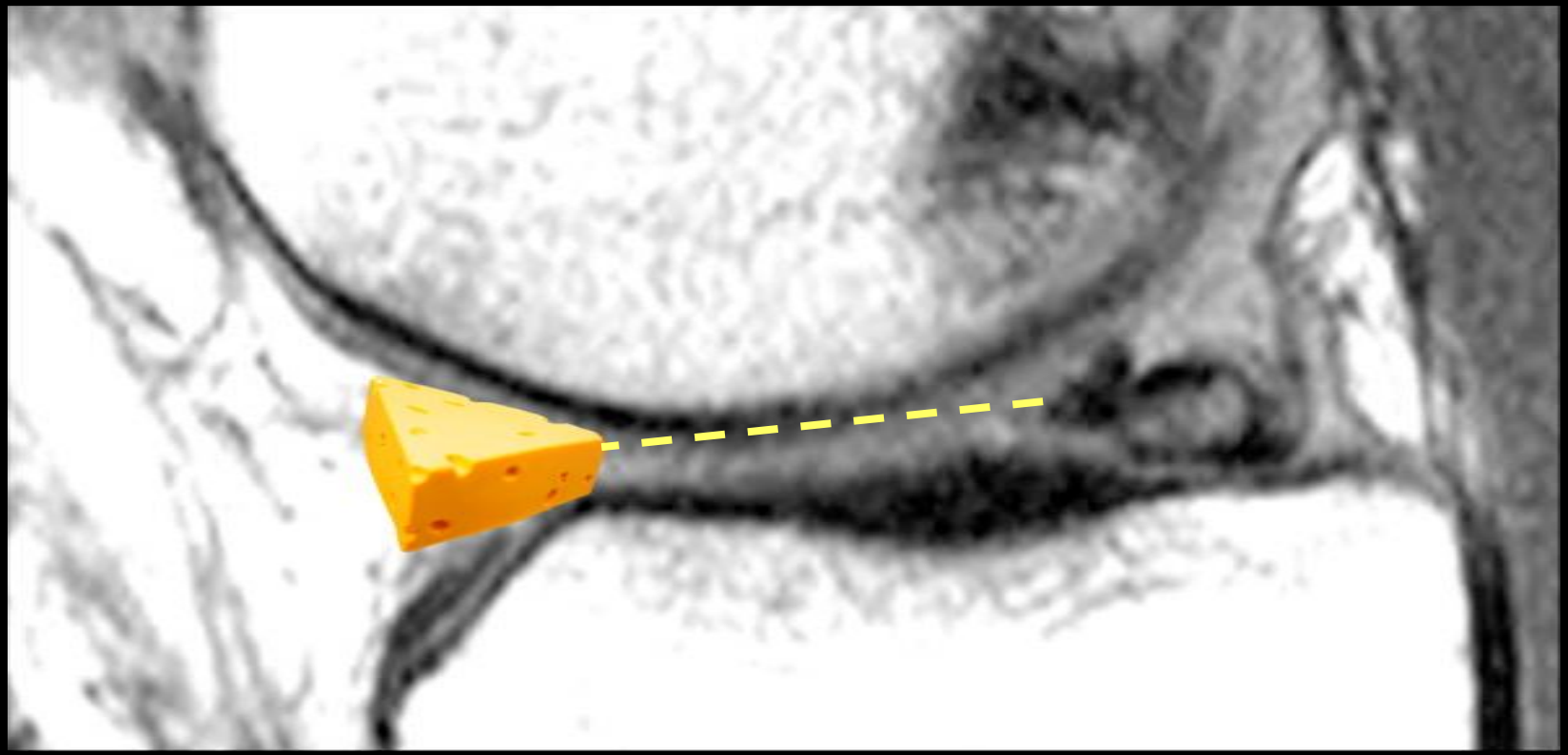
Posterolateral Corner Reconstruction

-MR appearance

-Metallic artifact at repair site

-Persistent thickening of repaired ligament

Thank You!



QUESTIONS?