Anterior cruciate ligament repair

Anatomy of the ACL

The ACL is composed of multiple fascicular subunits within larger functional bands. It is 38mm long and 10mm wide. It is smaller than the PCL.

It originates at the posteromedial aspect of the lateral femoral condyle and inserts into the intercondylar eminence. Its major blood supply is from the middle geniculate artery.

Physiology of the ACL

Strength
The ACL has a normal tensile strength of 2500 newtons in young adults.
Loss of the ACL produces abnormal kinematics and also frequently results in major degenerative changes.
The anteromedial bundle of the ACL is the most nearly isometric component throughout the ROM of the knee. The posterolateral bundle has the highest load when the knee is fully extended.

Function of the ACL

Two important roles:
1. Proprioceptive. The ACL contains numerous proprioceptive nerve endings.
2. Mechanical

-Frank (CCR 1997) talks about 4 important features:

i. The normal ACL carries loads throughout the entire range of flexion and extension of the knee, resisting anterior tibial translation and to a lesser degree tibial translation and abduction during knee flexion. It is the primary restraint to anterior tibial translation.

ii. The ACL carries only small loads during normal daily function; normal daily loads are only at about 20% of failure capacity

iii. The highest loads on the ACL occur through:
-Quadriceps powered extension of the knee
-Hyperextension of the knee
-Excessive internal tibial rotation
-Excessive valgus or varus forces if a collateral ligament is torn

iv. The ACL is a viscoelastic structure that can adjust to stresses over time

Compensatory mechanisms

Other anatomical structures in the knee can compensate for the loss of the ACL:

1. The posterolateral complex controls anterior tibial translation and anterolateral tibial rotation and is described as a secondary restraint
2. The medial collateral ligament and posteromedial complex control anterior translation of the medial side of the joint.
3. The hamstrings restrain anterior tibial translation
4. The posterior horn of the medial meniscus

Epidemiology of ACL repair

1 in 3000 per annum in USA. 50 000 reconstructions per annum in USA.

ACL injuries occur more frequently in females. Female basketballers are affected 3.5 times more frequently. Female soccer players are affected 2.8 times more frequently. They have a narrower notch. Estrogen may also lead to weaker ligament collagen.

Diagnosis of ACL rupture

Around 70% of patients with acute traumatic knee haemarthroses (within 2 hours) will have an ACL injury.

Can occur from contact (30%) or noncontact (70%). Direct contact injuries typically involve at least one collateral ligament.

Classic pop heard in 30-50%.

Lachman test

The most sensitive test is the Lachman test[1], which is performed with the knee in slight flexion; it is at this point where the secondary restraints are most lax. PL complex

"The examination is performed with the patient lying supine on the table with the involved extremity on the side of the examiner. With the patient's knee held between full extension and fifteen degrees flexion, the femur is stabilized with one hand while firm pressure is applied to the posterior aspect of the proximal tibia in an attempt to translate it anteriorly. (Description attached to photograph says that the distal hand grips the proximal tibia in such a manner that the thumb lies on the antero-medial joint line).

A positive test indicating disruption of the ACL is one in which there is proprioceptive and/or visual anterior translation of the tibia in relation to the femur with a characteristic mushy or soft end point.

A corollary to interpreting the test is that if a question remains in the examiner's mind as to whether the test is positive or negative, the ligament is torn." Torg, Sports Medicine 1976.

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[1] John W Lachman, Professor of Orthopaedic Surgery at Temple University

Anterior drawer test

The anterior drawer test mainly tests the anteromedial bundle of the ACL (tight in flexion).

If the patient has intact medial collateral ligaments the anterior drawer test may be negative because they act as secondary restraints to anterior translation with the knee flexed to 90 degrees. Smillie noted that "the drawer sign is minimal in isolated ruptures of the ACL". He also noted that if the sign is "maximal" it is almost certain that the medial ligament has been involved.

Torg mentions three possible reasons for false negatives in the anterior drawer sign in the acute setting:

1. Haemarthrosis and synovitis may make it impossible to flex the knee to 90 degrees
2. Strong hamstrings may be impossible to overcome
3. The strong convexity of the medial femoral condyle makes a ball to the socket formed by the concavity of the medial tibial plateau and medial meniscus.

Torg stated that for the anterior drawer test to be positive, either the medial structures had also to be torn, or there needed to be peripheral separation of the posterior horn of the medial meniscus.

Pivot shift test

The pivot shift test (McIntosh) goes from the reduced position in flexion to the subluxed position in extension. The jerk test goes the other way, from subluxed in extension to reduced in flexion.

Significant varus or valgus instability in extension is indicative of a more severe injury involving multiple ligaments and potentially both cruciates.

Meniscal injuries are frequently found – more than 50%. In acute ACL injuries the lateral meniscus is injured more frequently; in chronic injuries the medial meniscus is more frequently involved.
Can be graded as 0(absent), 1+(pivot glide),2+(pivot shift), or 3+(momentary locking).

Imaging in ACL rupture

Plain film

The Rosenberg (45 degree flexion PA weight bearing view) can show signs of chronic ACL deficiency, such as peaking of the tibial spines and narrowing of the intercondylar notch.

A Segond fracture (avulsion fracture of lateral tibial plateau) is pathognomonic of ACL injury. The capsule pulls off a piece of bone located between the fibular head and gerdy's tubercle.

MRI

95% accuracy for detecting ACL rupture. Can look for primary signs of rupture (absence of ligament in notch on sagital image) or secondary signs (bone bruises in LFC, lat tib plat, segond injury). The bone bruises in the lateral compartment are found in the anterior aspect of the LFC and posterior aspect of the lat tib plateau.
MRI is useful for delineating associated intraarticular pathology such as meniscal tears, and assessing the other ligaments.

Bone bruising or marrow changes in the posterolateral aspect of the lateral tibial plateau and midcentral aspect of the lateral femoral condyle occur in 80-90%.

Nonoperative treatment

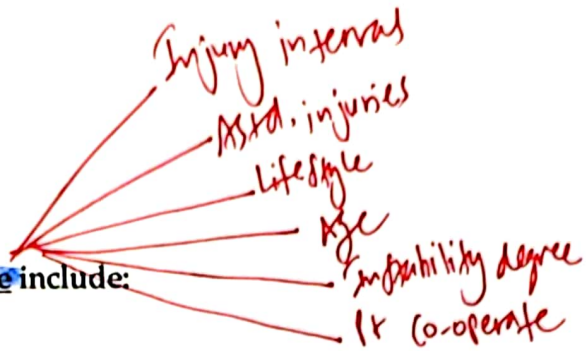
Aim is to control swelling and pain, with quick restoration of full range of motion.
NSAIDS, physical therapy form mainstay.
Muscle strength should have returned to 90% of the other side before the patient is allowed back to normal activities.
Avoid high-risk activities for 6 to 12 weeks after an ACL tear.
May still require minimal operative intervention such as meniscectomy or excision of impinging ACL stump. The latter isn't done for 2-3 months post injury because the stump may shrink.

Indications for surgical treatment

There is little agreement in the literature about the chance a patient has of progressing to functional instability after an ACL rupture. Figures range from 16% in one study to almost 100% in other studies.

There is also little agreement on whether or not radiographic evidence of OA will develop; figures show rates of mild OA ranging from 13% (2-10 yrs followup) to 68% (10-16 yrs followup). There are some reports saying that it happens more commonly in the knee that has been reconstructed (Daniel), most likely because these patients go back to high demand activities while the non-reconstructed patients do not- therefore, less OA without a recon.

Around 60% of nonreconstructed ACL injured patients will require meniscectomy within 5 years of injury. Prospective studies have reported lower rates of late meniscal tears requiring surgery – e.g. 24% at 10 years.



Factors that will influence the decision to operate include:

1. Interval from the injury to the operation

i. Operations on the ACL are more likely to be complicated by fibrosis if the operation is done in the first 4 weeks after rupture

ii. Also more likely to be complicated by fibrosis if the operation is done while the knee is acutely inflamed and the range of motion is restricted

iii. The operation can be done when the effusion is subsided and a nearly normal range of motion has been obtained. It is technically easier to do when the haemarthrosis is subsided.

iv. What about an ACL rupture + MCL + meniscus. Need to repair the meniscus asap, but risk of arthrofibrosis. Option is repair meniscus early, then brace knee and get ROM over 6 weeks while avoiding stress on MCL or meniscus. Then, once MCL is healed and and knee settled, do ACL. Or can do all acutely- currently literature not conclusive.

2. Association with other injuries of the knee

i. An isolated injury of the ACL is thought to be physiologically impossible

ii. However the injuries to other structures may not be major

iii. Associated injuries to major ligament complexes increase the likelihood that non-operative management of the ACL will result in functional instability

iv. The commonest associated injury is to the MCL

v. Injury to a meniscus is frequently associated with ACL rupture (50%). In acute injuries it is the lateral meniscus that is most frequently injured, but in chronic injuries it is the medial meniscus. If a meniscus is lost the knee will be more likely to go on to OA. Approx 50% of meniscal lesions associated with ACL rupture can be repaired. If the meniscus is repaired in a stable knee, 85% success rate, whereas only 50% in an unstable knee.

3. Lifestyle

i. The patient's level of activity is the single most important factor in the decision about whether or not to operate.

ii. Level of activity is classified according to the International Knee Documentation Committee evaluation form, which has four levels of activity:

Level I Jumping, pivoting or hard cutting e.g. football, soccer
Level II Heavy manual work or side-to-side sports e.g. skiing, tennis
Level III Light manual work or non- cutting sports e.g. jogging
Level IV Sedentary activity without sports

4. Age

i. Forty years is often quoted as the cutoff for operative vs. nonoperative treatment but this is related to the level of activity of the patient and a 50 year old engaged in vigorous activities would be a candidate for operation

ii. A recent study of ACL reconstructions in adolescents with a skeletal age of 14 revealed no growth or angular complications. Transphyseal tunnels were used.

5. Degree of instability

i. People with generally tight ligaments may be less likely to have problems after an ACL rupture, because secondary stabilizers of the knee are more able to cope in these patients

ii. Patients with less than ½ of the ligament torn and no positive signs of increased anterior translation can probably be managed nonoperatively

iii. Hence the degree of instability as assessed with the Lachman test is predictive as to whether a patient will suffer symptoms of instability. This, and the level of activity of the patient, are the two most predictive issues governing whether a patient will experience instability symptoms and hence benefit from surgery.

6. Cooperation by the patient

i. Patients must be able to comply with a rigorous physiotherapy program.

Fithian et al: OCNA 2002: "From the data we now possess, it seems that most patients with ACL injuries do well with ADLs at 5-15 years post injury. Most can participate in some sports activity, and will have some limitation in vigorous sports. Only a few will be entirely asymptomatic". The patients who are most profoundly affected are those whose preinjury activity level is the highest

Treatment options

1. Nonoperative treatment
2. Repair alone
3. Repair with augmentation
4. Extra-articular reconstruction
5. Reconstruction with autogenous grafts
6. Reconstruction with autogenous grafts and prosthetic augmentation
7. Reconstruction with use of allografts or a prosthesis

The underlying theme of the **Johnson et al Current Concepts Review from JBJSA 1992** is that there is a real paucity of randomized control trials and it is very difficult compare results in the literature.

Non-Operative Treatment

Acute tear: Aim is to settle the joint down- RICE, and then regain ROM and then regain strength so that the hamstrings and quads are at least back to 90% of the strength on the other limb.
Longer Term: Avoidance of activities that cause instability, hamstring strengthening. Bracing has not been shown to be of any benefit. Strengthening muscles and proprioception can greatly aid in preventing instability. Voluntary muscular contraction greatly reduces the amount of laxity demonstrable in an otherwise unstable knee joint.

Operative repair

Direct repair isn't strong enough unless there is supplementation with some type of autogenous graft.
Long term retrospective and prospective reviews showed a 40-50% failure rate within 5 years of 400 repairs in 8 different studies.
However use of autogenous graft generally requires a prolonged period of immobilization.

Extra-articular repair

Examples are the Losee, McIntosh and Ellison repairs, all of which use a strip of iliotibial band. They are unsatisfactory because they work by tenodesing the posterolateral aspect of the joint and the ligament is subject to gradual failure as it stretches. Also studies show no benefit in using these procedures in addition to an intra-articular reconstruction.

Reconstruction with autogenous grafts

Attempts to replace the antero-medial band of the ACL – this is the most nearly isometric portion of the normal ACL. Criteria for the strength of a graft has been set at 1730N.
Main methods are middle 1/3 of patellar tendon, and hamstring tendons.
Vascularized patellar ligament grafts are no stronger than free grafts. These grafts merely provide a collagen lattice, not a structural support, in the early stages (6-12 weeks) of graft resorption, revascularization, and restructuring with new collagen. The completely remodelled graft incorporation process can take from 6-12 months.
Important to realize that for the first 1-2 months after a repair the failure strength of the graft is related to the fixation method. The strongest method known is the interference screw (450 newtons), and this has only 50% of the failure strength of the graft.
In no animal models so far has the graft regained its original strength.

Patellar tendon

Advantages

i. Strong – 168% of strength of ACL initially, but this is for a 14mm wide tendon unit rather than the 9 or 10mm wide unit that is more often used
iii. Rapid healing of bone plugs (theoretically – not proved as of 1997)
iv. Early vigorous rehab is possible thus may be preferred in young high demand athletes

Disadvantages

i. Chronic anterior knee pain – 14-31%
ii. Extensor mechanism is damaged – but note that the patellar tendon fills up with scar tissue which gradually remodels over 12-24 months
iii. Patellar fractures (0.2%)

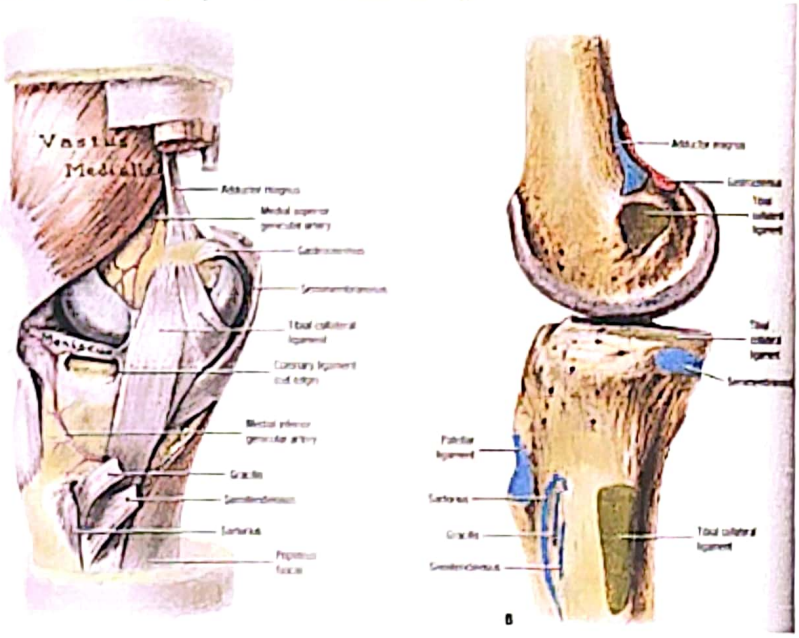
Other comments

i. The patellar tendon should not be tightly opposed because this can cause a patellar baja of up to 10%

Hamstring tendon

Anatomy of graft harvest

The sartorius tendon, in zone I of the medial side of the knee, overlies the gracilis and semitendinosis (Say Grace before Tea).



These latter two tendons insert as a conjoined structure, on average 20mm long, with the insertion site beginning on average 20mm below and medial to the tibial tubercle. The tendons become distinct on average 20mm from their insertion. The superficial medial collateral ligament lies under this area, contributing to zone II. The gracilis and semitendinosis tendons lie between zone I and II.

In about ¾ of knees there is an accessory insertion of semitendinosis into the tibia. This takes origin 5cm proximal to the insertion, and inserts 3cm below the main insertion. This must be freed up or it may lead to inadvertent division of the main tendon when the tendon is stripped.

The saphenous nerve lies immediately superficial to the gracilis tendon at the posteromedial joint line. When the knee is extended the nerve is taut upon the tendon; when the knee is flexed the nerve is loose and less likely to be damaged.

Advantages

i. Tendon regenerates, with normal tendinous tissue, and its insertion resembles a normal insertion
ii. Avoids anterior knee pain
iii. Theoretical advantage of creating a multibundled structure
iv. Strong and stiff graft – quadruple bundle ST and gracilis tendon has 4500N strength.

Disadvantages

i. Tendon may elongate
ii. Less secure fixation
iii. Hamstrings weak in first year

Several followup studies at 2 years have detected little or no significant difference in donor site morbidity between the two techniques.

The meniscus should not be used as a graft (it has been in the past!).
The iliotibial band is too elastic.

Prostheses

Experimental and unsatisfactory at present
Fatigue, fretting and wear result in a high failure rate. Costly also.
Associated with a high failure rate also, perhaps due to the generation of wear particles.

Allografts

Need to be carefully screened for viral disease and sterilized.
Take longer for revascularization and remodeling than autogenous grafts.
Long-term results are similar to allografts (5-7 yrs as of 1997).
Gamma irradiation and ethylene oxide damage the graft, and fresh frozen grafts are preferred.

Technical considerations of ACL grafts

1. No long term data prove difference between open and closed techniques.
2. The site of attachment of the graft to the femur is very important. If it is too anterior this results in high strain on the graft when the knee is flexed, which may restrict flexion if the graft remains intact (i.e. cause fixed flexion deformity), or it may simply elongate the graft. The most common technical mistakes are placing the tunnels too far anteriorly in the femur or tibia or both. This can cause impingement of the graft, resulting in a lump of scar tissue forming, the so-called Cyclops lesion and loss of extension.
3. If the graft placement is too posterior this will cause the graft to be too tight in extension.
4. The tibial site of insertion isn't considered to be as important. The ideal site is said to be the anterior half of the middle third on the lateral view of the tibia. This is behind the tibial projection of Blumensaat's line.
5. The tunnels should be collinear and the edges should be chamfered

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6. The fixation within the tunnels should ideally be as close to the joint as possible (aperture fixation) to avoid a windshield wiper effect.
7. The ideal graft tension isn't known. Too tight and there may be a decreased ROM, increased femoral tibial wear and delayed revascularization of the graft with myxoid degeneration. Cadaveric studies have shown an initial graft tension of 20-40N is required to maintain normal knee kinematics.
8. The issue of a notch plasty hasn't been resolved- in general, a soft tissue notch plasty should be done to clear tissue and minimize the risk of a cyclops, and a bony notchplasty should only be done if the ACL is impinging at the end of the case.
9. Management of coexisting meniscal tears:
   a. A displaced buckethandle tear needs to be fixed, then come back and perform the ACL repair when the knee has quietened
   b. May be better to leave other tears – the haematoma and inflammatory environment within the knee will help with healing of many tears.

Postoperative care

Ice and CPM

No long lasting benefits for either. May be some benefits in first several days?

Rehabilitation

Important: esp achieving full extension to prevent cyclops and limited extension from occurring, which is a bigger problem for the patient than the initial instability.

Closed chain exercises, where the knee is axially loaded during quadriceps contraction, are thought to cause less strain on the ACL than open chain exercises where the limb isn't bearing weight.

Optimal protocol remains controversial. Break it up into stages:

Pre-op: As above: RICE, ROM, Strength.

Post-op 0-2weeks: Goal is to achieve full extension and quads control- prevent a cyclops lesion.

Achieve 90 degress flexion

3-5 weeks: Maintain full extension and increase flexion.

6 weeks: Maintain ROM and increase strength with closed chain exercises.

Shane Waddell's patellar tendon ACL technique.

Positioning

Side support, TQ, knee flexed to 70 degrees

Incisions

First incision over distal half of patella and inferior pole, around 3-4 cm long

Second incision just medial to tibial tubercle, to allow access to tubercle and to tibial tunnel.

Steps

A. Harvesting graft

1. Expose patellar tendon and define its medial and lateral borders.
2. Incise patellar tendon longitudinally to provide desired graft thickness (10mm in big man)
3. Measure 25mm bone plugs within patella and proximal tibia
4. Start off bone by using osteotome to make using the dowel cutter easier.
5. Use dowel cutter to harvest plugs
6. Drill holes in mid point of plugs prior to removing them
7. Use osteotome to harvest plugs
8. Place 5 Ethibond sutures through drill holes and mark graft appropriately

B. Preparing knee

1. Normal arthroscopy portals
2. Exclude meniscal or other problems
3. Clean up medial wall of lateral femoral condyle – use combination of curette and arthroscope. Clean up ligamentum mucosum.
4. Establish graft entry point: 2-3mm of posterior wall should remain, at 11 o'clock in right knee and 1 o'clock in left knee. Make hole with awl. Commercial instruments are available to assist with femoral tunnel placement.
5. Get goldfinger and position with point just medial to lateral tibial spine. May need to clean up ACL stump a little but don't get rid of all of it. Set angle to 45-55 degrees and introduce other end via tibial incision. Drill wire through; should emerge into axilla of goldfinger. Note that another suggested tibial tunnel exit is just medial to the anterior horn of the lateral meniscus. Hale says should be posterior to intermeniscal ligament. JBJSB 2003 – Allum says the guide wire should emerge posterior to the posterior edge of the anterior horn of the lateral meniscus, 5-7mm anterior to the PCL and in the posterior half of the ACL stump if this is present. Formerly, graft placement in the anterior half of the footprint was advised.
6. Drill out tunnel with drill 1mm bigger than graft. This makes graft placement much simpler.
7. Drill wire into awl hole with the knee flexed
8. Drill out hole in femur, passing wire out the proximal femur
9. Clean out holes thoroughly with curettes and arthroscope
10. Run graft through tunnels. Secure in femur with RCI screw
11. Extend knee and see if graft impinges. If it does, will need to perform notch plasty.
12. Then extend knee and fix graft in tibia

C. Postop

1. Allows full weight bearing
2. Important thing initially is to obtain full extension

Hale hamstrings tendon technique

1. Harvest graft first. Make incision centred three fingers breadth below joint line, medial to tibial tubercle.
2. Dissect hamstrings free. Keep tension with curved clamp, strip soft tissue attachments off prior to using tendon stripper.
3. Keep distal attachment attached and place whip stitches in the two proximal ends.
4. Trim muscle fibres off hamstrings.
5. Place heavy nylon stitch between doubled over tendon ends, and secure this with two vicryl sutures.
6. Release the distal insertion in a lateral direction (to allow later easy transection of the tendons), then place vicryl tuberalizing stitch in distal attachment at some distance from its insertion
7. Get diathermy and release the tibial tunnel insertion.
8. Place the hamstrings back in the incision

Inside the knee

1. The lateral portal is more medial, as is the medial portal.
2. The stump and lateral wall is debrided.
3. A notch plasty is routinely performed with a small osteotome
4. The insertion point is thoroughly prepared. He aims to have his tunnel 1-2mm anterior to the rear wall
5. Rest of technique identical.
6. He tensions the graft in full extension.

Postop

Full weight bearing next day.
One dose of fragmin
No open chain quads

Assessing graft placement on post-op X-rays

On the lateral the tibial tunnel should emerge in the anterior half of the middle third of the tibia.

Prognosis/results

Biology of reconstruction

In the first 6 weeks after implantation the graft is synovialized while the centre necroses. Revascularization leads to cellular proliferation that repopulates the graft. Complete revascularization takes around 20 weeks, and is accompanied by an increase in the size of the graft (up to 3 times increased).

At one year after reconstruction the graft has 30-50% of the strength of the native ACL.

The collagen fibrils are smaller in diameter.

Biomechanical studies

JBJS 2002 cadaver study by Woo showed:

1. Reconstruction of the ACL with patella tendon or hamstrings graft is effective in reducing anterior tibial translation
2. However, it is less effective in restraining the anterior tibial translation when a knee has a valgus and internal tibial rotation force

Clinical results

Patients with intact menisci are much more likely to be happy with their results; at 5-15 years 87% of patients with intact menisci rated their knees as normal or nearly normal compared with 63% of patients requiring meniscectomy.

OKU 7 states 85-95% will have clinically stable knees and 80-94% will have a normal or nearly normal knee using the IKDC (International Knee Documentation Committee) rating system.

There is often poor correlation between the objective physician assessed results and the patient's perception of knee function and stability. Patients with meniscal lesions may have good objective stability but have poor subjective stability. Patients fixed with hamstring grafts have poorer objective findings on KT1000 testing but equal subjective results.

Failures

Unsuccessful long term results of ACL reconstruction range from 5-52% depending on the criteria used for definition.

60% of failures are related to poor tunnel placement leading to impingement and failure.

Other problems include:

1. Loss of Extension (most common complication)

Most common cause is a cyclops lesion, or anterior intercondylar notch scar tissue. Loss of extension is a big deal, and can leave the patient worse off than pre-op because it can cause knee pain and quads dysfunction. Potential causes of loss of extension include:

a. Cyclops lesion

This scar tissue forms in the notch and blocks full extension by impinging on the notch. Flexion is not restricted (whereas it is with arthrofibrosis). It is more likely to occur if:

i. Graft is impinging- ie tibial tunnel too anterior. This causes a cyclops both by blocking full extension, and also the continual impingement on the graft may stimulate the cyclops to form. Need to check that tibial tunnel guide wire isn't too anterior- can watch this arthroscopically by extending the knee. It is also better to use a femoral tunnel rather than an "over-the-top" technique.

ii. Inadequate debridement of ACL stump or notch plasty.

iii. Post-operative protocol blocks full extension- must allow and achieve full extension post-op to "block" a cyclops lesion from forming.

Treatment involves excising the cyclops lesion, correcting any contributing causes (eg notchplasty) and then aggressive physio post-op to maintain extension.

b. Arthrofibrosis. The commonest complication after surgery is a knee flexion contracture. Loss of extension is a significant cause of debility. Patients walk with a bent knee gait, have patellofemoral pain, have quadriceps weakness and poor functional results.

c. Graft Tensioning: A graft tension in 30 degrees of flexion is at a shortened position. This may make it harder to achieve full extension. JAAOS suggests tensioning in extension with 40N force.

Hence, methods to minimize the risk of loss of extension include:
1. Delay OT until joint is settled.
2. Adequate soft tissue and if required bony notch plasty.
3. Careful anatomic placement of tunnels (avoid anterior tibial tunnel) and intra-op impingement test.
4. Tensioning the graft with the knee in full extension.
5. Rehab: Immediate post-op full extension.

Apart from arthrofibrosis, other causes of stiffness include:
a. Cyclops lesion
b. Patella infera
c. Poor graft placement with impingement. An ACL graft with notch impingement will demonstrate increased T2 signal.
d. RSD

2. Infection – occurs in 0.5%
3. Reoperation rates of 5-21% for meniscal problems, hardware problems and loss of motion.
4. Knee pain
   a. From the patella
   b. From a saphenous nerve neuroma

Revision ACL surgery

Improperly placed tunnels may need to be treated with a two stage procedure with bone grafting of the tunnels as stage one, then redrilling when the tunnels have healed.