ACL Repair in Children

- a revival of an older technique

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KNEEguru eBooks

KNEEguru eBooks are brought to you by the clinical team associated with the KNEEguru website - http://www.kneeguru.co.uk . They are intended for anyone wanting to learn more about problems of the knee, but we make a particular effort to create content that is accessible to non-medical readers.

Via our online work - websites, online courses and eBooks - we are trying to help patients ensure that their own knee problems are understood. We explain key diagnostic issues directly to patients, in language that is easy to understand, so that they feel empowered to challenge the doctor when they feel something has been missed. To make things easier for readers, we also take pains to create clear simple explanatory drawings, and where appropriate we may also include video discussions or animations.

Section One

Introduction

The Anterior Cruciate Ligament (ACL) is one of two central ligament stays in the middle of the knee joint that help to secure the relationship to one another of the two long bones of the knee. These two bones are the femur (thighbone) and the tibia (shinbone) and the two ligaments can be seen within the notch between the rounded ends of the femur when the knee is bent.

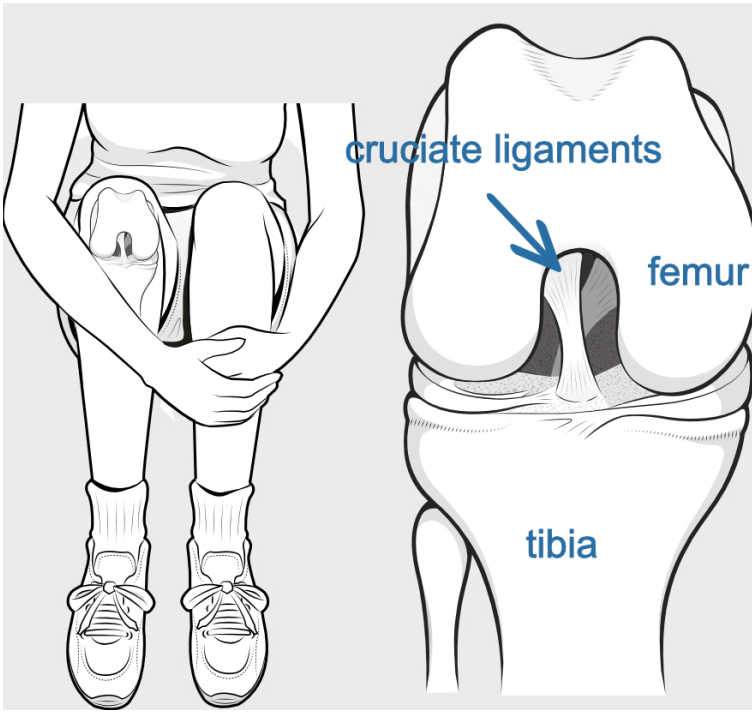


Figure 1.1 The bent knee from the front, showing how the cruciate ligaments are attached at both ends to the bones of the knee.

The ACL - the ligament in the front - prevents the tibia sliding forwards in relation to the femur when a person stops suddenly, and helps to contain rotational movement between the two bones.

Damage to the ACL is likely to make the joint unstable, and the child may lose confidence with normal school activities, and drop out of sport. Instability may also lead to damage to other structures in the knee. So this is a real problem.

The paediatric ACL injury has traditionally been thought of as relatively uncommon but such injuries are increasingly being referred to the orthopaedic ligament surgeon. With the increase in competitive sports, better awareness, improved imaging and greater demands on athletes at an earlier age, surgeons are seeing a significant rise in the number of children coming through - particularly in their adolescent years - with ruptured anterior cruciate ligaments. Australian Medicare statistics show, for example, in

patients under the age of 16 the numbers of reported ACL ruptures increasing year on year through to 2010, and this is certainly a trend that is being seen throughout the western world.

Section Two

Growth Plates

When it comes to how these injuries should be managed in this young age group, there is an issue that dominates the debate - the matter of the child's *growth plates.*

You see, long bones in the growing child get longer, not from the ends of the bones but from an active cartilage 'growth plate' a little way away from the ends.

This is properly called a 'physis', and it is a layer sandwiched between the end of the bone and the main body of the bone.

On the one side of the physis towards the end of the bone the region is called the 'epiphysis' and on the shaft side the region is called the 'metaphysis'. So the physis is like a cartilage 'sandwich' between them. As new cartilage is formed it is pushed out into the metaphysis and this subsequently matures into new bone, and the bone increases in length.

On X-ray the physes look like fractures, but that is because X-rays pass easily through cartilage and less easily through bone.

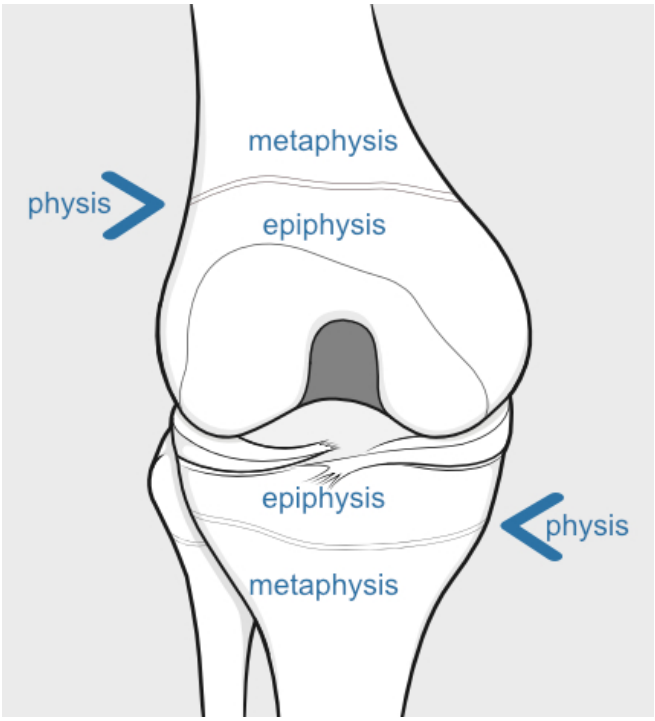


Figure 2.1 The straight knee from the front, showing the growth plates (at arrows). The cruciates have been removed just to simply the illustration.

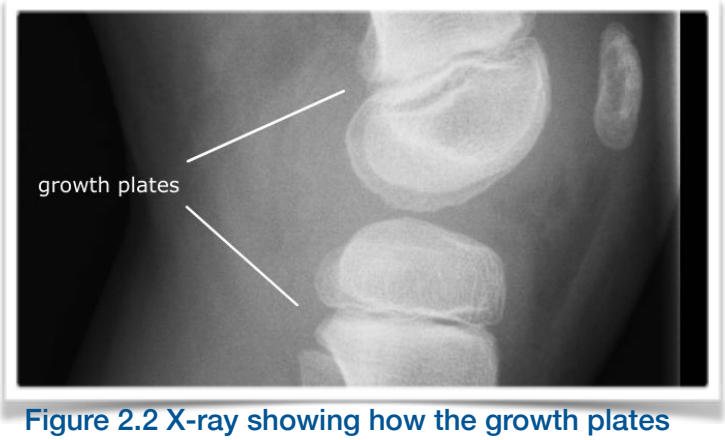
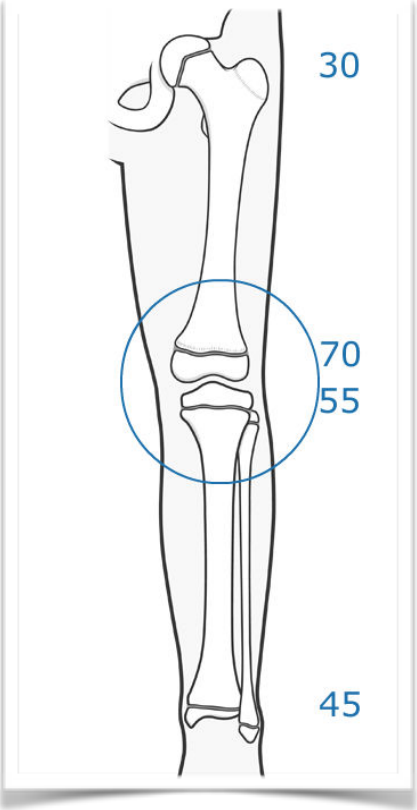


Figure 2.2 X-ray showing how the growth plates resemble fractures (breaks).

The various growth plates contribute different amounts to the final length of the adult bone. At the knee the growth plates of the thighbone or femur contribute to 70% of the eventual length of the thigh, while the growth plate of the shin bone or tibia contributes 55% of the eventual length of the shin.

You can appreciate that, although both are important, it is particularly critical to try not to damage the growth plate of the femur because this is where most of the growth will occur.



Section Three

The Big Dilemma

In adult cruciate ligament reconstruction surgery bone tunnels are drilled right through this region with no problem because in adults the plates are already fused, growth is complete and no harm is done.

However, in children damage to the growth plate may stop the bone growing or the knee may distort to an abnormal angle.

So surgeons worry about whether or not one should do nothing at all surgical - just go down the ‘conservative route’ - or whether one should operate to stabilise the knee, and if so how to do this without damaging the growth plates.

Parents and doctors have to make difficult decisions on behalf of these young people, and some are only small children not yet in their teens who cannot fully participate in the decision-making process.

If a choice is made to NOT operate, there are some real issues with compliance with bracing with small children, and these young patients may go on to develop chronic knee instability. Instability can interfere not only with sport but also day to day activities, and leave patients coping poorly. Episodes of the knee 'giving way' may result in further secondary injury of the meniscus or joint surface, and this can be disastrous.

It is now well appreciated that such conservative management gives poor results, but the concern continues that surgical efforts at re-stabilising the knee could jeopardise the growth plates, resulting eventually in a shortened or deformed limb.

Section Four

Children at risk

Children who injure their ACL tend to be those who play contact sports like basketball, or 'cutting' sports like soccer, where there are sudden abrupt turns and stops, and sudden changes of direction.

Injury might also occur on jumping and landing on the feet on a hard surface, when the immature quadriceps muscle of the lap is not strong enough to contain the action and the ACL may be ‘weedy’ and not the same strong structure one sees in an adult.

Teenage girls are especially at risk, with ACL injuries several times more common than in boys of the same age, because girls have increased risk factors to do with their body shape, their limb alignment, their muscle bulk and hormonal influences.

It may be difficult to obtain the history from the child, but the parent may have been an observer or spoken to witnesses, so it is always important to ask the parent, too.

The child may have felt a 'pop', and been unable to bear weight immediately afterwards. There may be immediate pain, although this is not always a major factor. Sudden onset of marked swelling may be reported. Typically things may then seem to settle down, but the child may continue to have an unusual gait or be reluctant to participate in activities.

Figure 4.1 Adolescent boy playing basketball.

Section Five

Patterns of Injury

There are three main patterns of ACL damage in a child - *proximal* (at the attachment to the femur), *mid-substance* within the ligament, or *distal* (at the attachment to the tibia) -

Proximal (at femur attachment)

Although not so frequently reported, proximal detachment is an injury that we have seen commonly in younger children, and this pattern seems to be associated with high speed injuries, such as skiing. The ligament tears off from its bony origin in the notch of the femur, leaving an 'empty notch' when this area is examined during arthroscopy.

Figure 5.1 Proximal.

Mid-substance

A mid-substance tear of one or both bundles of the ACL is a more common pattern in the older child or adolescent.

Figure 5.2 Mid-substance.

Distal (at tibia attachment)

The growth plate in young children can be weaker than the ligaments, and sudden strong traction on the tibial attachment may lead to an 'avulsion fracture', where a fragment of cartilage or cartilage-&-bone breaks off, still attached to the intact ligament. The site of avulsion is commonly at the anterior tibial spine in the middle of the top of the tibia. Such avulsions are more likely to occur in children before adolescence, while after adolescence, as mentioned above, it is more common for the ligament substance to tear rather than for an avulsion to occur.

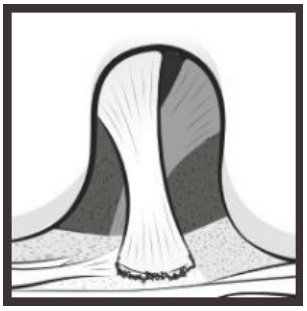


Figure 5.3 Distal.

Section Six

Evaluation

Generally the orthopaedic surgeon sees the child after the swelling has reduced and the parents are wondering if there is *really* anything wrong with the knee.

Examination, however, typically shows a lax knee, with positive signs on performing Lachman, anterior drawer and pivot shift tests - three standard tests for ligament laxity.

Figure 6.1 Lachman test.

Note that in children, the degree of translation (movement of the bones in relation to one another) for such laxity tests - for both operated and normal knees - is generally higher than that documented for adults. This may be due to constitutional increased joint mobility present in children.

MRI may not be very helpful - on an MRI scan the normally 'weedy' ACL in a child may look thickened when torn because of oedema (or fluid in the tissues), and this may confuse the observer. Signs on MRI of traumatised bone (bone oedema) on the tibia or the femur may offer a clue to the damage.

Section Seven

Options for Management

Whether or not to operate, and what operation to do continues to be the central issue seeing these children, and has been for a long time. Let's take a look at some of the work that has been done in the past when the child was managed conservatively - that is, without surgery.

So should we wait?

Bernard Moyen and his team [1] looked at rupture of the anterior cruciate ligament in children and they took 2 groups - those that they operated on quickly or those upon whom surgery was delayed until skeletal maturity. In 56 patients where the mean times to surgery was less than 5 months in the one group and more than 30 months in the other, the number of meniscal tears went up from 14% to 41% with the delayed group.

Another paper by Justin Roe's team [2] was a meta-analysis of 5,086 patients. They found that there was two times the risk of secondary damage if there was a five month delay to surgery, and six times the risk if there was a one year delay, and double the risk in anyone under the age of 17.

A further paper by Todd Lawrence [3], looking at 14 year data in patients where there was a delay of more than 12 months, again showed a massive increase; a four-fold increase in new meniscal tears, 14% of which were non-repairable bucket handle tears, and a significant number of lateral condyle injuries.

So the answer to the question of 'should we wait?' is probably NO, and that is the feeling of many surgeons who undertake the treatment of this injury in children.

The main concern about surgery is as I have explained growth disturbance. This *is* a really important complication - but it's extremely rare and certainly a lot more manageable if it does occur than if we see secondary damage to the joint surface or the meniscus in a developing adolescent.

So the consensus and the evidence is to treat, but there is no consensus over how we should carry out the surgery:

- ✤Should we completely avoid endangering the physes and do an 'extra-articular' reconstruction?
- ✤Should we go through the joint, but be 'all-epiphyseal' - in other words, below the physis on the femur and above the physis on the tibia, totally avoiding going through the growth plates?
- ✤Should we just shrug off the issue of growth disturbance and just go 'trans-physeal', that is through the growth plates?
- ✤Or should we do a 'hybrid' - avoiding the more important growth plate on the femur side, but going through it on the less significant tibia side?

Let’s look at each of these options in more detail -

Extra-articular

The first option is to try to stabilise the knee without going through the joint cavity or the growth plates - what we call an ‘extra-articular’ approach’. Early work at extra-articular stabilisation focused on techniques where tissue could be used in the so-called 'over-the-top' position. In these techniques there was no tunnel in the femur whatsoever.

A strip of the iliotibial band (ITB) is taken from the side of the thigh, preserving its lower attachment on the tibia. This strip of strong material is fed around the rear of the knee and back to the front of the joint without putting a tunnel through either femur or tibia. The free end of the ITB is

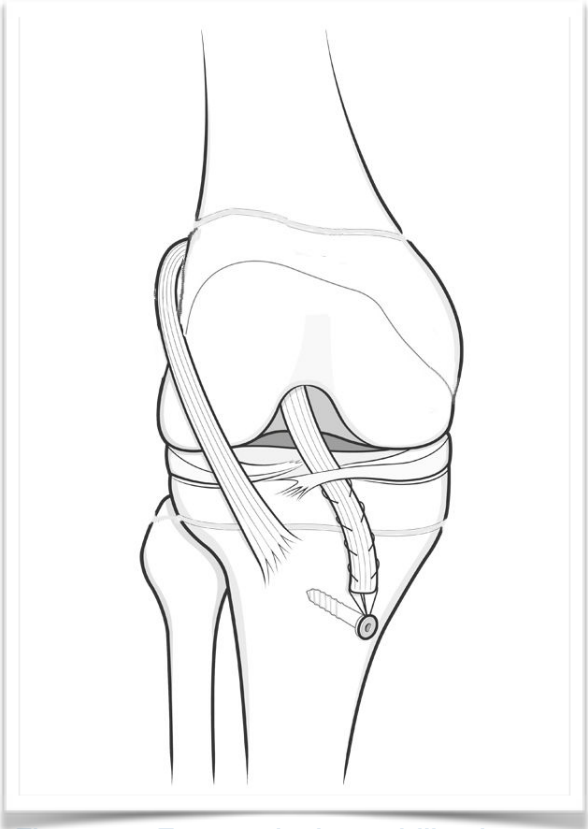


Figure 7.1 Extra-articular stabilisation.

secured below the growth plate on the tibia, so the growth plates are totally avoided.

Papers have been published to show good results, but this is not a technique that is currently undertaken by many surgeons.

All-epiphyseal

One of the real innovations in ACL surgery in general has been the development of what we call the 'all-inside' technique. This involves drilling the bone tunnels (or the newer 'sockets') from within the joint cavity, using 'retro-drills' such as the 'FlipCutter'. With this approach and the associated instrumentation, guided if necessary by fluoroscopic imaging, surgeons can go 'all-epiphyseal' - staying inside the ends of the bones without penetrating the growth plate.

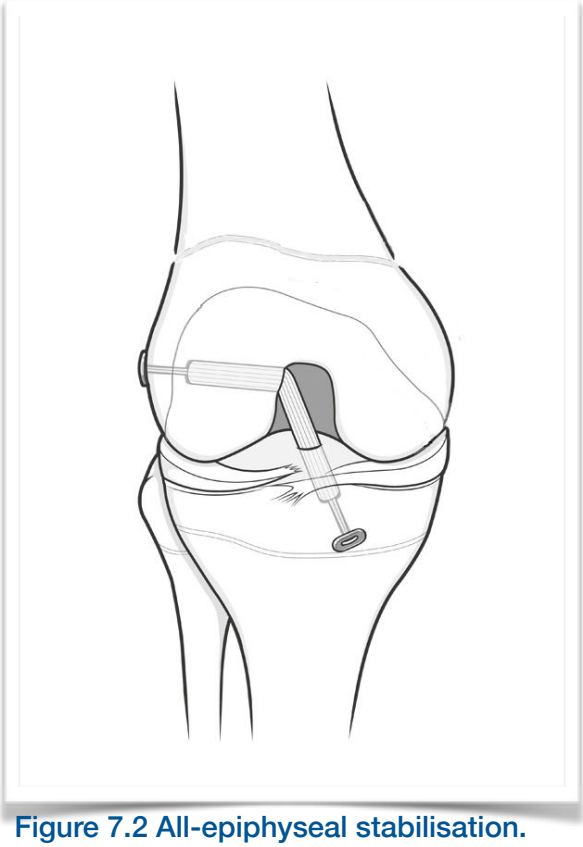


Figure 7.2 All-epiphyseal stabilisation.

In this option, the surgeon keeps the tunnels or sockets within the ends of the bone - that is within the epiphysis - and does not go anywhere near the growth plate. Gauges and fluoroscopic imaging ensure that the surgeon hits the target and does not compromise the growth plates.

Transphyseal

The next option is that of drilling right through the growth plates - what we call the ‘trans-physeal’ option.

The vast majority of angular deformities and growth disturbances after ACL surgery in children have been associated with bone plugs or fixation devices deployed across the growth plate. It is also considered that drilling

may cause heat damage and implants may have a pressure effect. Despite these risks, trans-physeal ACL reconstruction is frequently performed in skeletally immature patients with good outcomes, no or minimal growth disturbance and a high rate of return to previous activity levels. Tunnel positions generally need to be compromised, though, because although oblique tunnels are biomechanically favourable, they effectively increase the cross-sectional area of growth plate disruption.

Hybrid

If necessary the surgeon can perform a hybrid all-inside procedure, staying under the growth plate in the femur, but creating a tiny 3.5 mm drill hole through the growth plate on the tibia, using it to retro-drill from inside the joint a short but wider tunnel big enough to accommodate the graft.

Section Eight

Options for the graft material

As well as options for the placement of the tunnels, there are options for the kind of graft tissue or other material used for the stabilisation procedure.

These include -

Autograft

The first option is that of an autograft.

An autograft is a graft using the patient's own tissue - usually hamstrings tendons. The tendon that we can harvest from these small patients and use for reconstruction can be really a little pathetic. The reconstructed ligament remains vulnerable.

A 2009 paper by Shelbourne [4] reports a 17% failure of primary ACL reconstruction in patients under the age of 18 compared with 4% of those over the age of 25. In other words there is a significantly higher re-rupture rate in children. From the Danish registry [5,6], also, the numbers given for revision risk is more than 2½ times higher in those under the age of 20 than in those over the age of 20.

Because of the high failure rate that we see with reconstruction in this group, surgeons have considered alternative graft sources.

Allograft

The second option is an allograft. An allograft is a graft using donor material. As an alternative to using the child's own hamstrings we can use adult donor tissue for the graft. Usually this material is harvested from a cadaver - from someone who has passed away but who had donated their body to medicine.

Our young patients in general don’t do quite as well with cadaver allograft but an allograft from a living person is something that is gaining attention. This was a topic that was presented by Justin Roe on behalf of him and Leo Pincewszki at the ISAKOS meeting in Toronto 2013 - and it won a

prize. The obvious living donor for a child is the parent. Although either parent may prove suitable on tissue matching, it is probably the mother who will more commonly be the donor.

Native ACL

The third graft option is to use the native ACL and do a repair rather than a reconstruction. A 'repair' means that the old ligament is not cut away, but is retained. This is in contrast to 'reconstruction' where the old ligament tissue is removed and replaced. **Repair is an old technique that fell out of favour, but it is being reconsidered for children.**

Section Eight

Looking at ACL Repair as an option

As you have seen in a child the ligament itself may still be intact, but may have simply torn off from the attachment site at the femur or avulsed from the tibia, where a small fragment of bone commonly breaks away with the ligament. Even if there is damage to the ligament itself, it may be only partly torn.

Repair may be an alternative in all these cases.

Advantages of retaining what one can of the patient's native ACL include -

- maintenance of proprioception - or position sense - because nerves still exist within the remnant
- possibly no requirement to harvest the hamstrings tendons frequently used for adult reconstruction
- consequent absence of donor site problems, in either the child (or parent in those cases where we augment repair with parent tendon)

Excellent outcomes of repair in children have been observed thus far, and the technique continues to evolve. Repair is possible via an all-inside all-epiphyseal approach, and tunnel diameter can be reduced from 3.5 mm to 2.4 mm which is significant in this population group.

Augmented Repair

Because of the flimsy nature of the native ACL in most small children, the repair may be augmented by adding graft tissue to bulk up the construct or by the use of a temporary internal brace.

We are suggesting the term 'hybrid' to describe the combination of the native ligament and the parental allograft, but it might also be used to describe augmenting the native ligament with the child's own hamstrings tendon or parental allograft. By augmenting in this way, concerns regarding adequate graft dimensions are eliminated.

A different but related concept is that of an '*internal brace*' to support the native ligament while the repair heals. A tape of braided polyethylene FibreTape, for example, can provide temporary support for the healing repair, and it can then be electively removed after some months to prevent any tethering which could impair physis growth.

Section Nine

The ACL Repair procedure

Nowadays I would consider performing an ACL Repair in a chold, unless there is a reason not to.

The surgical management will depend upon the site and nature of the damage -

Proximal Detachment

The proximal tears are the ones that lend themselves most readily to repair, and the procedure is straightforward.

The technique involves lassoing the free end of the ACL and pulling it back onto its original footprint on the femur via a tunnel or socket drilled in the femur, where is it fixed with a fixation device.

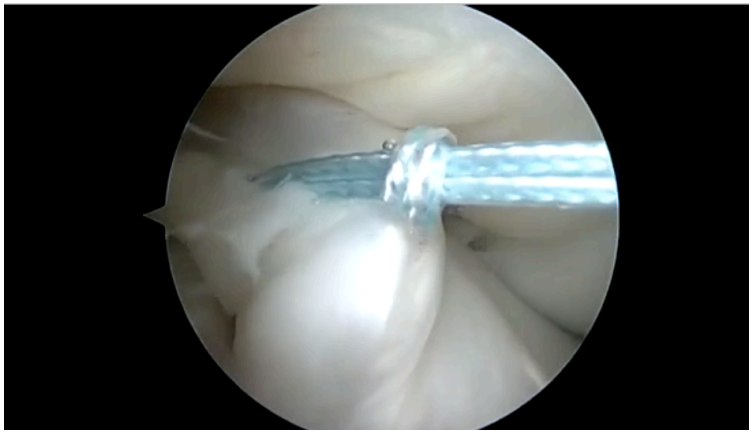


Figure 9.1 A lasso placed around the ligament.

We also use a FibreTape or braided polyethylene 'internal brace' when we do a repair. We don't simply repair the ligament as it is not strong enough without the support of the internal brace - it is generally too flimsy and vulnerable on its own. The internal brace can be removed after a few months. Such an internal brace would involve the need to drill a second tunnel in the tibia so that the brace can be securely fixed on both ends, usually with a button and suspensory ligament which are removed at the time that the polyethylene itself is removed.

If we can carry out a repair we can do so with *very small tunnels* - just 3 mm or less to pass sutures. It’s not burning any bridges - you are using the patients existing tissue. You are not harvesting tissue and therefore

causing further secondary damage which is what we have to do with a conventional reconstruction. Patients rehab much quicker because of the quick healing process and the minimally invasive surgery that is carried out. With objective and subjective assessment if all is going well they can return to full activity at 3-4 months, which is completely different to how careful we need to be following a traditional reconstruction.

Mid-substance Tear

For the mid-substance injuries, depending on the quality of the tissue, it may still be possible to re-tension and do a standard repair technique with the help of an *internal brace*, while preserving the old ACL.

What I currently use for the internal brace is a tape of braided polyethylene, which is very strong, and which is run alongside the ligament, and fixed at both ends, and retained until the original ligament ends have healed together.

However, if the tissue is poor quality then the surgeon can change to a hybrid graft and run alongside some tissue (usually the semi-tendinosis tendon taken from the child) as a biological internal brace. This would be called an ‘autograft’, that is using the patient’s own tissue. *Parental* tendon is another alternative for a hybrid graft, that is using the native ACL as a repair and living parental ‘allograft’ as an augmentation. There is no tissue typing or matching needed for such an allograft - It's avascular (has no blood supply) and has no immune potential. So in reality the ACL graft can be 'anyone-to-anyone, unlike blood transfusions or an organ transplant.

Distal Avulsion

When the injury occurs at the tibial end of the ACL it is usually associated with a bony fracture or avulsion. We would call it an 'insertional injury' (because it is at the ligament's insertion, rather than its origin on the femur). This type of injury associated with a bony avulsion is called a 'Mckiever', and these injuries have their own classification - type I, II and III depending on the amount of displacement.

If a patient presents with a Mckiever injury, in other words with a bony avulsion, historically the patient would have been put into a plaster in full extension, and the avulsed fragment would have been allowed to “gum up”. These days really have gone and anyone doing that is doing

historical treatment. Modern treatment is to do an arthroscopic procedure - to actually go into the knee, debride (or clean up) the footprint where the avulsed fragment has come from, remove any clot, and reduce the fracture, taking the avulsed fragment and putting it back perfectly like a piece of a jigsaw puzzle, and fixing it there with a device like a screw.

Section Ten

Rehabilitation

In terms of children the younger they are the more careful the rehabilitation.

We use as our index of maturity the ‘Tanner Scale’, which estimates a child’s maturity not by their chronological age but by the development or otherwise of secondary sexual characteristics.

ACL Rehab in children and adults is similar but there are also some differences. The Tanner 1 and 2 - the very young ones - are generally speaking less than 13 in boys and less than 12 in girls. Tanner grades 3 and 4 - which takes them up to skeletal maturity - we treat like adults, depending on how mentally mature they are.

With all adults - and most Tanner 3 and 4 - we allow a full range of motion and full weight bearing from day 1, but I don't encourage the patients to walk around too much on the repaired knees. It's just a matter of getting the range of motion going for the first two weeks, getting the quads muscles ‘firing’ with the physiotherapist and then progressing into an extended ACL rehab programme which sees many of them back to full sport at 12 weeks and including contact sport at 4 months.

This is very unique to *repair*. If we had instead replaced the tissue via a standard *reconstruction* they can't do the twisting and turning sports for 9-12 months.

So rehab after repair is much quicker and the patients are allowed to go much quicker - they can begin running at 9 - 12 weeks, perhaps even sooner. I think we need to move with caution and work out the process more scientifically or have a system in place such that we can work out when a patient is fit to return to sport, but universally it is 12 weeks to 16 weeks to full contact.

For the young children, however, it can be quite frightening having an operation, waking up in pain and discomfort - so to minimise that I splint the knee in plaster, and particularly the little ones - the 5 or 6 years olds - all go

into plaster. After 10 days the plaster is removed and the patients begin to mobilise with crutches. For the very little ones their parents push them around in a wheelchair or carry them and they just manage more slowly and also more carefully because of the concern around compliance. Then they go into a customised brace to allow range of motion but give them some protection. I also keep them off sport for 4 months before I allow them to return.

Section Eleven

Take-home message

Growth plates in a child need to be taken into serious consideration in children with ACL injuries.

Surgery is currently the preferred option to restore function and avoid the consequences of instability. A number of options exist and the surgeon will need to consider the site of the damage, the size of the existing tissue, and whether a parent agrees to internal bracing with polyethylene or even to donating their own tendon tissue to support that of the child.

ACL Repair rather than reconstruction also allows return to full activities much earlier in the rehabilitation process.

Section Twelve

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Further Reading

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