ACL Injury

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The anterior cruciate ligament is the most commonly disrupted ligament in the knee. Our understanding of this ligament, and our recognition of its importance to knee stability, has increased greatly over the past 20 years. Along with this, our ability to diagnose and treat this injury, has substantially improved. As a result, an injury which once spelled the end of a sporting career, can now be viewed much more optimistically.

A.C.L. Function

The normal anatomy of the knee is depicted below. The cruciate ligaments and the collateral ligaments provide stability to the joint by holding the bones together. Of those ligaments, the anterior cruciate is important in that it holds the knee together during twisting type activities. During everyday walking and in straight line running, the ACL is hardly used. As soon as any twisting is performed however, this ligament is essential. Without it, the knee literally twists apart, giving a feeling that the knee comes out of joint. It is this feeling of coming apart that gives rise to the instability, and/or loss of confidence in the knee, that is seen when the ACL is torn. As it is a rotatory instability, it occurs when twisting or sidestepping is attempted, or when uneven ground is encountered. If major, it may occur in everyday activities. In some however, it occurs only on the sporting field where it is hard to concentrate on protecting the knee, and where sudden twisting and turning occurs.

Injury mechanism

Injuries to the anterior cruciate ligament occur most often in athletic activities (especially twisting and turning sports, such as football and netball), but may be ruptured in work injuries and non-athletic activities. The injury can occur without contact, and often, it is associated with a sudden change in direction (e.g. side-stepping) or a sudden change in speed (a deceleration injury). It may also occur with the body falling over a fixed leg or with a hyper-extension (over-straightening).
injury to the knee.

When the injury occurs, the individual will often hear a ‘pop’ or ‘snap’, or experience the sensation of tearing inside the knee. The knee then swells, almost immediately, because of bleeding from vessels within the torn ligament. Generally, the injured person has to be carried off the field and finds that any attempt to weight bear is difficult because the knee feels extremely unstable. The immediate feeling of instability is due, not only to the loss of the ligament, but also to a loss of the nerve fibres within that ligament. These nerves provide a sense of where the joint is in space which is called proprioception. Loss of that sense, causes a loss of the sensation that tells you how bent the joint is, how fast it is bending, and so on. Without that knowledge, there can be no accurate feedback to the muscles that move the knee, or to the muscles that protect the knee: and hence, control of the joint may be lost, leading to a feeling of instability, or loss of confidence.

With time, the feeling of proprioception improves. This is because the nerve fibres in the other ligaments, gradually make up for the loss of sensation from the nerve fibres in the anterior cruciate ligament. This situation is never quite as good as the original but, if the demands on the knee are low, it may be sufficient to get by.

What happens when the ACL tears?
The ACL is responsible for holding the outside (lateral) compartment of the knee together. When the ACL tears, the lateral femoral condyle is released, and it then dislocates over the back of lateral tibial plateau, as shown below. This leads to a stretching (or tearing) of the outside structures of the knee, a crushing injury to the back (posterior) part of the lateral meniscus, and to an impaction injury where the middle of the lateral femoral condyle impacts on the sharp posterior edge of the posterior tibia. It is this latter injury that leads to the typical bone bruises in both those bones and, if those are present, then clearly, a total rupture of the ligament has occurred.

If the injury is big enough, it can cause tears of both menisci and damage to one or more of the joint surfaces (the lining cartilage otherwise known as hyaline cartilage). Other ligaments can also be torn, the patella can be dislocated and, with increasing violence, the whole knee can be dislocated. Ultimately, this can then lead to injury of the nerves and blood vessels of the leg, the latter representing a medical emergency requiring repair of the vessels to save the limb.

After the injury
What happens immediately after injury to the anterior cruciate ligament, is a sudden loss of control of the knee. This is something that gradually returns. In most people, it takes about two months to reach a level where they can think about playing sport again. Those who seem to get back to sport without surgery (less than 20%) often only have partial tears of the ligament. Whilst the injured knee in this group may be looser than normal, it is thought that function may be satisfactory because some of the proprioceptive nerve fibres remain intact. These are thought to provide enough feedback to the muscles around the knee to enable those muscles to compensate somewhat for the partial loss of the ligament. The concern for partial tears however, is that they are, by their nature, weaker. They may therefore go on to complete rupture at a later date without excessive provocation.

Even for those with a complete rupture, the feeling of stability does gradually improve over a 2 to 3 month period. If by that time however, full confidence in the knee has not been restored, then that knee will probably never be

The Pivot Mechanism: when the ACL tears, the lateral femoral condyle (on the outside of the knee), dislocates over the back of the lateral tibia, crushing the lateral meniscus in the process.
able to perform a twisting, turning sport again without ACL reconstruction. If a return to those sports is made, then a repeat injury is likely, due to the ongoing instability. From then on, every time that the knee gives way, more damage is done. Sooner or later, that damage will include injury to the articular lining cartilage, which is unreparable. This may herald an end to impact loading type activities and, in essence, represents the onset of osteo-arthritis which will progressively worsen with time. Because of this risk, it is now considered preferable to reconstruct the ACL relatively early on to try and prevent recurrent injury.

**Meniscal cartilages and articular (lining or hyaline) cartilage**

The menisci (meniscal cartilages) - sometimes known as ‘the cartilages’ - function as fillers to spread the load between the surfaces of the femur and tibia. The ends of these bones are not the same shape, and thus, the menisci are needed to make up for that incongruity. They primarily function somewhat like shock absorbers but they also have a secondary role to enhance lubrication and nutrition of the articular or lining cartilage.

Loss of a meniscus (particularly the lateral one) leads to a poor spread of weight across the joint surface. This means that loads are taken over smaller areas of the joint, and hence, pressures are higher, causing increased rates of wear of the lining surface. It also follows, that the more meniscus that is lost, the faster that wear occurs.

The articular (hyaline) cartilage covers the ends of the bones of the knee joint and allows for its smooth movement. It is a shiny, white, ultra low friction material, that acts as a bearing surface for the joint. (It is easily seen on the end of lamb bones etc.). This articular cartilage is very different from the meniscal cartilages (or menisci, mentioned above) and is the most delicate and irreplaceable structure within a joint. Once this gets damaged and wear starts to occur, a joint can no longer be returned to its normal state. Injury to this lining is treatable only by debridement, a process of cleaning up: removing loose fragments and smoothing the remaining damaged surface. This removes all the fragments which may potentially fall into the knee and, in a number of cases, it also helps to decrease pain. Despite this however, a permanent defect remains which shows almost no attempt to repair itself.

Once a defect exists in the smooth lining surface, it will only get bigger with time. It is this damage to the bearing surface of the knee that starts off the progressive process known as ‘osteo-arthritis’ (or ‘wear and tear’ arthritis).

The other factors that affect wear rates are age and usage. The young and the high demand athlete put their knees through much more than the older recreational sportsman. Indeed, a lateral meniscectomy in a sixteen year old is virtually guaranteed to produce wear, that is sufficient to be noticeable on X-ray, within ten years. On the other hand, a medial meniscectomy in a thirty five year old, may show very little change on X-ray for twenty years. In the young therefore, meniscal tears associated with ACL injury, should be repaired whenever possible. To protect that repair, and thereby to increase the success of that repair, the ACL must be reconstructed at the same time.

In the normal knee, the meniscus is a mobile structure that makes the joint spaces congruous and spreads the load over a wide area of the joint lining (articular surface). By increasing the area of distribution of the contact force, the local pressures are reduced and wear is prevented.

Loss of meniscus causes high pressures to be experienced at the point of contact of the femur and tibia. This pressure, especially at the time when impact loading is occurring, can exceed the breakdown strength of the lining of the joint (hyaline cartilage). This causes breakdown (wear) of that lining which, in essence, is osteo-arthritis, and which, once begun, will become progressive with time. To protect that repair, and thereby to increase the success of that repair, the ACL must be reconstructed at the same time.

After loss of a meniscus, it can be seen that the lateral (outside) part of the knee has higher contact pressures because of the convex on convex structure of that part of the joint. Hence, wear in the lateral (outside) compartment of the knee develops more rapidly than it does in the medial (inside) compartment of the knee (where the joint is convex on concave). This wear (osteo-arthritis) ultimately leads to the end of impact loading type sports, including all running. Ultimately, it may also lead to knee replacement.
As might be expected, if the articular cartilage of the joint is normal, and the menisci are normal, then the likelihood of returning to sport following ACL reconstruction is very high. Indeed, if the rest of the knee looks normal at the time of reconstruction, then the risk of progressive arthritis occurring over the next 10 years is also reasonably low, albeit that an injury to the anterior cruciate ligament is a major injury and, even if other damage can’t be seen at the time of injury, there is no doubt that other damage does occur and, with time, some osteoarthritis will present, usually in the patellofemoral joint.

**Damage to the articular cartilage** is a permanent injury, creating a pothole in the low friction surface of the joint, which will inevitably get bigger with time. The rate of progression of this depends on many factors including, leg alignment, activity levels and, in particular, the amount of impact loading activity that is done. If this injury involves the major weight-bearing aspects of the joint, and if it progresses, it will ultimately lead to more major surgery being, either a leg re-alignment (osteotomy) to try and unload the damaged part of the joint and make it last longer, or knee replacement.

**When the damage involves the patello-femoral joint**, the problem occurs, not so much with running, but with activities that involve the bent knee. This means that there will be difficulty with squatting, lunging, crouching, and stair climbing: noting that going downhill and down stairs is generally worse than going up. One of the things that has been observed over the last 20 years is that, by 10 years post reconstruction, nearly 70% of people will re-present because of problems of the patello-femoral joint: and this problem usually turns out to be an osteo-arthritis process, be that mild or otherwise.

**Damage to the menisci.** Whilst medial meniscectomy can look relatively benign for a few years, wear of the medial compartment will eventually occur and, again, its rate of onset and rapidity of onset will depend on the factors described above. Lateral meniscectomy, on the other hand, has a much less benign course, with osteoarthritis coming on sooner and progressing more rapidly than its counterpart on the medial side. Indeed, lateral meniscectomy is the commonest cause of retirement of elite athletes in the world today. Even if the ACL is perfectly reconstructed therefore, if the lateral meniscus is injured badly enough to require some resection, then osteoarthritis will ensue, and probably within a few short years.

**Who warrants surgery?**

The majority of people who injure their anterior cruciate ligament will probably benefit from surgery. To some extent this is age dependant, and the requirement for surgery does decrease with age. This is not only because the demands placed on the knee decrease with advancing age, but also, the ability to cope with proprioceptive loss improves with age. The opposite situation occurs in the young age group (under 18), where almost all tears are complete, and the majority tend to be very symptomatic. In this group therefore, almost all patients will develop enough instability to warrant surgery.

Those who sustain injuries to other ligaments of the knee, in addition to a tear of the anterior cruciate ligament, are more likely to require surgery. The timing of this will often depend on what other ligaments are injured at the same time and, whether or not, these need either operating on or splinting, to allow optimal healing.

Those with suspected meniscal tears which may be repairable, may also be better off considering surgery. It is not always possible to know whether a meniscal tear will be repairable or not until the knee is arthroscoped, however, the newer MRI scanners can provide some good information in this regard. Similarly, if the injury seems major and suggests this possibility, then surgery may be a better long term alternative, attempting to preserve meniscal function, and hence protecting the articular cartilage lining.

Obviously, it is possible to repair a meniscus and leave a torn ACL alone but, the breakdown rate of meniscal repairs in an unstable knee is more than double the failure rate in a stable knee. For this reason therefore, isolated meniscal repair without ACL reconstruction is rarely performed. If a meniscal tear is symptomatic and requires treatment and, for reasons of time or employment, a reconstruction cannot be performed, then partial meniscectomy is undertaken. This situation is regarded as a compromise to hasten return to work, and is not a substitute for reconstructive surgery. Twisting, turning sports then need to be avoided, until such time as the knee is made stable.

**Conservative treatment**

**Lateral Meniscal Repair: Inside-out technique.** Sometimes this can be done all arthroscopically (from inside) with no other incisions being required.
Treatment for injuries of the anterior cruciate ligament cannot be standardized, because of individual differences in injury patterns, and because of the different expectations individuals have in regard to return to sporting activities. In the patient who sees sport purely as recreation and who would consider giving it up if it meant that an operation could be avoided, a hamstring re-education and rehabilitation program may provide a satisfactory knee for everyday use. This type of exercise program however, is not a substitute for ACL reconstruction because the ligament itself never heals. What it achieves is better control over the knee, by improving strength, and by improving the feedback from the other ligaments (proprioceptive training). Given adequate provocation however, the knee will still give way and further injury may occur.

Patients with an old anterior cruciate ligament rupture need to avoid recurrent giving way and buckling. If these episodes are associated with pain and swelling, and are frequent, it is a sign that the knee is developing progressive wear and tear arthritis (osteo-arthritis). Patients in this situation need to either, consider the option of surgical reconstruction or, change the demands that they are placing on their knee.

For those patients who are athletic and who do not wish to consider giving up sporting activities, a surgical procedure to reconstruct the ligament will provide the best chance of returning to a reasonable level of performance.

**Anterior cruciate ligament reconstruction**

Reconstruction of the anterior cruciate ligament is a complex surgical procedure and there are many different ways to go about it. The preferred method, at this time, is to use a portion of tendon (or tendons) from elsewhere as a graft. In most cases this means using two hamstring tendons (semi-tendonosis and gracilis) or using the central third of the patella tendon, but other tendons can be used. Artificial ligaments are currently available in many different forms (including LARS), however, to date, none of these have been shown to last long enough to make them desirable as a primary procedure. They may have a roll to play where other methods have failed, but they are not sufficiently durable to allow long term return to any form of sport, most failing by 2 - 3 years. (For further details on graft choice and selection, see the end of this information sheet.)

Reconstruction of the anterior cruciate ligament is done in an arthroscopically aided manner. This does not mean that there are no incisions however, because the graft still has to be harvested in a standard open type manner, albeit through one or two small incisions. What it does mean, is that the knee joint itself is not opened, as all the work inside the joint can be done via the arthroscope (keyhole if you like). This causes less pain and a shorter hospital stay, and allows for an earlier and better range of knee motion. It may also induce less wasting of the muscles post operatively and, perhaps, an earlier return to normal knee function. Return to sport however, is dependent on the strength of the ligament, and hence, whether the surgery is performed in an open manner or via the arthroscope is irrelevant: that recovery taking 9 to 15 months to occur fully.

Reconstruction of the anterior cruciate ligament is now an everyday procedure thanks to advances in instruments and techniques that have occurred in the last 20 years. Patients are in hospital for 1 or, at most, 2 nights and generally, no brace is required. Crutches are necessary for 4 weeks, until the ends of the tendon graft have started to heal into the bone and, by 6 weeks, most people can walk with only a minimal limp. By eight weeks a swimming and bike riding program can...
begin and this can be increased over the second six weeks.

When first put into the knee, the tendon graft is dead (having been removed from its blood supply at the time of harvest) and the ends are just held in with screws or similar devices. Hence, in the immediate days following surgery, the weak link in the chain is the fixation at the ends of the graft. Over a period of about 6 to 8 weeks however, the ends start to heal in and the graft becomes a permanent part of the knee. In order to survive injury however, the graft has to come back to life and be able to heal itself in response to both minor injuries and to repeated stress. This process begins when a blood supply is re-established, with new vessels growing in from the freshly healed ends. Such changes begin within a few weeks of surgery and progress steadily over the next 12 to 18 months. MRI studies of the blood supply show that, by 18 months, there is full restoration of vascularity. This probably means that, after this period of time, no further healing of the ligament occurs.

**Graft strength**

From a strength point of view, the weakest link in the first six weeks is the fixation at the ends of the graft. After that time, the weakest link is thought to be the graft itself. Once the blood supply starts to grow down it and through it, the old dead collagen in the graft starts to be removed; to be replaced by new collagen: a process which has been enabled by the new blood supply. This process may take over a year to complete but, most researchers feel that the weakest period is at about the eight week mark. Following this, the graft construct does begin to strengthen, and it is thought that by 4 months, some running can be safely commenced. By 6 months, full training for sport can be started, however, the exact timing of return to sport will depend on individual progress, including, most importantly, the regaining of proprioception in the knee. This means a return of the ability to run around corners, and to twist on the knee.

Whilst there are other rehabilitation protocols which are more rapid than the above, experience over the last 25 years of ACL reconstruction, has determined that the above is safe and has the least risk of damaging or loosening the graft. Similarly, more intense exercise early on, has not been shown to significantly shorten the time to safely return to sport.

With regard to the above, the graft is probably strong enough to play some sport at the five-month mark, whereas it is certainly not strong enough at the 3 to 4 month mark (as has been evidenced by the attempted early return of players to various football codes over the last few years). In order to play sport however, one has to feel a degree of confidence in the knee. This feeling of confidence is not dependent on how good or how strong the graft is, but rather, is related to the recovery of proprioception in the joint. This is a process that takes some 15 months to fully occur, but is usually reasonably advanced by nine months: by which stage, most people feel
At the 6 to 8 week mark, it is generally safe to start a bit of walking around the house or similar is generally satisfactory but, any longer to 4 weeks. After the second week, a bit of walking around is slightly tighter when the knee is fully straightened and, especially where hyper-extension (overextension) is achieved early, it is a sign that the graft may be slightly loose. In this situation, the knee is generally not so sore and, in contradistinction to what one might expect, it has to be acknowledged that the ligament counteracts the inevitable swelling that occurs in it. Such swelling can lead it to be slightly short and tight, and hence to cause the knee to lose full extension. Ideally, the knee should be within 5° of full extension at the six-week mark, and pretty much achieving full extension by the three-month mark. Given that the graft will gradually stretch out over time, it is preferable that it is slightly tight to begin with.

When the graft is slightly tight, the knee is generally slightly sore. This is a situation where the graft is clearly intact and hence can probably be pushed a little bit harder. On the other hand, where full extension is recovered very easily, and especially where hyper-extension (overextension) is achieved early, it is a sign that the graft may be slightly loose. In this situation, the knee is generally not so sore and, in contradistinction to what one might expect, it has to be protected until it is confirmed to be stable. This process may take three or more months and in the initial phases may require the protracted use of crutches.

Up until the 6 to 8 week mark, whilst the ends of the graft are still healing in, the knee needs to be quite protected. Like a credit card, which will tolerate being bent once or twice but will not tolerate being bent 100 times, the graft fixation may survive a fall, but may not survive the repetitive loading that occurs with everyday walking. This is because the graft is slightly tighter when the knee is fully straightened and, every time a step is made, the graft is pulled on a little bit. If this happens too often in the early phases, the fixation of the graft will fail. This makes the use of crutches very important in that it prevents the leg going through too many cycles. We therefore feel that it is important to use the crutches full-time for the first couple of weeks, and then part-time in the next 2 to 4 weeks. After the second week, a bit of walking around the house or similar is generally satisfactory but, any longer walk, should be either avoided or done with crutches.

At the 6 to 8 week mark, it is generally safe to start a bit of swimming and bike riding, but any walking for exercise should be avoided. The exercise bike is perhaps the safest reasonable exercise that one can do without aggravating or damaging the graft. When first attempted, just a short five minute spin with minimal resistance, done twice a day, is adequate. By three months however, a distance of 10 to 15 kilometres on a road bike is possible. This should be slowly built up to, being guided by swelling and pain.

In the first six weeks it is permissible to swim with a Pull-Buoy, which holds the legs up, and means that kicking is not necessary. After the six-week mark, a little bit of kicking can be commenced, generally beginning with a lap or two kicking followed by a few laps with the Pull-Buoy. This can then be slowly increased such that, by the three-month mark, the legs can be kicking for every lap.

Walking in the water is also quite a good exercise but, initially, this needs to be walking on the spot rather than traversing the pool. When the pool is traversed the quadriceps pull the tibia forwards to move it against the water. The quadriceps pulls on the upper tibia and the hinge for this is the ACL. This sort of activity therefore, puts quite a bit of strain on the ACL, making it what is known as an ‘open kinetic chain’ activity. This is something that should be avoided for the first two to three months, in contradistinction to ‘closed kinetic chain’ exercises, where the ACL is not under stress. This is something your physiotherapist will help you with when the time comes, usually around the eight-week mark.

Post-operative bracing

For most reconstructions, particularly those using hamstring tendons, we normally use a straight leg brace to hold the knee in near full extension. This is not to protect the ligament so much as to keep the knee still. Excessive movement tends to increase bleeding into the joint which, in turn, leads to increased swelling and increased pain. We like the brace to be used for about 10 days fairly much full time. Having said that, the brace does not allow full extension because of a pad that is behind the knee. Hence, it will need to be loosened off or removed in order to place the knee into full extension (as required 3 times per day). It can also be removed when sitting quietly. In this situation, the knee can safely be taken to 90° without any harm, but should not be taken past that angle.

Physiotherapy

Whilst in hospital, everyone will be seen by a physiotherapist who will make sure that they can manage on crutches (including negotiation of stairs if necessary). The therapist will also provide a baseline exercise program including, most importantly, exercises to straighten the knee as described above. Other than those basic exercises which are done three times a day, the most important thing in the first six weeks is rest.

Patients are reviewed one week and six weeks following...
surgery and any changes to the above regime will be instituted then. For most people however, no formal therapy is required in the first 6 to 8 weeks. Patients who may benefit from early therapy are those who have tight knees and who are having more trouble than usual getting motion back. This includes the patient with repairs to other ligaments and menisci, whose knees may be tight due to the stitches in the capsule around the joint.

Once the first eight weeks have elapsed, when the graft has joined to the bone at each end, and when the new ligament has started to heal, further therapy may be helpful to begin the muscle strengthening process that is required to return to full function. The decision to begin muscle strengthening however, is based on how the knee is progressing in terms of swelling, range of motion and tightness. If the knee is loose and moves easily, strengthening will be delayed whereas, if the graft is tight, it can be started earlier.

The time frame that people find therapy most beneficial is the 3 to 6 month period, when they are starting to jog or run. A rehabilitation program at this stage can also help with the process of regaining proprioception, something that is essential for a safe return to sport.

Whilst therapy is not essential for recovery, there is no doubt that it leads to more rapid muscle strengthening and, most importantly, earlier recovery of proprioception. In addition, a good sports physiotherapist can provide an exercise program that is predominantly a closed kinetic chain program, which means it will not excessively stress the ACL graft.

**Time off work and Sport**

Students can generally return to school or university at the 7 - 10 day mark, provided that the amount of time spent on their feet is limited. They will need to use crutches and, if they have to do a lot of walking around campus, they may choose to use their crutches for longer than usual.

People in a sit down job can usually return at the 2 week mark. If the job involves prolonged standing however, then 4 weeks may be more realistic.

If there is moderately heavy work to be done, then 2 months is the 3 to 6 month period, when they are starting to jog or run. A rehabilitation program at this stage can also help with the process of regaining proprioception, something that is essential for a safe return to sport.

If there is moderately heavy work to be done, then 2 months is the commonest problem. Obviously everybody has some bruising, but occasionally, it is such that the knee becomes swollen and sore, and the normal mild discolouration that extends to the foot becomes very obvious. This gives discomfort, particularly when standing up, and may last 2 weeks. To a degree this can be avoided by using the brace for most of the time and not walking around too much when first allowed home from hospital. However, some people bleed and bruise more easily than others, and occasionally the knee will require aspiration of the knee to relieve the pressure in the joint. Rarely, if there is excessive bruising or recurrent bleeding into the joint, then studies looking for disorders of coagulation may be indicated.

**D.V.T.’s** (deep venous thromboses) also occur but are uncommon (less than 5%). These represent clots in the deep veins of the leg, usually the calf. They may occur at the time of surgery, or sometime over the next few weeks. Most commonly however, it is in the first 10 days. If noticeable, it is usually as an ache in the calf at the back of the leg. If this is occurring, then a doppler (ultrasound) scan can be used to detect it, and appropriate treatment organised.

Usually, some mild thinning of the blood will be organised for every ACL reconstruction, most commonly being aspirin 100mg per day for 2 weeks. When a patient is at higher than normal risk for this complication (e.g. a significantly positive thrombophilia factor like Factor V Leiden) then this prophylactic thinning of the blood can be upgraded to low dose clexane injections, extended over a longer period of time, or both. These measures, particularly the latter upgrades, increase bleeding and bruising however, and thus will be instituted based on a risk benefit assessment.

The at risk period for getting a DVT is generally regarded as being the first two months, albeit that the majority occur within the first 10 days. For those who travel in that period of time however, consideration of further anticoagulation should be given and, depending on distances travelled, prophylaxis may be indicated even out to the three month mark. This can be done using clexane (or similar) injections, and usually by self injection. A newer alternative however is to use oral anticoagulants, which may not be on the PBS listing yet, but are not overly expensive. Different tablets are taken as per their recommended dose regime. For rivaroxaban, 10mg taken 1 -2 hours before travelling, and repeated at 18 hours if still travelling, will provide good prophylaxis, especially if combined with flight socks or flight stockings. Such travel would include plane flights, long-distance car journeys and long train journeys.

**Problems and complications of surgery**

Overall the number of people who have problems following ACL reconstruction is small. Nevertheless, problems do occur, and these need some consideration.

**Bruising** in the immediate post-operative period is the commonest problem. Obviously everybody has some bruising, but occasionally, it is such that the knee becomes swollen and sore, and the normal mild discolouration that extends to the foot becomes very obvious. This gives discomfort, particularly when standing up, and may last 2 weeks. To a degree this can be avoided by using the brace for most of the time and not walking around too much when first allowed home from hospital. However, some people bleed and bruise more easily than others, and occasionally the knee will require aspiration of the knee to relieve the pressure in the joint. Rarely, if there is excessive bruising or recurrent bleeding into the joint, then studies looking for disorders of coagulation may be indicated.

**P.E.** (Pulmonary Embolism) is perhaps the most serious complication of all surgery and anaesthesia, and indeed,
can be fatal. The problem of having clots in a vein (DVT) is always that they may spread to the lungs. This, fortunately, is a rare event, occurring perhaps just once in every 100 cases. It generally presents as chest pain which is worse with deep breathing. It may also lead to intermittent shortness of breath and a general feeling of unwellness. Unfortunately, whilst we can reduce the incidence of DVT’s by the use of low-dose peri-operative anticoagulation, the same cannot be said for pulmonary embolism. Standard peri-operative anticoagulation does not seem to change the incidence of pulmonary embolism, almost as if it is a separate disease entity.

For those at high risk of PE therefore, more substantial anticoagulation is required which may involve full, and prolonged, anticoagulation with warfarin, rivaroxaban, or similar agents.

**Deep infection** is uncommon, occurring in less than 1 in every 500 cases. If detected early, it is treatable, hopefully such that recovery can follow without loss or failure of the graft. Nevertheless, the graft is threatened by this problem and the situation requires prompt treatment, including arthroscopic washout of the knee and antibiotics. In order to decrease the risk of infection, peri-operative antibiotics are always given. Also, the graft is harvested in a manner which, where possible, avoids excessive contact with the skin and; usually, it is soaked in vancomycin (an antibiotic that has very high potency for skin organisms, is absorbed well into the graft tissue, and does not alter the biomechanical properties of the graft).

**Loss of full extension** of the knee is the most common medium to long term problem encountered. Some 10% of people who undergo ACL reconstruction, have a scarring and tightening reaction to that surgery. The reason for this is unknown, but it does lead to a general tightening of the knee as a whole. This means slower initial progress, with the knee being stiffer and more painful in the early weeks. At the end of the day however, whilst the initial progress is slow, this reaction leads to a thicker stronger graft with good long-term stability.

This generalised tightening of the knee, which includes all the soft tissues and capsule around the joint, is, in essence, a frozen knee. It is a reaction to injury of one sort or another and, not uncommonly, it can be seen after the initial injury: and therefore may be present prior to surgery. If this is the case, it is very important to await resolution of this process before undertaking surgery. Sometimes this means rest, time (perhaps even weeks), physiotherapy, and the occasional judicious use of cortisone. Once it has resolved, it is then safe to proceed with surgery without the risk of aggravating the condition, something that can otherwise lead to prolonged, and occasionally permanent, loss of motion.

In almost all cases of post-operative stiffness, resolution occurs given an adequate amount of time. Certainly as the nine month mark passes, when scar tissue starts to soften and stretch out, most will go on to regain full motion. Generally, full extension comes back before full flexion and, by 1 year, less than 5% have any residual loss. For that group, there are procedures that can be undertaken to help this problem and, if necessary, these can be performed. With the newer techniques of reconstruction however, this type of secondary surgery is becoming less and less needed.

**Cyclops Lesions** are accumulations of scar at the front of the ACL graft. They are not present initially, but rather they develop slowly over a period of weeks and months. They initially start out as soft scar but can become harder with time, sometimes incorporating cartilage and bone. Because of where they form they can be pinched between the tibia and the femur when the knee goes into extension. This not only restricts extension (the ability to get the knee straight), but it can also lead to pain when it is pinched. That pain is usually felt just below the inside of the patella.

Whilst this occurs more often in tight knees than loose knees, it can occur in both. What is important, is to distinguish between this problem (which is just a mechanical block) and the frozen knee type picture described above. If it is the former, then surgery to remove the lesion is relatively straightforward and gives rise to a rapid resolution of both pain and loss of extension. If it is the latter, then surgery can aggravate the condition, leading to further deterioration and prolonging the time to recovery.

**Graft loosening and failure** may also occur. Just as there is a 10% group at the tight extreme, so there is a 10% group who seem to progressively loosen with time. This group regains motion early and easily and, as a consequence, their knees are not particularly sore. Accordingly, they tend to return to activity early, and tend not to protect the knee as much as perhaps is ideal. In some instances this can cause early failure of the graft.

If failure occurs in the first six weeks then it is usually a failure of fixation. In this time frame, the graft can usually be freed up from the bone and new fixation applied. After six weeks, the graft is so solidly healed into the bone that it becomes impossible to free it up. Hence, if it can’t be freed up, the only solution may be a formal revision of the reconstruction. It is therefore important that, where possible, the knee is checked
for stability at the six-week mark.

A cause of late failure (6 - 12 months), is where the graft fails to get a new blood supply and thus, fails to come back to life. If it remains dead however, it does not have the capacity to heal, and hence, everyday stresses will eventually lead to progressive rupture of its fibres. Revision reconstruction may then be necessary and, fortunately, is usually successful.

**Graft re-rupture** can and does occur. No graft is as strong as a normal ligament, and hence, a big enough injury can cause damage to it. As it turns out however, rupture of the ACL in the other leg is more common than rupture of the graft. This is not because a graft is stronger than a normal ACL, but rather, it is thought that a large percentage of those who rupture an ACL have weaker than normal ligaments in the first place. This means that they are therefore more susceptible to rupture of the ACL in the other knee. For the same reason, there are some families where several generations all rupture their ACL’s.

Age is also a factor in this, with recent studies indicating that the very young (under 16) have not only a high incidence of re-rupture, but a very significant chance of rupturing the opposite ACL over the following 15 years, with the latter incidence approaching 65%. This is thought to be due to a combination of, congenitally weak ACL’s, loose or weak collagen tissue (as indicated by hyper-mobile joints), high levels of activity, and the long period of exposure to sport.

**Patello-femoral pain** or ache under the kneecap (patella) is common once activity has begun. This is mostly due to the muscles being wasted and weak and, in this scenario, it responds well to exercise, particularly of the VMO muscle. Physiotherapy for this can be very helpful, both to re-educate this muscle and to improve patello-femoral joint function. For most therefore, this is a treatable and self limiting problem.

Patello-femoral pain can also occur from damage to the articular lining of the patella itself. This happens to the extent that it is clearly visible in about 10% of ACL injuries and, unfortunately, it can prove relatively difficult to treat. Nevertheless, this problem is generally minor, and usually does not interfere with sporting activities to any great extent. What is known however, is that even if the patello-femoral joint looks normal at the time of reconstruction, slow degeneration of the patello-femoral joint does occur with time, such that 70% of patients with reconstructed knees will re-present for review by the 10 year mark because of it.

**Patella tendonitis**, or ache from the remaining patella tendon, is not uncommon at some stage during recovery from a patella tendon graft. This occurs because one third of that tendon has been used to reconstruct the ACL, leaving just two thirds of the tendon to deal with the loads and stresses. In most people this occurs when running is commenced and, generally, this is around the 5 to 6 month mark. Sometimes this leads to an inability to run, but it is usually transient. The extra stress that is put on the remaining tendon stimulates it to get bigger and stronger (hypertrophy) until it is able to cope. As such therefore, with time, the tendon usually settles down and stops aching when used.

**Ache from the tibial fixation screw** is not all that uncommon early on but, fortunately, is rarely bad enough for long enough to require treatment. Also, many of the screws that are used for hamstring reconstructions are biodegradable and, ultimately, over 2 years, will dissolve. Prior to that happening however, the screw occasionally comes loose, in which case it can be easily removed.

Once the six-week mark is reached, the screw is no longer necessary anyway, the ends of the graft having healed adequately to bone by then. This means therefore, that it can be removed any time after that with minimal consequence. Similarly, after that period of time, if the screw is prominent enough to interfere with kneeling then it can be removed.

**A screw ganglion** is a fluid lump that develops around the screw, often some years after reconstruction. It presents as a lump near the scar that can be quite hard but is not red or inflamed. It is thought to represent fluid leakage from the knee joint which has made its way, either down past the screw, or through the central cannulation of the screw, creating a build up under the skin. Whilst not harmful, it can be a little bit sore, and certainly can be clearly visible. Removal of the screw is indicated, and this is often accompanied by bone grafting of the tunnel to seal the leak. Usually bone bank bone is used.

**Summary**

The anterior cruciate ligament is a major and important ligament in the knee which is commonly injured. Treatment depends on the age of the patient, the exact nature of the injury, the nature of any associated injuries, the lifestyle of the patient, and their future sporting aspirations. In those patients who are willing to alter their lifestyle, a rehabilitation program may be adequate but, for the majority, especially for those who want to return to twisting and turning sports, a reconstruction may be a better alternative. With the advent of better operative procedures to reconstruct this ligament, such as have been developed in the last few years, the problems that used to be associated with this form of surgery are less common and the functional results are better. In general 90% of those undergoing reconstruction will return to their previous sport, and more than 70% will be able to compete at their previous level.

Nowadays, an inability to return to sport at the pre-injury level, is rarely due to loss of the ACL, such is the success of reconstruction. Rather, it tends to be due to unreparable damage that has been caused to other parts of the knee, either at the time of the initial injury, or in subsequent injuries.
Graft Choices

When ACL surgery was first conceived in the mid-1980s, the middle third of the patella tendon was always used as the graft. 10 years later, hamstring tendons started to become used, simplifying the procedure, allowing it to be done through a single small incision, decreasing pain and decreasing the risk of long-term stiffness and loss of extension. In addition, the use of hamstring tendons avoided the defect in the tibial tubercle, thus increasing the ability to kneel following surgery.

Double bundle reconstruction

In more recent years, the normal ACL has been described as a two bundle construct, at least from a functional point of view. With that in mind, following the lead of the Japanese, many centres have tried to reconstruct it as a two bundle construct by taking each of the two individual hamstrings (gracilis and semi-tendonosis) through separate tunnels on both the femoral and tibial sides. This is in deference to standard practice, which is to use both hamstrings as a single graft, passing them through a single tunnel in the tibia and into a single tunnel in the femur. Whilst this double bundle approach looks good in the laboratory, it has proven less successful in reality. In practice, the failure rate has been quite high, usually due to the failure of the smaller gracilis tendon which tends to be used as the postero-lateral bundle. This is the bundle that prevents excessive rotation and is therefore very important in twisting and turning sports. In some studies where the knee has been re-arthroscoped, the failure of this bundle is over 50%. Whilst this does not always lead to an unstable knee initially, it can lead to a weaker construct which may fail in time. It also means that any biomechanical benefit that may have been gleaned from a double bundle construct, has been removed. In addition, after the rupture of one tendon, the volume of graft is less than it would have been with a standard single bundle construct.

To some extent the jury is still out on this technique but, the number of surgeons still performing a double bundle reconstruction has dwindled over recent years. Even it’s most avid supporters are now saying that only 20% of people have large enough knees to be able to accommodate four tunnels, thereby significantly limiting the number of people who may be suitable for this.

Despite the above, there has been no shortage of people trying to get double bundle techniques to work. Centres have tried using hamstring tendons from both legs, allograft tendons, split quadriceps tendons, tendon augmentation with prosthetic devices etcetera. Unfortunately, none of these methods have reproduced the success, with the high return to sport and low re-injury rates, that a single graft reconstruction has. Hence, despite some theoretical advantages, these have not been born out in practice.

Single bundle reconstruction for partial ACL rupture

Whilst double bundle ACL reconstruction may not be the most reliable reconstruction that we can do, the theory behind it has taught us a lot about how the ACL works. As part of this process we now have a good idea about which part of the ACL controls rotation (postero-lateral bundle), and which controls anterior translation (antero-medial bundle). As a consequence
of this, we are now much better at diagnosing partial ruptures of the ACL and determining which functional component is damaged. The corollary of this is that, in a partial ACL rupture, we can now reconstruct just the damaged portion of the ACL using a single hamstring tendon. In this situation, because part of the old ACL remains intact, it acts as a splint for the new portion. In addition, the new bundle often passes through part of the remaining bundle, and hence gets its new blood supply back more rapidly and heals more rapidly.

These partial ACL reconstructions are, without doubt, the best reconstruction that we do. They are sometimes a little bit stiff for a while but, eventually, they seem to replicate normal mechanics better than any other type of graft. This means that, where previously we may have treated a partial tear conservatively and waited to see how it got on over time, we are now more encouraged to reconstruct them in the hope of restoring near normal anatomy and function.

**Hamstring tendon grafts** are the standard choice for the majority of Orthopaedic Surgeons worldwide. This is for all the reasons described above plus, with increasing experience, it allows treatment of the partial rupture. For the vast majority of surgeons, a single bundle graft using two tendons (gracilis and semi-tendonosis), doubled up to make four strands, is the graft of choice. Whilst hamstring weakness is a theoretical concern, genuine weakness at a year is uncommon, rarely representing more than 5% of total hamstring strength. For those who play hamstring dominant sports at a high level however, an alternate graft may be considered.

**Patella tendon grafts** remain a good choice in some individuals. They require two skin incisions, they are more painful than a hamstring reconstruction, and they may permanently prevent kneeling because of the residual defect in the tibia. On the plus side however, the fixation is a little more solid, and less protection of the graft is needed. As a patella tendon graft is stiffer (less stretchy) than a hamstring graft however, it is less forgiving, which makes loss of extension a bit more likely. This means that more therapy and more vigilance is required to ensure that the knee goes straight and that full function returns.

The reason to consider the use of a patella tendon graft is that the failure rate after return to sport is slightly lower than it is for a hamstring tendon graft. Over a large population base however, it is harder to get the same result as a hamstring tendon graft because of the somewhat higher complication rate. Thus, whilst it may be the graft of choice for a high level, male, contact sportsman with ready access to physiotherapy, it is probably not the graft of choice for the majority. Also, it is not suitable for isolated bundle reconstruction in partial ACL rupture.

**Artificial ligaments** have been around for over 30 years. The first one that came to the market place was the Kennedy LAD (ligament augmentation device), which was a Dacron braid, designed to be placed alongside a standard graft, to act as a splint for that graft. The theory was that this would allow early activity by holding the knee together, protecting the graft whilst it was healing. It was an augmentation device, and was never designed to be a ligament in its own right. Even when used as an augment however, the outcome was no different from using just the biologic graft tissue alone.
Hence, it went out of favour.

Since then, the dream of getting people back to sport and function early, has seen the introduction of multiple other devices. These have included both whole ligaments and augmentation devices, manufactured from a variety of materials including, Dacron, PTFE, carbon fibre and polyethylene terephthalate (PET). An example of the latter is the LARS device, where LARS stands for Ligament Augmentation Reconstruction System.

To date, none of these artificial ligaments have passed the test of time. None have been shown to consistently allow an earlier return to sport, and none have shown any difference in the long-term outlook. Like anything artificial, if it is bent or stressed often enough, it will fail. Hence, whilst there are some individual cases where the LARS ligament seems to have allowed an early return sport, the overall picture is clouded by a high number of failures and a return to sport time that is statistically similar to a biologic graft. For this reason, and with a long-term outlook in mind, a biologic grafts seems to be a better procedure in most situations, and one which now has over 25 years of follow-up.

Whilst no good guidelines are available for the use of artificial constructs, the use of an augmentation device (being a strip of artificial ligament that is about half the size of a full ligament) may still have a place. That place may well be in the older patient, who has to return to work early, and may have to return to a job such as scaffolding, where any failure of the reconstruction could have serious consequences. In the older patient, the graft gets its new blood supply much more slowly, and hence, it takes much longer to strengthen than in the young. This is probably the reason for the increased failure of biologic grafts with increasing age. In this group therefore, it may be appropriate to use an augmentation device as an internal splint, to protect a biologic graft whilst is recovering. This would seemingly provide some strength to the construct, allowing an earlier return to work, with a higher chance of success of the biologic graft in the longer term. In that longer term, one would then expect that the augmentation device would fail, but that the biologic graft would heal and survive. Whilst this may well prove to be the case, it is as yet unproven. This means that, whilst it may seem like a good idea in theory, it may not be vindicated by time.

**Revision ACL reconstruction**

Just as there are many ways of primarily reconstructing this ligament, there are many ways of revising it. In general terms, I believe that the ligament construct should be changed and, where possible, the second ligament harvest should be from the same limb. The latter consideration is both cosmetic and functional, keeping both the scars, and any loss of function associated with graft harvest, in one leg. My view therefore, is that if there has been a primary patella tendon reconstruction, then a hamstring tendon should be used to revise it, and vice versa. I believe this because often, the cause of failure of the graft is unknown, and hence, it seems to makes sense to put in a different construct, rather than to simply redo the first procedure by putting in the same construct, albeit harvested from the other knee.

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**Other options for revision**

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**The Losee Procedure 1 - Left Knee**

A strip of fascia lata is used - middle third or half

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<th>Procedure 2 - Left Knee</th>
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<td>Lateral gastrocnemius tendon</td>
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**The Losee Procedure 2 - Left Knee**

The fascia lata strip is used to stop the femoral condyle dislocating off the posterior tibia
Where multiple grafts have been used, either for one knee or for both, alternatives include the use of quadriceps tendon, fascia lata, allograft tendon, synthetic ligament or combinations of the above. Another alternative, where reasonable tissue is still available, is to perform an extra-articular tenodesis. This is where tendon, commonly fascia lata from the side of the leg, is used to tighten up the outside of the knee, and thereby prevent rotatory instability. Before true (intra-articular) ACL reconstruction was performed, such extra-articular procedures were the mainstay of reconstructive surgery for the ACL deficient, unstable knee. They are not used as a primary reconstruction any more but, almost certainly, they have benefit as an augmentation in the revision situation, particularly when it is a second or higher order revision. This type of combination surgery, which was commonplace in the mid to late 1980’s, is now starting to win back favour amongst experienced ACL surgeons, particularly those who deal with failed ACL surgery requiring revision.

**Prevention of ACL Injury**

The PEP program (Prevent Injury and Enhance Performance) published by the NCAA, and implemented by the University of Rochester Medical Centre after review of ACL Injury in female athletes.

YouTube link:

[http://www.youtube.com/watch?v=t_yz7yWLo5o](http://www.youtube.com/watch?v=t_yz7yWLo5o)

**Questions and concerns**

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Further information can also be obtained on this and other related topics, such as:
Knee arthritis
Osteotomy
Knee replacement