Management of anterior cruciate ligament injury: pathophysiology and treatment

Anterior cruciate ligament injury, a common soft tissue injury of the knee joint, is increasing in incidence particularly in young active people. It causes instability of the knee that leads to meniscal tears, cartilage defects and early osteoarthritis. This review summarizes aspects of anterior cruciate ligament injury management.

The knee is the largest joint of the human body and consists of two articulations: a tibiofemoral and a patellofemoral joint (Snell, 2007; Chivers and Howitt, 2009). The former is a double condyloid joint that allows transmission of body weight from the femur to the tibia. The latter is a gliding joint which represents the extensor mechanism (Chivers and Howitt, 2009; Flandry and Hommel, 2011).

The stability of this complex articulation depends on soft tissue structures including the anterior and posterior cruciate ligaments, the medial and lateral collateral ligaments, the medial and lateral menisci as well as the bony configuration and dynamic muscle action (Chivers and Howitt, 2009; Flandry and Hommel, 2011).

Ligamentous knee injuries are common especially in active young adults as a result of the high levels of sporting activities (Arbuthnot and Brink, 2010). Such injuries often lead to joint instability, damage to other ligaments, articulating cartilage and menisci, and development of early osteoarthritis (Khan et al, 2011). Treatment may include an operative or non-operative approach.

This is the first of two articles reviewing different aspects on the management of anterior cruciate ligament injuries. The first article summarizes current best knowledge about the pathophysiology, mechanisms and available treatment strategies for these injuries, and the second article discusses the various aspects and the technical steps of the surgical reconstruction of the anterior cruciate ligament.

Mr Sulaiman Alazzawi is Specialty Registrar in the Trauma and Orthopaedic Department, Royal London Hospital, London E1 1BB

Mr Mohamed Sukeik is Specialty Registrar in the Trauma and Orthopaedic Department, Princess Alexandra Hospital, Harlow, Essex

Mr Mazin Ibrahim is Specialty Registrar in the Trauma and Orthopaedic Department, University College Hospital, London

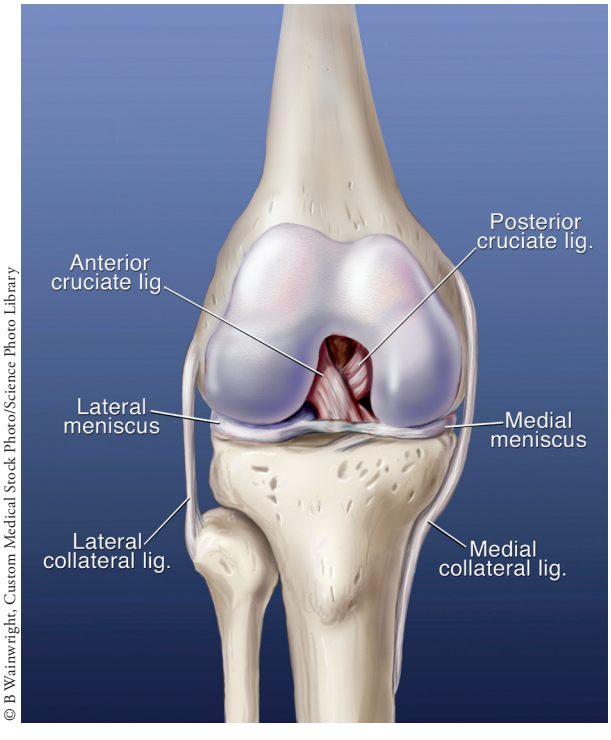
Professor Fares S Haddad is Consultant Orthopaedic Surgeon, Divisional Clinical Director of Surgical Specialties and Director of the Institute of Sport, Exercise & Health, University College Hospital, London

Correspondence to: Mr S Alazzawi (salazzawi2@gmail.com)

Anatomy and biomechanics

The anterior cruciate ligament is an intra-articular ligament with an average length of 30 mm and width of 10 mm (Andersson et al, 2009). It originates from the posterolateral aspect of the intercondylar notch and emerges anteriorly to insert onto the intercondylar eminence (Flandry and Hommel, 2011) (*Figure 1*). It consists of an anteromedial and a posterolateral bundle. There is also a suggestion that there may be a third indeterminate bundle (Duthon et al, 2006; Flandry and Hommel, 2011). The anteromedial bundle tightens in flexion whereas the posterolateral bundle tightens in extension (Chhabra et al, 2006). The blood supply to the anterior cruciate ligament originates from the medial and lateral inferior geniculate and the middle geniculate arteries (Flandry and Hommel, 2011). The ligament receives its nerve supply from the posterior articular branches of the tibial nerve (Duthon et al, 2006).

Figure 1. The right knee joint, with the patella removed, showing the bones, ligaments and menisci.



The main function of the anterior cruciate ligament is to provide stability by resisting hyperextension, anterior tibial translation and rotational loads (Duthon et al, 2006; Flandry and Hommel, 2011). This function is less important during normal daily activities than during athletics or high physical demands. Hence, the patient's age and level of activities play an important role in deciding appropriate treatment after anterior cruciate ligament injuries (Kaar et al, 2011).

Mechanism of injury

Anterior cruciate ligament injury is usually the result of a non-contact injury whereby a combination of movements such as femoral adduction and internal rotation, knee flexion, or tibial rotation with the foot and ankle in valgus result in partial or complete anterior cruciate ligament tears (Brophy et al, 2010). A video analysis study also showed an increased risk of injuring the anterior cruciate ligament when the foot is fixed in the ground, the knee is abducted and the hip is flexed (Boden et al, 2009; Kaar et al, 2011). There is a high risk of injury during deceleration of the lower limb, with the quadriceps maximally contracted and the knee at extension (Shimokochi and Shultz, 2008). While anterior cruciate ligament rupture occurs predominantly as a result of a non-contact injury, incidents during contact sport like football can also result in anterior cruciate ligament injury (Walden et al, 2011).

Risk factors

These can be divided into intrinsic and extrinsic factors. Intrinsic factors include female gender, being a professional athlete (Laxdal et al, 2007), variability in neuromuscular activation, anatomical variation of a smaller intercondylar notch or a steeper posterior tibial slope (Khan et al, 2011), other associated lower limb injuries and hormonal influences such as the increased risk of anterior cruciate ligament injury seen during the pre-ovulatory phase of the menstrual cycle (Hewett et al, 2007; Brophy et al, 2010). Extrinsic factors include the type of footwear and its interaction with the ground and the weather conditions, with low rainfall and high evaporation carrying a higher risk for anterior cruciate ligament injuries (Brophy et al, 2010). The anterior cruciate ligament is also at risk in sports like football, skiing and basketball (Moksnes and Risberg, 2009). Several studies have shown that using training to prevent anterior cruciate ligament injury in various sports has a significant role in reducing the number of such injuries (Ettlinger et al, 1995; Caraffa et al, 1996; Hewett et al, 1999; Brophy et al, 2010).

Diagnosis

Many patients with acute anterior cruciate ligament injury describe feeling a 'pop' within the knee joint. Rapid onset of swelling and pain follows this and lasts for a few days (Cimino et al, 2010). Joint effusion and reduced range of movement are evident on examination of the injured knee. Further assessment during the acute phase can be limited by the pain and swelling. As the swelling settles down, patients experience joint instability and may report the knee giving way (Cimino et al, 2010).

Clinical tests commonly used to assess anterior cruciate ligament function and integrity include the anterior drawer, the pivot shift and the Lachman tests. The Lachman test is the most accurate with sensitivity of 85% and specificity of 94%. The pivot shift test has good specificity of 98% but poor sensitivity of only 24%. The anterior drawer test shows good sensitivity and specificity (92% and 91% respectively) in chronic cases, but not in the acute phase (Benjaminse et al, 2006). Magnetic resonance imaging is usually the preferred radiological investigation to confirm the diagnosis. Besides the avoidance of radiation, it has the benefit of identifying additional meniscal, chondral, bony and collateral ligament injuries (Cimino et al, 2010). Early prompt diagnosis of anterior cruciate ligament injury is associated with fewer secondary meniscal or chondral injuries, reduced recovery time and is also more cost effective (Ball and Haddad, 2010).

Treatment of anterior cruciate ligament rupture

The treatment of anterior cruciate ligament ruptures is either non-operative including physiotherapy, supportive bracing and physical activity modification, or operative whereby the ligament is repaired or reconstructed. Advantages of surgical treatment include restoring joint stability and minimizing the risk of subluxation, which prevents further injuries to the menisci and articulating cartilage and delays early onset osteoarthritis (Moksnes and Risberg, 2009). Surgical treatment is the preferred choice for athletes, young active patients with high physical demands, patients with multiple knee ligament injuries and those who remain symptomatic after a trial of non-operative treatment (Kaar et al, 2011). Patients who are less involved in sporty activities and especially middle-aged or elderly patients may benefit from the non-operative approach (Kaar et al, 2011). Patients' age, the level of sports activity, history of menisectomy, obesity and osteoarthritis of the contralateral knee increased the risk of early onset osteoarthritis after anterior cruciate ligament rupture that was managed non-operatively (Segawa et al, 2001).

Patients who had a symptomatic meniscal tear associated with a torn anterior cruciate ligament achieved significant success rates of meniscal repair when the anterior cruciate ligament was reconstructed during the same operation (Konan and Haddad, 2010). A meta-analysis included 615 patients, with a minimum of 10 years follow up, and showed that those who received non-operative treatment for their anterior cruciate ligament injury had significantly higher relative risk (relative risk = 4.98; $P<0.00001$) of developing any grade of osteoarthritis than those treated with reconstructive surgery (relative risk = 3.62; $P<0.00001$) (Ajuied et al, 2014).

Role of platelet concentrates on anterior cruciate ligament healing

Platelet concentrates contain several growth factors that help in fracture healing, treatment of tendinopathies and tendon repair. Out of six randomized controlled trials studying the use of platelet concentrates in anterior cruciate ligament surgery (Ventura et al, 2005; Orrego et al, 2008; Nin et al, 2009; Figueroa et al, 2010; Silva et al, 2010; Vogrin et al, 2010a), hamstring tendons were used in five studies and bone–patellar tendon graft was used in one study. Four trials reported clinical and functional outcomes but only Vogrin et al (2010a) found that the platelet concentrates group had better anteroposterior knee stability at 6 months follow up (P=0.011). Radiologically, there has been some evidence that platelet concentrates may augment healing in anterior cruciate ligament reconstructions from three of the studies included (Ventura et al, 2005; Orrego et al, 2008; Vogrin et al, 2010b) but this effect was not associated with an earlier return of function or improvement in pain scores.

Return to sport activities

A meta-analysis of 5770 athletes who underwent anterior cruciate ligament reconstruction showed that 82% of patients returned partially to sport participation, 63% returned to their pre-injury level and 44% returned to competitive sport at final follow-up. Eighty-five per cent of participants achieved normal or nearly normal knee function when using activity-based outcomes (Ardern et al, 2011). The relatively low rate of return to competitive sport despite the high rates of successful outcome in terms of knee function was thought to be a result of other factors like fear of re-injury (Ardern et al, 2011).

Anterior cruciate ligament injury in children and adolescents

The mechanism of anterior cruciate ligament injury in children and adolescents is similar to that in adults. However, treatment of this injury in skeletally immature patients requires special considerations such as the type of injury, physiological age, skeletal maturity, the patient's choice of treatment and compliance (Utukuri et al, 2006; Schachter and Rokito, 2007).

Non-operative treatment can be useful for a patient who sustained a partial anterior cruciate ligament tear with no or minimal knee instability or one with undisplaced or minimally displaced avulsion injuries (Schub and Saluan, 2011). It can also be used as an initial treatment strategy until the patient reaches skeletal maturity, when anterior cruciate ligament reconstruction can be performed in a similar approach to an adult (Schachter and Rokito, 2007). This depends on the child using a brace and 'looking after' the knee. Otherwise, non-operative treatment gives less desirable outcomes than the surgical approach (Schachter and Rokito, 2007; Schub and Saluan, 2011). Those who were treated non-operatively were at a higher risk of developing meniscal and chondral injuries, early degenerative changes and persistent knee instability (Schachter and Rokito, 2007; Schub and Saluan, 2011).

Surgical treatment includes primary repair in cases of anterior cruciate ligament avulsion or fracture of the tibial intercondylar eminence. Proximal anterior cruciate ligament avulsion can be performed surgically using a suspension device like the TightRope fixation device (Arthrex, Naples, Florida, US) (Wardle and Haddad, 2012). Otherwise, the preferred surgical option would be an anterior cruciate ligament reconstruction using a hamstring graft as this is associated with less risk of leg length discrepancies and axis deviations (Frosch et al, 2010; Schub and Saluan, 2011). The main problem with surgical reconstruction is the anatomical position of the bony tunnels, which have to be performed through the distal femoral and proximal tibial physes and may disturb the growth plate and subsequently cause longitudinal or angular growth disturbances (Schachter and Rokito, 2007; Schub and Saluan, 2011). However, such risk has been reported to be less than 2% (Frosch et al, 2010). Different approaches to minimize growth plate damage include physeal sparing, transepiphyseal, partial transphyseal and transphyseal techniques (Schub and Saluan, 2011).

Future and new development in anterior cruciate ligament reconstruction

Over the last few years, findings from an increased number of laboratory, biomechanical and clinical studies have helped to improve the management of anterior cruciate ligament injuries. However, some areas are still developing with the potential of introducing new concepts. For example, the role of biological factors in the augmentation of anterior cruciate ligament graft healing is not completely established. Moreover, understanding of the role of genetics might influence the management of anterior cruciate ligament injuries. The development of the double bundle anatomical technique has yet to be clarified into a better role with specific indications (Lubowitz, 2010). Advances in tissue engineering may reduce the need for anterior cruciate ligament autografts (Lubowitz, 2010).

Conclusions

Ligament reconstruction is the gold standard for surgical treatment of anterior cruciate ligament injuries. However, there remains plenty of controversy surrounding its techniques (Haddad, 2014). Surgical management is useful for those who are symptomatic and for young adults with high physical demands. The role of biological factors is yet to be confirmed. Although most patients achieve excellent postoperative functional outcomes, not all are able to return to competitive sports post surgery. **BJHM**

Conflict of interest: none.

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KEY POINTS

- Anterior cruciate ligament injury is usually the result of a non-contact injury.
- Patients with anterior cruciate ligament injury usually described feeling a 'pop' within the knee joint, experienced rapid onset of swelling and pain.
- Commonly used clinical tests to assess anterior cruciate ligament are the anterior drawer, the pivot shift and the Lachman tests.
- Magnetic resonance imaging is the preferred radiological investigation to confirm the diagnosis.
- Surgical treatment is the preferred choice for athletes, young active patients, patients with multiple knee ligament injuries and those who remain symptomatic after a trial of non-operative treatment.

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