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EC MICROBIOLOGY
Review Article

Overview of Anterior Cruciate Ligament Injury: A Literature Review

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Received: November 01, 2018; **Published:** December 27, 2019

Abstract

Anterior Cruciate Ligament (ACL) injuries are one of the most prevalent injuries in sport. ACL tears would result in a significant functional difficulties, severe pain and joint effusion. Based on a type of contact mechanisms, ACL injuries can be divided into three types: Type I: Direct contact, type II: Indirect, and type III: Noncontact. The management of ACL injury should start with a clinical evaluation by orthopedic specialist to confirm the ACL rupture. The most reliable clinical test is Lachman's, while a radiological assessment with magnetic resonance imaging (MRI) can also be used. Several factors should be considered prior to deciding a surgical intervention; including age, amount of instability, activity status of the patient. There is no obvious difference between immediate and delayed surgical treatment in terms of recovery outcomes following rehabilitation. ACLR surgery can be done by using either bone–patellar tendon–bone (BPTB) autograft, hamstring autograft, quadriceps autograft or allograft (graft from a donor) tissue. Although, surgical treatment has shown good outcomes, surgical revision may be required in many cases.

Keywords: *Cruciate Ligament Injury*

Introduction

The knee is one of the most frequently injured joint in college athletics sport injury. According to 16 years of 15 NCAA sports' epidemiology data, approximately 54% of all injuries are lower extremity, which is the highest compared to other body parts [1]. Although the rate was not stated, the author stated that the lower extremity injuries were "mostly consists of knee and ankle joints" [1]. The high prevalence of knee injuries may stem from structures that stabilize the joint alignment. Therefore, structures of the knee joint anatomy need to be discussed, especially static and dynamic structures that enhance stabilizing knee joint.

An anterior cruciate ligament (ACL) plays an integral role in knee joint stability. Once an individual tears an ACL, the individual immediately experiences various functional difficulties as well as severe pain and joint effusion. In athletic setting, because of the functional difficulties, most ACL injured athletes were forced to limit their physical activities and restrict their athletic participation, and rate of the time loss is the longest compared to ankle and traumatic head injuries [1].

ACL tear of the knee is one of the most common sports injuries [2]. It often leads to instability of the knee especially during exercise or heavy work, and in such cases usually requires surgical treatment [2]. The treatment of choice is reconstruction using most commonly either a bone-patellar tendon-bone autograft or a quadrupled semitendinosus and gracilize (hamstrings) tendon autograft. The purpose of ACL reconstruction is to restore normal stability and to protect the knee from further injury [3,4]. It has been reported that approximately 350,000 ACL reconstruction surgeries are performed in the US [5]. After ACL reconstruction surgery and rehabilitation, the newly grafted ACL provides stability on knee joint, and most people are able to return to their desired physical activities [6,7]. Adequate knee stability is a key for returning to a physically active lifestyle because it allows the knee joint to have more dynamic control without episodes of giving out. The aim of this study is to provide an overview of the ACL anatomy, injury incidence, mechanism, and management.

Methods

We performed an extensive literature search of the Medline, Cochrane, and EMBASE databases on 1 October 2019 using the medical subject headings (MeSH) terms "Anterior Cruciate Ligament" AND "Anterior Cruciate Ligament Injuries" AND "Anterior Cruciate Ligament Reconstruction". Papers discussing ACL, its injuries and re-construction were screened for relevant information. There were no limits on date, language, age of participants or publication type.

Anatomy of the ACL

The ACL is a band of dense connective tissue, which courses from the femur to the tibia. Micro-anatomically and histologically it is one structure [8,9]. The ACL runs from the posteromedial aspect of the intercondylar notch on the lateral femoral condyle anteriorly, medially, and distally attachment the tibial eminence [10]. The cross-sectional shape of the ACL is not circular, elliptical or any other simple geometrical form. This shape changes with the angle of flexion, but is generally larger in the anterior-posterior direction. The narrowest part of the ACL is at mid substance level (35 mm2) [10].

Functionally, Girgis., *et al*. (1975) divided the ACL into two parts, the anteromedial (AM) bundle and the posterolateral (PL) bundle named for the orientation of their tibial insertions. This anatomy is already well seen in a fetus [11]. Amis and Dawkins measured changes in fiber length during knee flexion/extension and found that the fiber bundles are not isometric [12]. The PL bundle is tight in extension and loosens in flexion after its femoral origin moves anteriorly, whereas the AM is tight in flexion and becomes lax as its femoral insertion moves posteriorly during extension [12].

However, the anteromedial bundle is the part of an intact ACL with the least length change during passive extension-flexion of the knee [13]. Furman., *et al*. showed that transection of the anteromedial bundle caused a positive anterior drawer sign and a negative Lachman sign, while the converse was true for the posterolateral bundle [14]. This suggests that partial ruptures can affect different bundles, depending on the posture at the time of injury.

ACL role in mechanical stability

The ACL predominantly provides the knee joint stability for restricting anterior tibial displacement. Although the AMB and PMB are slightly movable with knee motions (flexion, extension, and rotation), inside of lateral condyle where the AMB and PMB originate has an isometric area [12,15]. From the isometric area in lateral condyle to the anterior intercondylar area where the ACL inserts distally, the ACL provides mechanical stability. Maximum tolerable stress created by a metal machine called tensile load for the ACL is reported as 2160 ± 157 Newton [16].

The distal femur has a convex appearance, and the proximal tibia has a concave shape. Because of the convex and concave articulation between the distal femur and proximal tibia, rolling, gliding, and spinning motions occur in dynamic knee motions. ACL is theorized to provide mechanical stability anterior and posterior rolling and gliding motions in conjunction with posterior cruciate ligament (PCL). In addition to the anterior and posterior stability, the ACL and PCL are believed to supply side by side (valgus and varus) stability with rotation [17,18].

Incidence of ACL injury

Summary of the reported incidence in literature is summarized in table 1. Accompanying injuries include other ligament sprains, meniscal tears, articular cartilage injuries, bone bruises, and sometimes intra-articular fractures [4]. The incidence of ACL tears depends on the type of sport, and more injuries occur during a game than in training. These sports with a high-risk to sustain an ACL injury include sports, which require the athlete to make sudden decelerations, accelerations, and other unanticipated running and cutting maneuvers [19].

Study	Country	Summary of results
Sanders., *et al*. [29]	USA	The incidence of ACL injuries to be 68.6/100,000 person-years. The incidence was significantly higher in males compared to females (81.7 vs 55.3/100,000 person-years), with the peak in incidence (241/100,000 person-years) between 19 and 25 years in males compared to a peak in incidence (227.6/100,000 person-years) between 14 and 18 years in females
Herzog., *et al*. [30]	USA	There were 385,384,623 person-years and 283,810 ACL reconstructions from 2002 to 2014 with an overall increase of 22% in ACL reconstruction rates
Daniel., *et al*. [31]	Finland	The annual incidence of isolated ACL injury has been reported to be 30/ 100,000 persons and that of a combined ACL injury 98/100 000 persons at physically active populations
Gianott., *et al*. [32]	New Zealand	The reported incidence rate was 1147.1/100,000 persons for non-surgical injuries and 36.9/100,000 for ACL surgeries. Noteworthy, males had a higher incidence than females, in both types of injuries.
Gans., *et al*. [33]	USA	According to the American Injury Surveillance Program, there were 1105 ACL injuries (from 2004 to 2014), 126 of them were recurrent. The highest rates of ACL injuries were with male soccer players, followed by female gymnasts and female soccer players
Olsen., *et al*. [34]	Norway	The incidence of ACL injury in handball among men was 0.24 per 1000 game hours, and among women 0.77 per 1000 game hours
Pasanen., *et al*. [35]	Finland	Among females, the incidence rate of ACL injuries in soccer was 0.6 per 1000 game hours, and in floatball 3.6 per 1000 game hours
Gwinn., *et al*. [36]	USA	The ACL injury rates per 1000 athlete-exposures (one athlete-exposure is defined as one athlete participating in one practice or game where he or she is exposed to the possibility of an athletic injury). In soccer, the incidence of ACL injury was 0.8 per 1000 athlete-exposures among women and 0.1 per 1000 athlete-exposures among men intercollegiate athletes. In basketball, the injury rates were 0.5 among women and 0.1 among men, respectively
Rekik., *et al*. [37]	Qatar	The overall ACL injury rate in male players was 0.076 injuries/1000 hours of exposure

Table 1: Incidence of ACL injury.

ACL injury pathomechanics classifications and distributions

ACL injuries can be classified into three different schemes based on a type of contact mechanisms: Type I: Direct contact (external force was directly applied to injured knee and was probably the proximate cause of injury), type II: Indirect contact (external force was applied to athlete but not directly to the injured knee. The force was involved in the injury process but was probably not the proximate cause), and type III: Noncontact (forces applied to the knee at the time of injury resulted from the athlete's own movements and did not involve contact with another athlete or object) [20]. Sherman., *et al.* have classified patients into four types according to type of ACL tear and tissue injury as shown in figure 1 [21,22].

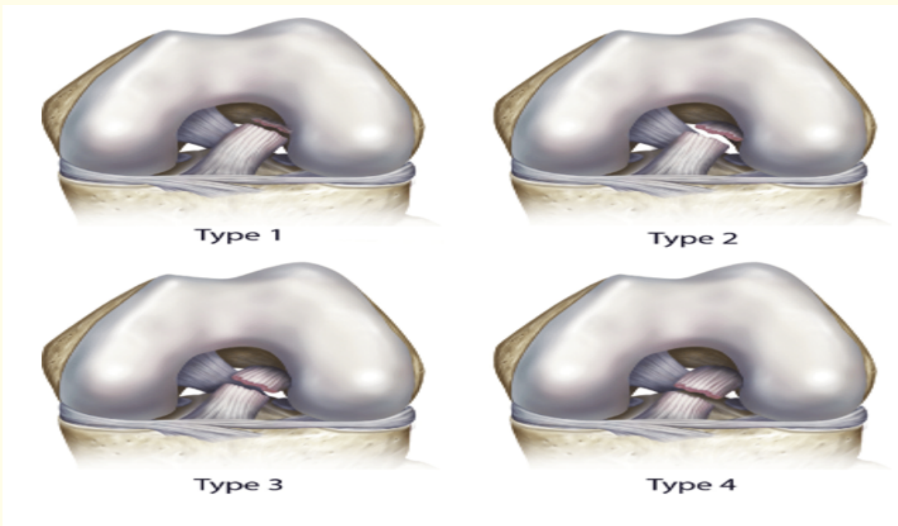

Figure 1: *Type 1 tears were true soft-tissue avulsions with minimal ligament tissue left on the femur. Type 2 tears had up to 20% of the tissue left on the femur. Type 3 tears had up to 33% of the ligament tissue left on the femur. Type 4 tears were true midsubstance tears with up to 50% of the ligament tissue left on the femur [21,22].*

Previously published studies that investigated the path mechanics of ACL injuries tried following the above classification schemes [23-27]. However, they did not differentiate the direct and indirect contact ACL injuries [23-27]. They simply combined the two mechanisms (direct and indirect mechanisms) and expressed it as a contact ACL injury [23-26,28].

The available data confirmed that approximately 60 - 70% of all the ACL injury is noncontact in nature [23-27]. The NCAA female soccer and basketball athletes demonstrated 2.7 higher overall ACL injury incidents compared to male athletes who participate in the same sports [27]. Additionally, epidemiological data indicated that the prevalence of noncontact ACL injury mechanisms in female athletes is approximately 10 - 20% higher than their male counterparts [26,27]. From the evidence, it can be interpreted that young female athletes are the most susceptible to non-contact ACL injuries. Since approximately 60 - 70% of all ACL injuries are non-contact in nature, it is estimated that rest of the ACL injury mechanisms (30 - 40%) involves a contact mechanism including either direct or indirect contact. All referenced studies did not differentiate between direct and indirect contact mechanisms and actually combined them as a contact mechanism [23-28]. Thus, it is difficult to estimate a distribution of the direct and indirect mechanisms within the contact mechanism of ACL injuries.

Management of ACL injury

A suspected ACL injury will usually be treated in the emergency room by a general practitioner or sports medical professional [2]. The RICE (Rest, Ice, Compression and Elevation) principle should be applied as soon as possible and non-steroidal anti-inflammatory drugs are usually prescribed to alleviate symptoms [38]. The patient typically cannot walk and is instructed to use crutches and to contact an orthopedic specialist [38]. Non-weight bearing is encouraged to avoid any additional damage to the knee joint and its structures [2,38].

Initial evaluation

The orthopedic specialist will do a clinical evaluation (e.g., Lachman's test, Anterior Drawer test, Pivot Shift test) to determine a positive ACL rupture. The Lachman's test is regarded as the most sensitive and reliable test [39]. Magnetic Resonance Imaging (MRI) can also be used for assessment, especially when it is suspected that other structures such as the menisci and other ligaments are also injured. According to Bach and Boones, three treatment strategies exist; non-surgical treatments, arthroscopic surgery and anterior cruciate ligament re-construction (ACLR) surgery [39]. Surgical reconstruction is still deemed the gold standard for treating an ACL rupture and is recommended by 98% of surgeons for patients that wish to return to their pre-injury level of sport participation [40]. Subsequently, the ACL is the most reconstructed ligament in the body [41].

Operative versus non-operative management

A decision for or against surgery is based on several factors including age, amount of instability, activity status of the patient [38]. Whether specialists decide to operate immediately or delay surgery seems to have no impact on the recovery outcomes following rehabilitation [42]. According to Sanders., *et al.* a third of ACL injured patients choose to delay ACLR surgery for one to 10 years post-injury [29]. It is unclear why so many patients decide to delay surgery, but possible reasons include recurrent injury, chronic instability and the limitation of activities.

General indications for surgery include being a young active individual participating in sports that involve pivoting, cutting and jumping for more than five hours per week, a maximum arthrometer measurement difference greater than 5mm or experiencing three or more episodes of instability within a one year period [39]. Marx., *et al.* reported that patients who desire to return-to-sport tend to influence the orthopedic surgeon's decision to operate or not [43]. ACLR involves replacing the ACL with a tendon from another part of the patient's body to restore knee stability and facilitate recovery. A proper reconstruction will ideally mimic the ACL's original anatomy allowing the knee to regain its previous level of functioning [44].

According to Meuffels., *et al*. [45], the worldwide ACL reconstruction rate is more than 200,000 per year, whereas Mall., *et al.* [46] estimate that between 100,000 and 150,000 ACL injured athletes undergo reconstruction surgery in the United States annually. According to Tan., *et al.* the rate of ACLR has increased 1.5 fold over the past 12 years [47]. ACLR surgery can be done by using either bone–patellar tendon-bone (BPTB) autograft, hamstring autograft, quadriceps autograft or allograft (graft from a donor) tissue [39,44,48]. Autograft is safe with fast healing at the graft implant site but involves a secondary surgical site that also needs to heal. Allograft involves fast recovery with a short hospital stay [49]. ACLR surgery is not without risk and although researchers report a 5-year graft survival of 95%, revision surgery is sometimes necessary [50].

Conclusion

The incidence of ACL injury is much higher among athletes and in males compared to females. Sports that require the athlete to make sudden decelerations, accelerations, and other unanticipated running and cutting maneuvers; are the highest risk for ACL injuries. ACL reconstruction is still the gold standard treatment to retain the highest possible pre-injury level of movement.

Funding

None.

Conflicts of Interest

No conflicts related to this work.

Acknowledgments

None.

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Volume 16 Issue 1 January 2020