

Anterior cruciate ligament injury: from biomechanism to complications of reconstruction – an overview

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Abstract

The aim of this study was to review the literature in order to present indications for anterior cruciate ligament (ACL) reconstruction surgery, the techniques of its performance, and potential complications. Indications for performing ACL reconstruction (ACLR) include knee instability and episodes of giving way, accompanying meniscal injuries, multi-ligament knee injuries, and the desire to return to a high level of physical activity, even among patients over 40 years of age. There are two main types of grafts: autografts and allografts. In the autograft group, the transplant material is most commonly taken from the hamstring tendons, quadriceps tendon, and patellar tendon. For a better understanding of the surgical procedure, this study includes photos from the ACLR surgery using hamstring tendons. The most common complication after ACLR is graft damage resulting from another knee injury. Among additional complications following ACLR, notable issues include arthrofibrosis, graft displacements, septic arthritis, and saphenous nerve injury.

Introduction

The knee joint is the largest joint in the human body [1]. From an anatomical point of view, this hinge joint forms a functional connection between the femur and the tibia, therefore, the anatomical axis, the mechanical axis and the load axis of the knee joint are closely related to the biomechanics of the entire lower limb [2]. Due to its size and function, the knee joint is a complex anatomical structure, built and operating based on the principles of tensegrity [3].

The knee joint contains the anterior cruciate ligament (ACL), which is one of the two cruciate ligaments responsible for stabilizing the knee [1]. In addition, it provides rotational stability of the knee joint with spotty and cantilever load [4]. Injuries to the anterior cruciate ligament such as a sprain, rupture or complete ACL rupture occur with a high frequency, making it the most vulnerable ligament in the knee [5]. Athletes are a group of people who are particularly affected by injuries associated with anterior cruciate ligament injury [4]. They occur as a result of both contact and non-contact mechanisms.

This paper is devoted to the analysis of methods of anterior cruciate ligament reconstruction. From

widely available scientific sources and research results, it can be concluded that there are many proven ways of reconstructing the anterior cruciate ligament [6]. That is why the presence and function of ligament and tendon elements in the knee joint are so important, as well as cartilage-fibrous structures in the form of meniscus: lateral and medial [7].

Biomechanics, anatomy and injury mechanism of anterior cruciate ligament

The most important ligament ensuring stabilization of the knee joint during anterior-posterior movements is the anterior cruciate ligament located inside the joint [2]. Its role is to limit excessive movement of the tibia relative to the femur, allowing the knee joint to function properly and ensuring its stability [8, 9]. The ACL begins on the inner surface of the lateral condyle of the femur and ends in the anterior intercondylar area of the tibia [6]. The ACL is a structure that, due to its function, is relatively often damaged in the form of stretching, tearing or complete rupture as a result of a torsion injury with extension and a valgus component [10]. This situation most often occurs as a result of an injury resulting from sports activity or

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an injury suffered during a traffic accident and is described as a torsion injury occurring with a stabilized foot and a slightly bent knee – most often it is a sudden twist of the body [11, 12]. In the case of a valgus injury, other elements of the joint are often damaged. A triad of injuries then occurs – ACL, tibial collateral ligament and medial meniscus damage [13]. Uncontrolled hyperextension of the knee joint, combined with internal rotation, exceeding the possible range of motion, leads to ACL and adjacent structures damage, which, as a consequence of the injury, excludes the patient from activity for at least several weeks or even months [14].

At the functional level, we can diagnose whether an ACL is damaged or not, using the anterior drawer test [15]. Episodes of knee joint instability reported by the patient, the so-called “knee giving way” are also helpful in assessment. The problem of damage or rupture of the ACL concerns above all young, physically active people, athletes and people of different ages practicing sports or intensive forms of recreation, as well as participants in traffic accidents [16]. Due to such a wide risk group, ACL injuries of various degrees, including complete ruptures of this structure, are one of the most common injuries in the knee joint, posing a challenge for orthopedists and physiotherapists.

Indications for grafting

Selecting the appropriate candidates for anterior cruciate ligament surgery is essential for restoring limb function and preventing secondary injuries. In a study by Sanders *et al.*, patients who did not undergo ACL reconstruction (ACLR) after an ACL tear experienced more frequent secondary injuries, including meniscal damage and osteoarthritis, leading to a higher rate of total knee arthroplasty (TKA) [17]. These findings emphasize the importance of establishing precise surgical indications. ACLR can be categorized as either acute or delayed, based on timing. Contrary to previous beliefs, acute ACLR (within 8 days of injury) has been found not to increase the risk of arthrofibrosis or joint stiffness [18]. However, delaying ACLR for more than 6 months after injury is associated with a higher incidence of medial meniscus injuries, often requiring meniscectomy and subsequent delayed ACLR within 2 years of the initial injury. The optimal timing for ACLR appears to be 6–8 weeks after the first injury [19].

The primary criteria for surgical intervention in ACL injuries are knee instability and episodes of giving way [20]. It is crucial to emphasize that surgery is necessary in these cases, irrespective of any initial non-operative treatment. When making treatment decisions, it is also essential to assess the condition of the menisci. The presence of concomitant meniscus damage with an ACL injury often warrants prompt anatomical ACL reconstruction, combined with simultaneous meniscus repair [21]. What represents

another crucial indication for surgery is the presence of multiligament knee injuries (MKIs), which in addition to the ACL involve at least one of the following structures: the posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL) [22]. Similarly to meniscal injuries, delaying surgery in these cases is not advisable, with addressing all damaged structures during a single surgery being the most advisable solution. For MKIs, it is recommended to minimize the waiting time to approximately 3 weeks after the injury [23].

Surgical intervention is the preferred choice, particularly for young adults aiming to regain a high level of activity following an injury [24]. For patients with low physical activity levels and a minimal risk of knee instability, a more suitable approach is rehabilitation, with the option of delayed surgery if required [25, 26]. It is important to emphasize that age is not a contraindication for ACL surgery [27]. Patients aged 40 and above achieve treatment outcomes comparable to younger individuals and can return to their pre-injury level of physical activity. Therefore, the choice of treatment methods primarily depends on the patient's expectations, physical activity level, and any concomitant knee joint injuries [28].

Types of grafts used in ACL reconstruction

Currently, there are many types of grafts available on the market for ACL reconstruction surgery. These grafts can be categorized as autografts, which are grafts obtained from the patient's own body, allografts, which are grafts sourced from a donor, or synthetic grafts made from artificial materials.

Among autografts, the following types can be distinguished: hamstring tendons (HT), quadriceps tendon (QT), and patellar tendon (BPTB). Hamstring tendons are further divided into semitendinosus and gracilis tendons, as well as the adjacent sartorius tendon. To obtain hamstring autografts, an incision is made medially below the tibial tuberosity near the pes anserinus (Figures 1–3).

After the autograft has been obtained, its preparation begins in order to form a transplant material (Figure 4). One research has shown that grafts with a diameter greater than 7 mm have a higher likelihood of success compared to grafts with a smaller diameter [29]. Following these procedures, the graft is placed in tunnels that had been drilled in tibia and femur prior to implantation (Figure 4). The last step of the implantation is fixing the graft with a method of choice, such as simple suture, endobuttons, interference screws (Figure 5). The sequence of the ACLR procedure implantation remains similar to each other regardless of the transplant material.

Another autograft option, the quadriceps tendon, is harvested from the central portion of the quadriceps tendon just above the patella. There are two



Figure 1. Skin incision for hamstrings autograft

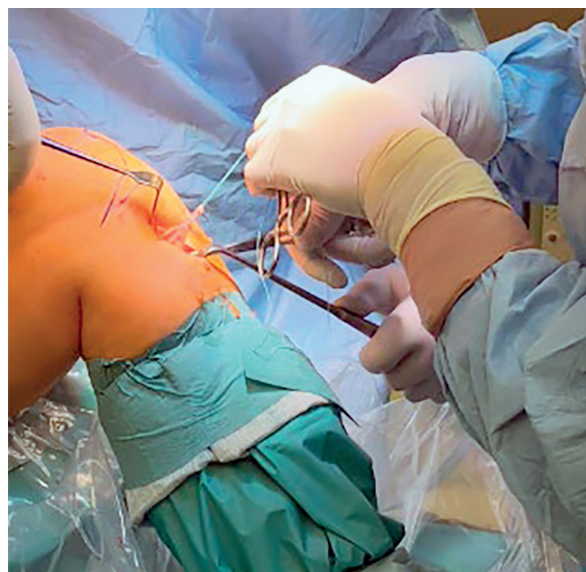


Figure 2. Graft harvesting

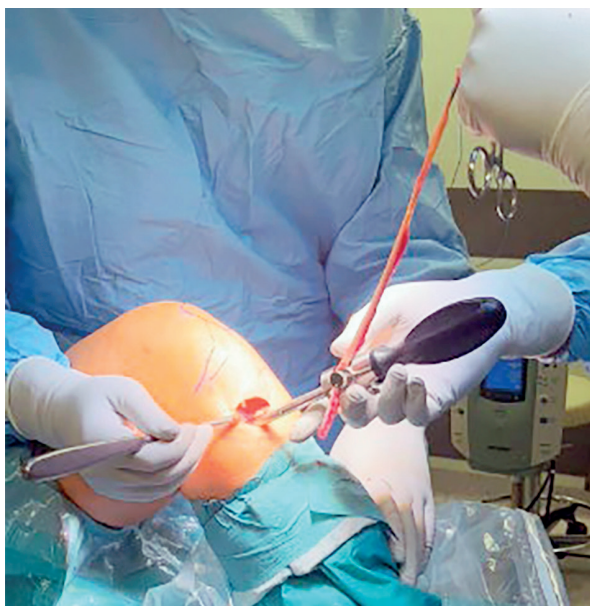


Figure 3. Graft harvesting



Figure 4. Formed hamstring graft prior to fixation in drilled tunnels

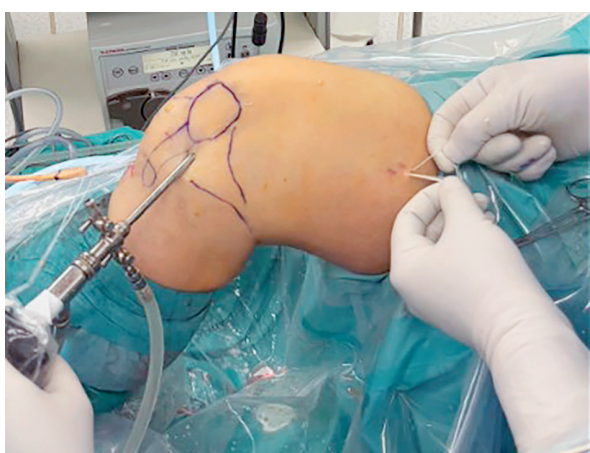


Figure 5. Graft fixation on the femoral aspect

variations of this graft: one with a bone block from the patella (QT-PB) and one without a bone block. The patellar tendon autograft is obtained by taking a 1/3 middle portion of the patellar tendon along with bone blocks on both sides. The incisions for QT and BPTB grafts are larger compared to hamstring tendon grafts, resulting in a larger subsequent scar, which might pose a cosmetic concern to some patients. Several studies have compared these autograft options, revealing that the clinical and functional outcomes are similar among them [30, 31].

There were no significant differences in tests such as anterior drawer, Lachman, pivot shift, and lever signs [32]. Additionally, the risk of failure is comparable across all types of autografts. It has been noted that postoperative pain at the donor site is much lower for QT and HT type grafts compared to BPTB type grafts,



Figure 6. Femoral component of the ACL graft

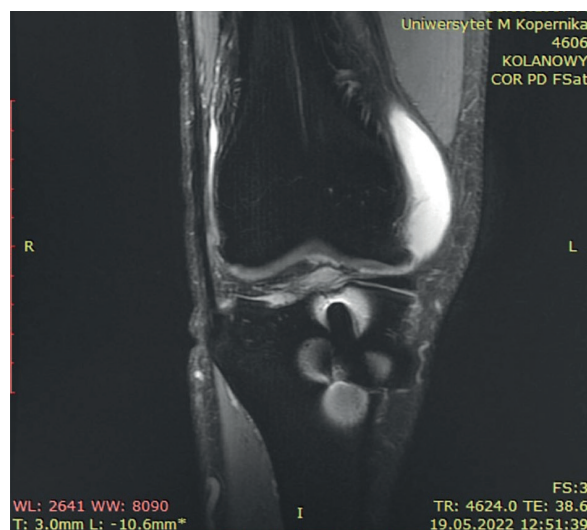


Figure 7. Tibial component of the ACL graft

which may lead to discomfort during kneeling [33] (Figures 6, 7).

Another category of grafts is allografts, which are acquired from deceased donors. The most commonly used allografts for ACL reconstruction are the patellar tendon and the Achilles tendon [34]. One significant advantage of this method is that it avoids trauma to the patient's tissues during graft acquiring, thus eliminating complications such as chronic pain, swelling, and hematoma [35].

Allografts can be used in two ways: with or without prior graft irradiation. The main advantage of using an irradiated graft is an increased chance of graft acceptance, but irradiation weakens the graft material, affecting functional outcomes. On the other hand, non-irradiated allografts show similar functional outcomes as autografts but carry a higher risk of graft rejection due to the host's immune response [36, 37].

Synthetic grafts, like allografts, offer the advantage of avoiding the need to obtain grafts from the patient, but the clinical and functional outcomes are worse than in autografts [38].

The choice of the graft type significantly affects the following factors: the length and cost of the procedure, postoperative pain, the possibility of local complications, the time required to return to physical activity, and aesthetic aspects [34]. Each type of graft has its own advantages and disadvantages, so the choice should be based on the individual needs of the patient, considering factors such as age, physical activity level, cosmetic concerns, and any existing medical conditions or discomforts of the patient.

Complications after ACL reconstruction

Although ACL reconstruction is a routine procedure, there are many potential complications fol-

lowing it. The most common are graft impingement and graft tear [39, 40]. They occur as a consequence of trauma or injury to the knee joint. In imaging tests, we observe the presence of fluid buildup within the joint and bone marrow contusion of the tibial condyle. Clinically, it manifests as a recurrent pain and restrictions in the knee's mobility [41].

Another example is arthrofibrosis and the cyclops lesion, which is marked by aching limitation of knee joint extension caused by a nodular scar mass [42]. A systematic review conducted by Noailles *et al.* highlighted specific factors that increase likelihood of its occurrence, including pre-surgery knee inflammation, stiffness prior to surgery or hamstring spasm following it [43]. Consecutive but extremely rare complication is a graft ganglion in the fixation tunnel. This is a long-term sequela, typically occurring in people who subject the knee to higher than average strain e.g. athletes. The reason for their formation is excessive movement of the ligament graft in the tunnel or mechanical overload of the graft. It usually manifests itself with non-specific chronic pain and limited joint mobility [44, 45]. Malposition or displacements of the graft are also important complications [40]. Incorrect positioning of the graft tunnel can result in issues such as instability, loss of knee flexion or extension, knee pain, and potential graft rupture. For instance, a tibial tunnel placed too posterior may lead to a vertical tunnel with inadequate rotational stability of the graft, possibly causing PCL impingement [46]. If there is a lack of full range of motion in either flexion or extension (or both), it is essential to implement a prompt management with a manipulation and arthroscopic arthrolysis [47].

Dangerous complications after ACL reconstruction are inflammatory reactions. Typical signs of an infection after this procedure include severe pain, swell-

ing, redness, the rise of temperature and stiffness [41]. The main cause of contamination is bacteria, such as coagulase-negative *Staphylococcus* [48]. Treating the infection should include a lavage, intravenous antibiotics and arthroscopic debridement [49]. In some cases, it might be necessary to remove the graft. Although septic arthritis of the knee is a relatively rare complication after ACL reconstruction, it is a severe one [50, 51]. There also have been cases of fungal osteomyelitis but they are even more infrequent complications [52]. Donor site complications are more likely while using grafts from patellar tendon compared to hamstring tendon grafts. While obtaining a patellar tendon graft, there is a risk of patella fractures during surgery. Improper bone cuts during graft harvesting can also lead to patella fractures [47]. Other potential issues include tears of the tendon, bursitis and hematoma. With hamstring tendon grafts, the most common donor site complication is the accumulation of fluid [53]. Additionally, during the procedure, cutting the tissues carries a risk of causing another intraoperative complication, such as nerve damage, especially saphenous nerve injury, which may lead to hyperesthesia and numbness on the inner part of the knee [47].

Conclusions

As presented in this paper, there are various methods of ACL reconstruction, each with its own advantages and disadvantages. The typical classification includes autografts and allografts derived from various anatomical structures, and in the case of allografts, also from synthetic materials. It is crucial that the choice of a specific method is based on the surgeon's experience and the patient's characteristics. Performing ACLR should be considered, especially among young, active individuals, as well as in patients with significant instability of the knee joint and if there are concomitant injuries to the menisci or other ligaments of the knee joint.

The appropriate selection of patients for ACLR is crucial due to potential complications of chronic instability of the knee joint, such as meniscal injuries or osteoarthritis, which may necessitate total knee arthroplasty in the future. Among the complications of ACLR, graft damage, typically resulting from injury, is the most common. However, it is essential to keep in mind less common complications such as arthrofibrosis, malposition or displacements of the graft, wound infections, or even septic arthritis of the knee. Taking actions to reduce the frequency of postoperative complications is essential, and further research is key to developing clear guidelines for indications for surgical treatment.

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Ethical approval

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Conflict of interest

The authors declare no conflict of interest.

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