Ligamentous Knee Injuries in Amputees

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Combat-related musculoskeletal injuries occur commonly during military conflicts, as in Iraq and Afghanistan, and are caused by high-energy blasts. Ligamentous knee injuries resulting from these blasts are often associated with lower extremity fractures or traumatic, transtibial amputations. Ligamentous knee injuries in amputees are often difficult to diagnose for a variety of reasons, including massive soft tissue trauma and delayed ambulation. While the algorithm for treatment is similar in non-combat, multi-ligamentous knee injuries, the timing of surgical intervention, graft choices, and methods of fixation are more limited. Additionally, the presence of traumatic brain injury and associated extremity trauma make rehabilitation of these injuries much more complicated. Despite these challenges, the recognition and treatment of ligamentous knee injuries in amputees is critical to returning these patients to an active lifestyle. (Journal of Surgical Orthopaedic Advances 21(1):44–0, 2012)

Key words: ligamentous, knee, multi-ligamentous, high energy, lower extremity

Introduction

Since the onset of Operations Iraqi and Enduring Freedom, more than 34,000 U.S. military personnel have sustained combat-related musculoskeletal injuries (1). Most of these injuries occur from a blast, sustained either on foot or while inside a vehicle, and these explosions account for 80.7% of all musculoskeletal combat casualties (2). Previous studies have demonstrated that over half (54%) of all combat-related wounds involve the extremities (3). A large percentage of these patients have immediate, traumatic amputations; others receive lower extremity amputations later for unsalvageable limbs. The major amputation incidence rate is 2.1 per 1000 soldier combat-years for these conflicts (2), with approximately 50% of these transtibial amputations.

Civilian multi-ligamentous knee injuries are typically associated with knee dislocations and can result from high- or low-energy mechanisms (4-8). Multi-ligamentous knee injuries following transtibial amputations are extremely rare, and it is difficult to obtain consensus on the true incidence, best treatment, and expected outcomes from the available literature. Our experience with the treatment of transtibial amputees over the past 5 years suggests multi-ligamentous knee injuries coexist within a subset of extremity trauma patients and are often unrecognized.

The purpose of this article is to describe this subset of lower extremity combat amputees with concomitant ligamentous knee injuries. We will highlight the typical mechanism of injury, clinical presentation, ligament injury patterns, associated injuries, treatment process, and rehabilitation for these difficult to treat patients.

Clinical Presentation

History

In all trauma patients, ligamentous knee injuries can be overlooked due to more serious injuries. This is especially true in the combat injured (8,9), who are resuscitated in-theater and undergo external fixation to stabilize high-energy extremity fractures. The principle of damage control orthopaedics often mandates concomitant treatment of thoracic, abdominal, and extremity injuries with ongoing fluid resuscitation in a limited time period. In the process of stabilizing these patients, a spontaneously reduced knee dislocation or an unstable knee joint may be easily overlooked.

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Failure to progress with ambulation is often the first clue to knee instability and may not occur until later in the recovery process. As a result of multi-system organ injury and complex extremity trauma treated with limb salvage, many patients are not capable of ambulating until months after their initial injury. They often have such devastating ipsilateral or contralateral lower extremity injuries that they are unaware of a concomitant knee ligament injury. In the event of an amputation for failed limb salvage, it could be more than a year before patients even attempt to ambulate. Significant advances in prosthetic design and institutional support have given all amputees heightened functional expectations, and in some, the expectation to return to running and cutting activities. Failure to achieve these goals is voiced to the physical therapist and prosthetist who often address the problem by modifying the rehabilitation program or adjusting the prosthesis (10). Continued difficulty with ambulation then results in an orthopaedic referral.

Physical Exam

The principles of physical examination in the combat-injured patient are the same as in the civilian and are divided into phases. In the acute injury phase, a thorough secondary survey is essential to the prompt recognition of a knee ligament injury. Popliteal artery injury and neurovascular compromise from displaced fractures and compartment syndromes are common in the battlefield injured. Spontaneous knee dislocation and reduction are thought to accompany traumatic blast injury and can be easily overlooked in the critically wounded patient. Thus, it is important to remember that multi-ligamentous knee injuries can occur in the amputated and non-amputated limbs.

It is difficult to perform a knee exam during the initial resuscitation, but special attention needs to be paid to a knee effusion or abnormal varus or valgus motion in the extended knee. Provocative ligamentous testing is impractical or impossible in the mangled extremity, so any extremity with a suspected knee ligament injury should be stabilized with an immobilizer or bridging external fixator.

Arterial flow must be carefully evaluated to rule out a vascular injury as an unrecognized popliteal artery injury could result in loss of limb (11). Performing an ABI as described by Mills et al. (12) in this setting is impossible in the traumatic amputee. An on-table arteriogram during the resuscitation phase is often required to assess the vascular status.

Within 48 to 72 hours after the initial injury, most patients have been transferred to a regional hospital thousands of miles away from the conflict. Here they receive continued resuscitation and wound debridement while they await transport to their Level V treatment facility. Once there, definitive plans are made for evaluation and treatment of their wounds. Most wounds are closed and fractures definitively stabilized approximately 1 month after the initial injury, but completion of wound care may take months if infections develop or complex soft tissue coverage must be obtained. This coincides with the end of the window for early ligament reconstruction or augmented repair. In the patient with a recognized multi-ligamentous knee injury, ligament repair can be performed concomitantly with definitive fracture fixation and soft tissue coverage. However, due to associated injuries and prolonged rehabilitation delaying functional mobility and ambulation, to date, ligament reconstruction in our amputee population has only been performed in the late setting.

Specific challenges to the physical exam of the combat injured amputee are mostly related to difficulty controlling and testing the knee (Fig. 1). Posterior drawer testing is the most reliable of the standard provocative physical exam tests. Assessing varus and valgus opening and anterior tibial translation with the Lachman are unreliable. Amputation decreases the length of the residual limb and significantly reduces the lever arm for these tests. To compensate, the examiner can perform stress testing with the prosthesis on. The silicone liner and prosthesis will significantly diminish the examiner's sensitivity; however, the patient can often relate subjective side-to-side differences. Intraoperative testing often gives the best information with testing enhanced by insertion of half pins into the residual limb to enhance manipulation.

FIGURE 1 AP radiograph of short transtibial amputation common in our patient population. A short residual limb can make physical examination of ligamentous structures challenging.

Imaging

As in the civilian trauma patient, radiographs of the involved knee should be obtained. Some authors have suggested the use of stress radiographs, specifically varus stress radiographs, to identify injury to the collateral ligaments (13); however, the applicability of these radiographs in amputees is often limited. Advanced imaging, specifically magnetic resonance imaging (MRI), can be helpful in evaluating ligamentous injury, pattern, and location. Standard external fixators can be exchanged to MR compatible fixators (Fig. 2). As useful as it may seem, MRI is often not an option in the combat amputee secondary to ipsilateral extremity hardware and/or retained shrapnel. While spiral CT arthrography of the knee is a potential alternative to MRI, its value in the diagnosis of ligamentous knee injuries, specifically the anterior cruciate ligament, remains undetermined (14).

Abnormalities during gait analysis include side-to-side differences and a mild varus or valgus thrust can assist in diagnosing the involved ligaments. We have included gait analysis at our institution as part of a standardized approach to these injuries (Fig. 3). Often, the final decision to proceed with surgical reconstruction is based on a complaint of instability by the patient and the examiner's clinical suspicion.

Ligamentous Injury

The classification of multiple ligament knee injury was initially developed by Walker at al. (15) and later modified by Wascher et al. (16). It is an anatomic classification that categorizes level of injury after knee dislocation based on ligamentous injury, in addition to associated periarticular fracture and neurovascular disruption (Table 1). In the

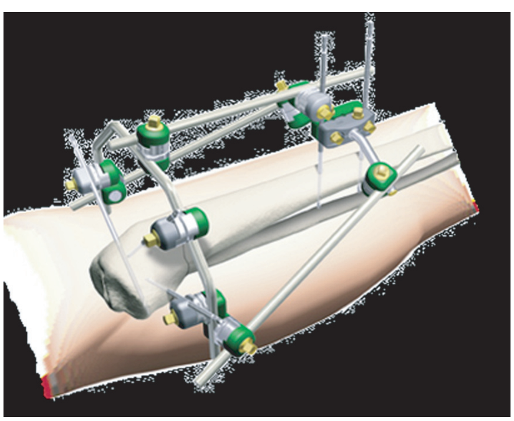

FIGURE 2 MRI compatible frames, seen in above image, are an option in a patient with an ipsilateral or contra lateral injury necessitating external fixation.

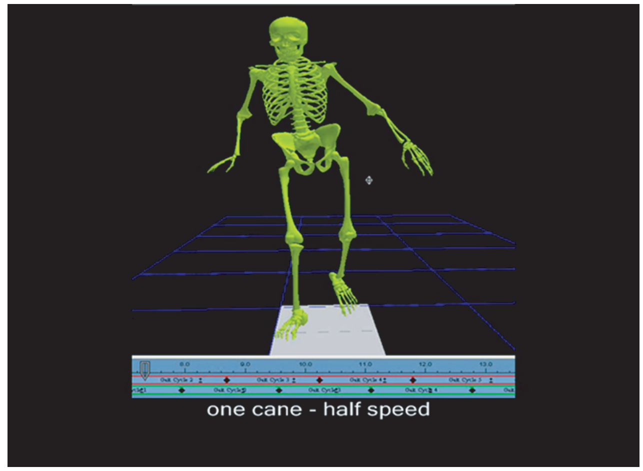

FIGURE 3 Gait analysis can be used as an additional modality to diagnose ligamentous injuries in amputees, though with little success at our institution.

TABLE 1 Classification of multiple ligament knee injury

Class	Description
KDI	Cruciate intact knee dislocation
KDII	Both cruciates torn, collaterals intact
KDIII	Both cruciates torn, one collateral torn
KDIV	All four ligaments torn
KDV	Periarticular fracture-dislocation

Adding the suffix C indicates vascular injury and adding the suffix N indicates neurological injury.

civilian literature, patterns of injury after a knee dislocation always involve one or both cruciates with or without collateral ligament involvement (8). Patterns in the battlefield amputee are similar with nearly all involving the ACL in our experience.

Associated Injury and Early Results

Combat-related lower extremity amputations rarely occur in isolation. In the 4 years after the start of Operation Enduring Freedom, there were 381 surviving amputees with 441 major amputations (17). Associated injuries included concomitant local and distant long bone fracture in 39%, multiple amputations in 16%, peripheral nerve injuries in 12%, and major soft tissue injury in 41% (17). The incidence of knee injuries is unknown.

To date, there have been no published studies which investigate the epidemiology, treatment, or outcomes of associated ligamentous, cartilage, or meniscal pathology following trauma-related lower extremity amputations; however, such investigation is underway at our institution. Eight patients with trauma-related amputations had associated ligamentous injuries on the ipsilateral or contralateral extremity. All patients that sustained a transtibial amputation (five of eight) from a blast mechanism had associated knee pathology, including Grade II to III chondromalacia in 50% and meniscal tears in 100%. Additionally, 50% of patients with combat-related amputations developed arthrofibrosis prior to ligament reconstruction. In contrast, none of our non-combat transtibial amputee population (three of eight) had associated meniscal or cartilage lesions, nor did any develop arthrofibrosis.

Treatment

The treatment of patients with a ligamentous knee injury and associated amputation is similar to the treatment algorithm for those without amputation with some important exceptions.

In the setting of high-energy trauma resulting in an amputation, the principles of damage-control orthopaedics supersede and often directly compete with the recognition and treatment protocols for mulit-ligamentous knee injuries. Significant osseous and soft tissue defects prevent early ligament repair or reconstruction. Furthermore, assessment of knee stability is hindered by the use immobilization devices, spanning external fixators, negative pressure wound management systems, and traction. For these reasons, we have found that the time to diagnosis of a ligamentous knee injury in the setting of a combat-related lower extremity amputation is delayed to a mean 27 (median, 15) months. If these statistics are to improve, it is imperative that the orthopaedic surgeon maintain a high index of suspicion for associated ligament instability in the setting of the battlefield trauma amputee.

There is no valid indication for early ligament reconstruction in the battlefield amputee due to significant soft tissue injury and the high incidence of infection. Recently Gordon et al. (18) reported the outcomes of lower extremity amputations with concomitant long bone fracture proximal to the amputation level. Roughly one-third of patients who underwent femoral fixation developed clinically active infections. Collateral ligament repair has been performed early in the treatment process with marginal success. Delayed treatment allows for capsular healing, minimizes the risk of arthroscopic fluid extravasation and compartment syndrome, facilitates preoperative range of motion gains, allows for eradication of infection, and provides for interval healing of collateral ligament injuries (20-22). When ligamentous injury is recognized early and the soft tissues permit, ligament reconstruction can be performed prior to prosthetic fitting and gait training.

In general, symptomatic cruciate and collateral ligament injuries are treated with reconstruction once functional motion is restored and the clinical situation allows. In patients with Grade II PCL tears or those with partial ACL tears, strong consideration should be given for cruciate ligament reconstruction. Biomechanical studies have demonstrated increased force transmission through the cruciate and collateral ligaments in extremities with an ipsiatleral transtibial amputation and especially with improper sagittal prosthetic alignment (19). Additionally, advances in prosthetic technology allow many of our young, motivated patients to return to high levels of function to include competitive sport.

Primary repair alone of the MCL, LCL, posteromedial, and posterlateral corners in the traumatic amputee is unreliable given the associated soft tissue damage, poor quality of the remaining tissue, and increased graft stress experienced during rehabilitation and activity with prosthetic use. Stannard's (23) study prospectively comparing repair versus reconstruction in a non-amputee population demonstrated the superiority of reconstruction versus repair alone (37% failure rate in the repair group versus 9% in the reconstruction group). Consequently, our preferred method of treatment is to perform a reconstruction whenever possible.

Reconstruction in the multi-ligamentous knee injury is classically performed with autograft or allograft tendon. In the traumatic amputee, allograft tissue is the preferred graft source for several reasons. The spectrum of associated injuries is broad and harvesting autograft hamstring, quadriceps, or patella tendons within the zone of injury increases the probability of infection and further compromises patient function. Allografts are variable and include Achilles tendon with strut, bone-patellar tendon-bone and all soft tissue. The choice of allograft and method of fixation are largely dependent on surgeon technique and training. However, the altered knee biomechanics and ligament forces (19,24) experienced by amputees have led us to use cortically based/suspensory fixation devices. Interference screw fixation may not offer adequate fixation in the patient with disuse osteopenia or bone poor quality. While hardware prominence and pain with prosthetic wear are theoretical concerns, no patient in our series has required hardware removal and skilled prosthetists are able to provide custom sockets to minimize potential sites of irritation.

Rehabilitation

Rehabilitation of the traumatic amputee is a complex process requiring a team effort that begins at the time of injury and continues after discharge. Many injured service members are high functioning, healthy, young adults. The main focus of rehabilitation is to return the patient to the highest level of physical function. Our institution's rehabilitation team utilizes a staged program that encompasses four phases: (1) initial management, (2) preprosthetic, (3) prosthetic/ambulation, and (4) progressive activities/return to active duty.

Passive knee range of motion is begun immediately after cruciate ligament reconstruction but is delayed for 2 weeks if collateral ligament surgery is performed concurrently. Patients work on core stabilization, hip strengthening, and isometric lower extremity exercises throughout the rehabilitation program. The goal is to restore functional motion by 6 weeks postoperatively. Once functional range of motion is obtained and associated traumatic injuries are treated, the rehabilitation program initiates closed kinetic chain exercises (CKCE) in a similar fashion to the population with intact lower extremities. Closed kinetic chain exercises are desirable because they minimize shear forces at the knee joint (25) and reinforce co-contraction of both the quadriceps and hamstring muscles. Amputees are not allowed to weight bear for approximately 6 weeks after ligament reconstruction. After this point, the remaining rehabilitation course mirrors that of the non-amputee protocol.

Not only is the residual limb affected in the amputee population, but the intact limb also is at risk for injury secondary to compensatory gait patterns increasing load across both hip and knee joints. Three of the most common secondary complications due to compensatory and/or altered stresses in people with lower-limb amputation are osteoarthritis, osteopenia/osteoporosis, and back pain (26). During the gait cycle amputees spend more time on the intact limb than the prosthetic limb and as a result, increased loads are experienced on the intact extremity compared those without amputation during natural cadence walking (27-29). Long-term exposure to higher repetitive loading forces leads to increased strain in the primary and secondary joint stabilizing structures and eventual degeneration of weightbearing joints (30,31).

Complications

Complications are to be expected after a multi-ligament knee reconstruction in the traumatic amputee and are correlated with the degree of soft tissue trauma and patient compliance. We have had no cases of graft infection or graft failure in our amputees. One soldier required a revision of the PCL reconstruction performed on his non-amputated extremity. This amputee fell onto the flexed knee while trialing a new prosthetic limb and ruptured his graft. A general observation of our wounded warriors is that non-compliance is common and seems to be linked to traumatic brain injury. This has been observed in many of our patients, but to date, none has resulted in graft compromise.

The future of ligament reconstruction in our amputee population is promising. We continue to modify our gait analysis technique to help identify ligament instability but rely primarily on the patient's complaints of instability and an intraoperative examination to identify the involved ligaments. Heightened awareness of ligament injury has shortened the time to recognition and treatment of these debilitating injuries from months to days after injury.

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