Review Article

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Considerations in the Management of Knee Dislocations in the Limited Resource Setting (KD-LRS)

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Abstract

Knee dislocations (KD's) are an increasingly recognized and potentially devastating injury that crosses between sports medicine and trauma. This intersection of orthopaedic specialities involves differing patient populations with individual challenges. While much of the literature on managing knee dislocations comes from academic centers in economically advantaged countries, the majority of knee dislocations worldwide are treated in limited resource settings (LRS). Even in high income countries, such as the United States, there are significant rural and underserved populations whose available treatment can often mimic LRS in developing nations. Additionally, there are patients with these injuries who refuse allograft reconstructions based on personal or religious beliefs. We have recruited authors with extensive experience in the management of KD's who also have a special interest in managing the KD patient in the limited resource setting (KD-LRS). Additionally, the LRS environment should not be confused with the quality of professional care provided as the LRS has no limits on human capital.

Our topics will include acute evaluation and management of the KD, management with or without delayed ligament reconstruction, staged management, use of external fixation, reliance on autografts for ligament reconstruction, and management of the neglected KD or delayed presentation. Our goal is to provide a road map, in an area which has very limited references or direction, for the clinician practicing where "less, often has to be more" or utilizing what is available to its greatest capacity.

Keywords/phrases: Limited resource setting (LRS), Knee Dislocation, Neglected KD, Treatment Gap, Autograft KD reconstructions.

Introduction

The current management of knee dislocations (KD's) has gained great interest and refined focus over the past decade with many arthroscopic advances allowing for single stage multiple-ligament reconstructions in high-income countries, where expense even for the underinsured is absorbed by well funded systems. Readily available operating room time, advanced arthroscopic systems with water management pumps, availability of allografts, widespread access to a variety of arthroscopic fixation devices, and newer techniques such as double bundle posterior cruciate ligament reconstructions are frequently cited as the standard of care that is expected to be applied to all communities and patients.

Patients treated by some of the authors in a large hospital in Cape Town, South Africa, often travel long distances to access health care, are often unemployed with minimal or no health insurance, or have manual labor needs which make compliance with post-operative care and rehabilitation difficult. Interestingly, the rural patient experience in the USA, often mimics some of these circumstances.

Furthermore, our orthopaedic center in Albuquerque, New Mexico, USA, often treats Jehova's Witnesses and Native American patients who refuse allograft tissue on religious grounds; thus, we are often faced with the need to perform multi-ligament reconstructions with only autograft tissue.

Finally, although some literature points towards a potential advantage of early rather than delayed surgical treatment of KD's, this is still an unanswered question that can only be resolved by randomized trials comparing early versus late surgery, and immobilization versus early motion after multi-ligamentous surgery [1]. The current STaR trial (the Surgical Timing and Rehabilitation (STaR) Trial for MLKIs Network) is investigating these challenges to provide optimal care for the KD patient.

Since most literature on the management of KD's originates from high volume centers in high-income countries, there are no specific guidelines for limited resource settings both in developing countries and under serviced areas in the developed world. This gap of a global understanding makes management of KD's difficult outside of such developed countries. In LRS, patients often work as manual laborers and are frequently under-insured which leads to catastrophic loss of income or health care

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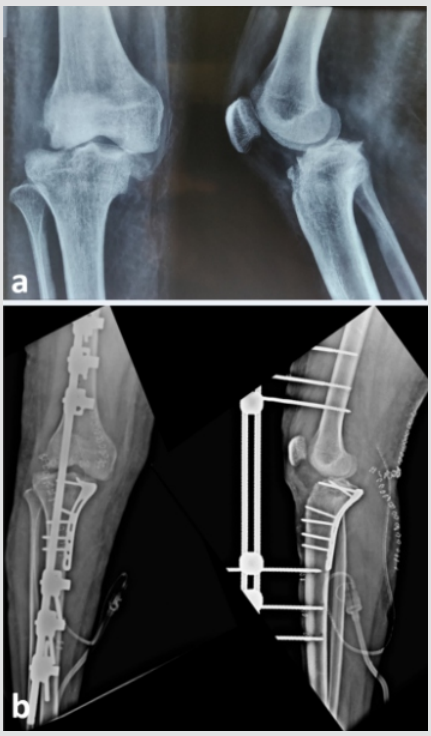

Figure 1: A. Case of knee dislocation with tibial plateau fracture. B. Primary management by fracture fixation and external fixation to keep the unstable knee reduced was performed at a general hospital in a LRS. This patient subsequently underwent an ACL and PCL reconstruction at a more specialized center after fracture healing.

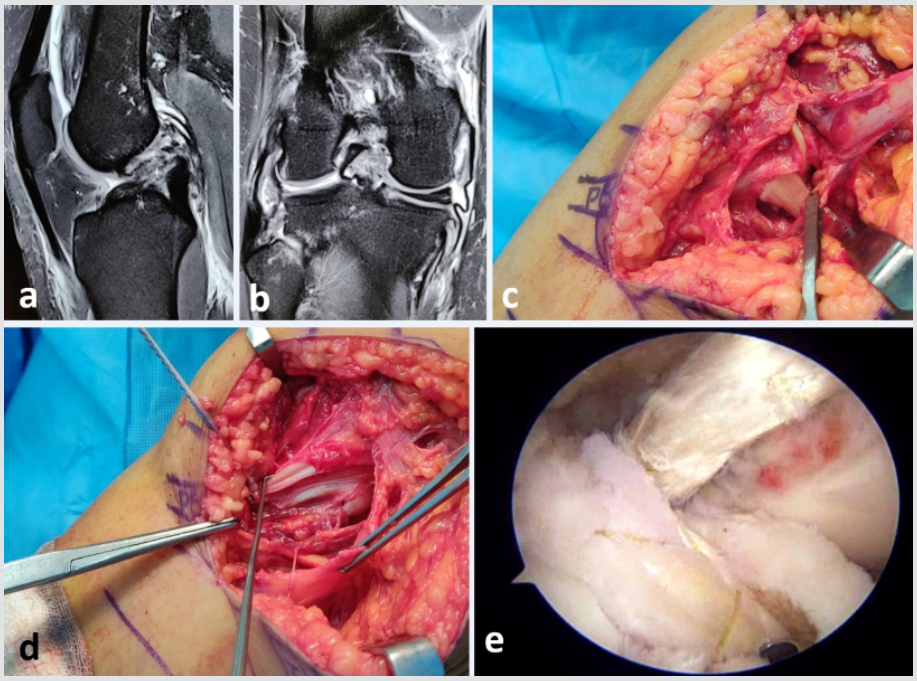

Figure 2: MRI scan of a KD showing complete rupture of the ACL and PCL in sagittal section (A) and MCL in coronal section (B) in proton density fat-saturated sequence. C. Intra-operatively, the medial capsule, deep and superficial MCL, and posterior oblique ligament were found torn. D. First stage repair of all torn medial structures was performed with suture anchors. E. A second stage arthroscopic ACL and PCL reconstruction was performed after 6 months on achieving full range of motion and good quadriceps strength.

expenditure after a KD. Furthermore, poor access to surgical care and postoperative physiotherapy, long transfer times or distances to adequate surgical facilities, limited access to surgical equipment and training in arthroscopy, as well as the lack of allograft availability presents unique challenges to surgeons caring for these patients. These challenges encountered in the LRS demand an adaptation in the approach to KD's currently promoted by high-volume, high-resource centers and must lead to revised guidelines and recommendations for the management of these injuries [2-7].

The aim of the following article is to describe acceptable solutions for the management of KD's in a resource-restrained environment. It will include acute management and vascular assessment, non-operative, staged and delayed management of knee dislocations, open ligament surgery, external fixation, autograft choices and repair of ligaments, and the management of neglected knee dislocations.

Acute management and vascular assessment

Message: Priority 1) life, 2)limb, 3)vessel, 4) soft tissue, 5) fractures, 6) ligament.

Although the assessment and management of the ligamentous injury is important in KD's, in the acute setting life and limb threatening injuries take priority. The limb should be assessed for neurovascular compromise, open wounds, and extra-articular fractures. A high index of suspicion is required as over half of KD's present spontaneously reduced [8]. If the knee presents dislocated, immediate reduction and stabilization should be performed, followed by careful vascular assessment.

Figure 3: Case of a Navajo Native American patient who refused allograft tissue for ACL/MCL/PLC injury (KDI-M-L). A, B. Coronal and sagittal plane MRI demonstrating the cruciate and collateral ligament injury. The patient was reconstructed using all autograft: ACL–ipsilateral QT autograft, MCL– ipsilateral double semitendinosus hamstring autograft with imbrication of the posteromedial capsule/POL, LaPrade-type PLC– contralateral gracilis and semitendinosus hamstring autograft. C, D. AP and lateral post-operative radiographs demonstrating the reconstruction.

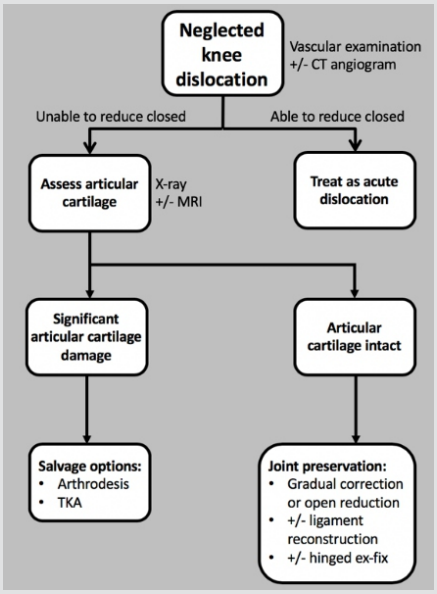

Figure 4: A proposed algorithm for neglected knee dislocations.

Figure 5: A,B. AP and lateral radiographs of a poorly controlled HIV-infected 33yr old female patient with a 4-year old neglected knee dislocation. Radiographs demonstrate signs of chondrolysis and joint destruction.

A delay in vascular injury diagnosis can lead to compartment syndrome and/or amputation in up to 20% of patients [9, 10]. A failure to restore perfusion to the limb within 8 hours increases the amputation rate to 86%, compared to 11% if performed within the 8 hour window. The use of an ankle-brachial index (ABI) above 0.9 can be reliably utilized to confirm an intact popliteal artery in the patient with an isolated knee injury [11, 12]. The multi-trauma patient with associated fractures above or below the KD often makes the ABI more difficult to reliably use. Stanndard et al., described a clinical protocol with serial examinations of vascular status performed by nursing staff and the attending orthopaedic surgeon [13]. Although this protocol has high sensitivity and specificity when followed, for many developing countries with busy trauma centers, it is not possible for staff to perform regular documented vascular assessment. Therefore, the treating physician should have a low threshhold for routine angiography given the limited ability for continued observation and documentation of adequate pulses as required for non-invasive approaches. LRS also have limited access to ultrasound or computerized tomographic angiography. An absent pulse, active bleeding or an expanding hematoma, distal ischemia, or

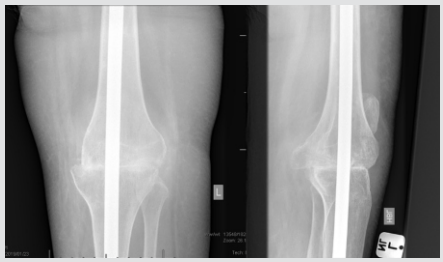

Figure 6: A, B. AP and lateral radiographs 6 months after surgery in the previous patient showing union of the knee arthrodesis with an intramedullary nail.

popliteal bruit warrant emergent exploration for immediate revascularization by a vascular surgeon. Our approach in the LRS is to perform a single shot angiogram in patients with diminished ABIs, which is highly accurate and readily available in the LRS [14].

Magnetic resonance imaging (MRI) is extremely useful in the management of KD's, but may not be available in the LRS patient [15]. If MRI is not available, then a thorough physical examination is required to identify the injured ligaments and the knee should be classified according to the Schenck Anatomic Classification (Table 1) [16]. The clinical finding of medial furrowing usually indicates a locked posterolateral knee dislocation (PL-KD). For a PL-KD, immediate surgery is required to avoid soft tissue necrosis medially [17]. Careful evaluation of pre and post reduction radiographs is critical to identify any avulsion fractures, patella alta (ie., patellar tendon avulsion) or infera (ie., quadriceps rupture), patellar subluxation (ie., MCL & MPFL), or any evidence of tibio-femoral subluxation. The presence of post-reduction tibio-femoral subluxation requires early surgery with closed reduction and external fixation or open reduction and ligament repair.

Non-operative or early surgical management

"(After reduction) the limb is bound in straw, and after a few days' rest, gentle bending and straightening of the knee to prevent it growing stiff are allowed, till pains have gone off, and the limb has recovered its former strength." [18]. This treatment approach for knee dislocations described by Heister in 1745 might seem archaic, but it could potentially still be applicable today in many parts of the world. Although non-operative management of KD's leads to inferior results when compared to surgery, the knowledgeable use of non-surgical treatment can sometimes result in acceptable outcomes [19-23]. When limited resources preclude performing surgery, a closed reduction and a period of immobilization can lead to a functional knee. An older study by Taylor et al., showed that KD's immobilized less than 4 weeks tended to have functional instability, whereas immobilization greater than six weeks resulted in permanent loss of motion [24]. We recommend placing the patient in a long leg cast or brace near full extension for between 4-6 weeks. The patient should be non-weightbearing during this time. Repeat radiographs should be obtained during the period of immobilization as we have seen knees that have subluxed in a cast or brace. After cast removal, a period of rehabilitation is required to regain motion, strength and function.

External fixation can also be used for definitive management of the dislocated knee and will be discussed in more detail in a later section. This is particularly useful in the setting of open injuries (to allow wound management), vascular injuries(to allow monitoring of pulses), and patients with multiple trauma that are unable to participate in the rehabilitation necessary after ligament surgery [25] (Fig. 1). The fixator is left on for 4-6 weeks, and a manipulation under anesthesia (with or without arthroscopic lysis of adhesions) is performed at the time of removal. The

Figure 7: A, B. AP and lateral radiographs of a chronically dislocated right knee after attempted acute repair of only the patella tendon and medial collateral ligament at outside hospital.

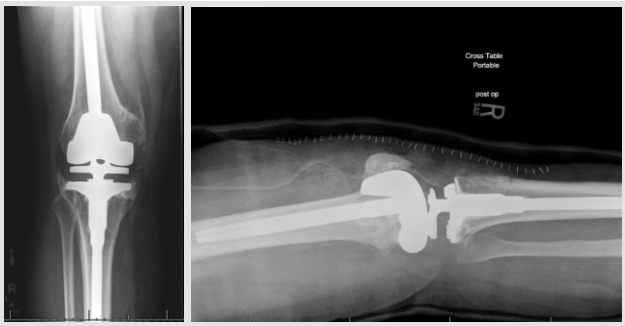

Figure 8: A, B. AP and lateral radiographs following hinged total knee arthroplasty for the previous chronically dislocated knee with patellar tendon reconstruction using polypropylene mesh.

Table 1: Schenck (Anatomic) Classification of Knee Dislocations	
	Injury Description
KDI	One cruciate torn with subsequent dislocation. Either one or both corners torn. KD I implies an intact cruciate ligament in the knee.
KDII	Both cruciates torn with both collaterals intact.
KDIII	Both cruciates torn with one corner/collateral torn, subset M or L. KDIIIM if medial side/medial corner torn with both cruciates. KDIIIL if lateral side/lateral corner torn with both cruciates.
KDIV	Both cruciates torn with both collaterals/corners torn
KDV	Fracture-dislocation of the knee (Wascher modification).
	*Stannard further described KDV's with following subsets:
KDV-1	Fracture-dislocation with a single cruciate injury
KDV-2	Fracture-dislocation with both cruciates torn, collaterals/corners intact
KDV-3	Fracture-dislocation with both cruciates and one collateral/corner torn
KDV-4	Fracture-dislocation with both cruciates and both collaterals/corners torn
*Subset "C" denotes arterial injury; Subset "N" denotes neurologic injury	

clinician should then reevalutate the knee after several weeks to assess for functional motion and the presence of instability. Often in such scenarios, the PCL and collaterals have healed and activities of daily living (ADL's) are easily accomplished.

Early surgical management for bony avulsions or insertional ligament tears can also result in acceptable results [26-30] (Fig. 2). When a vascular reconstruction is required, repair/reattachment of ligament avulsions can often improve the stability of the knee and avoid future multiple ligament surgery. In one case report, immediate vascular reconstruction combined with reattachment of the PCL and MCL (KDIIIM-C) followed by delayed reconstruction of the ACL allowed for functional restoration at 20 year followup [16]. In another case, a patient requiring early intramedullary nailing of an ipsilateral tibia fracture, underwent concomitant PCL and posterolateral corner repair. This resulted in a functionally stable knee without the need for an ACL reconstruction.

In summary, in some patients, non-operative management can lead to successful and acceptable outcomes in the limited resource setting. Furthermore, selecting patients with avulsions for early surgical repair can allow for an inexpensive but effective approach to achieve functional stability.

Staged management

In the LRS, the use of a staged management approach is often indicated in order to minimize complications such as arthrofibrosis. Most patients with a reduced knee and good neurovascular status should be placed in a hinged brace and started on an early range of motion program. Cook et al. showed that stiffness is more likely if surgery is performed acutely (within 3 weeks from injury) and three or more ligaments are injured (KDIII or KDIV) [31]. Hence, early ligament surgery in the setting of three or more functionally disrupted ligaments has a high rate of stiffness and should be avoided in the LRS where physical therapy access is often limited. Although early motion can result in a less stable knee, in our experience residual laxity is more easily treated than permanent stiffness.

Patients with a delayed KD presentation often have some stiffness present. In these patients, the use of home range of motion exercises can sometimes result in healing of some or all of the ligaments torn. Immobilization of patients with stiffness is contraindicated as a flexion contracture is often present. With proper instruction in a home exercise program, these patients improve their function and decrease the number of ligaments requiring delayed reconstruction.

External fixation for staged management

The use of external fixation in the staged management of knee dislocations is recommended in certain circumstances (Table 2) [32, 33]. Careful monitoring is needed to identify and treat complications such as pin tract infections, stiffness and loss of reduction. External fixators allow for vascular monitoring, access to wounds and early mobilization of multiple trauma patients. External fixators are used with greater frequency in LRS. Placement of the pins should be away from the site of future ligament surgery at least 10-15cm proximal and distal to the knee joint. Amongst various configurations, placing two femoral pins anterolateral and two tibial pins anteromedial, with two connecting rods, achieves the greatest stiffness biomechanically and limits violation of the extensor mechanism. The fixator is tightened with the knee in 10^0-20^0 of flexion and left on for 3-6 weeks to allow soft tissue injuries to the skin and underlying tissues to heal while simultaneously improving ligamentous stability. In settings where access to external fixators is even more limited, cross pinning of the joint using two 3+mm Steinman pins has been described as an acceptable alternative [34, 35]. The duration of external fixator treatment should be planned at the time of placement and discussed with the patient, taking into account: associated injuries, social situation/distance from medical care, and the definitive plan for ligamentous management. The fixator is ideally removed under anesthesia which also allows manipulation to increase range of motion. This should be followed by a gradual increase in weight bearing and a home physiotherapy program. Once motion has been restored, ligament reconstruction can be performed for any remaining laxity.

In the high resource setting, external fixation is a useful way to immobilize knees with extensive soft tissue or vascular injuries or if bracing is not an option due to high BMI or multitrauma. A highly constrained hinged external fixation construct is an alternative but needs to recreate the center of rotation of the knee and is expensive. Gradual closed correction of a neglected knee dislocation using an Ilizarov or hexapod- type circular external fixator is an attractive option as it minimizes soft tissue damage and devascularization. Following the gradual correction, the frame can be converted to a hinged system, thus allowing range of motion while providing a level of constraint superior to a brace [36, 37]. In the LRS, the indications for external fixation are widened and can result in a decreased need for future ligament reconstruction.

Autograft options

The greater the ligament involvement, Schenck Classification KDIII & KDIV, the greater the need for eventual reconstruction. In high resource settings, most KD ligament reconstructions are performed using allograft tissue although some patients will refuse allograft based on personal or religious beliefs [38-40]. In LRS, allografts are not readily available and multiligament reconstructions must be performed using only autograft. The surgeon must evaluate what autografts are available. The readily available autografts include the ipsilateral and contralateral bone patellar tendon (BTB), quadriceps tendon (QT) and hamstring tendons (semitendinosus and gracilis). Use of both the BTB and QT from the same knee should be avoided to

minimize the risk of patellar fracture. Thus there are usually 4 readily available autografts for reconstruction of the ACL, PCL and collateral ligaments.

ACL reconstruction can be performed using any of the autografts outlined above. The choice of autograft will be determined by the number of ligaments requiring reconstruction as well as surgeon preference. We prefer a single bundle reconstruction of the PCL anterolateral bundle in most KD's. The use of a QT with a long tendon harvest allows for a large graft with easier passage into the tibial tunnel. The ability to perform a double bundle PCL reconstruction is somewhat limited with KDIII or greater injuries, but can be performed if collateral ligament reconstructions are not required.

Early repair of collateral ligament avulsions can be successful but studies have shown a higher failure rate with primary repair compared to reconstruction (40% failure repair vs 6% reconstruction) [41]. However, some of these studies are limited by the fact that the collaterals were repaired first and then a delayed reconstruction (several months later) of the cruciates was performed, thus limiting some of the conclusions that can be drawn. For the posteromedial corner, we use a doubled semi-tendinosus autograft to reconstruct the superficial MCL and an imbrication of the posteromedial capsule to tighten the posterior oblique ligament (POL)[42]. This technique avoids the need for an additional POL graft. Posterolateral corner (PLC) reconstructions can be performed using techniques described by LaPrade or Arciero. A recent biomechanical study showed these to be equally effective; however the Arciero reconstruction requires only a single semitendinosus graft, whereas LaPrade's technique requires an additional gracilis graft [43]. Another option for the posterolateral corner is performing a biceps tenodesis. Fanelli has reported good results with this procedure [44]. Importantly, only half of the biceps tendon should be used to avoid excessive weakening of a dynamic varus stabilizer.

The MPFL is often torn in KDIIIM injuries. While the MPFL frequently heals during the initial stages of treatment, there are scenarios with a KDIIIM that present with a chronically subluxated patella. In such instances, a lateral release is usually required to center the patella and a medial retinacular reefing or MPFL reconstruction with gracilis tendon is necessary to stabilize the patella.

Another graft which has gained interest more recently is the peroneus longus tendon. It is accessed with minimal dissection 2cm proximal to the lateral malleolus and runs posterior to the peroneus brevis musculature. A tendon stripper can be advanced up to around 5cm distal to the fibular head to avoid damage to the common peroneal nerve. A consistent diameter (6-8mm single strand) throughout its length of 20-25cm provides an excellent graft, with equal superior tensile strength compared to more commonly used grafts. It has been described for use in ACL, PCL and PLC reconstruction with minimal donor site morbidity [45,46].

Use of autografts for ligament reconstruction can be summarized as follows:

PCL: Ipsilateral quadriceps harvest with bone plug to give added length to allow for spanning from tibial tunnel to femoral tunnel. As noted above, the use of a single bundle PCL reconstruction may be preferable with the greater number of ligaments involved.

ACL (in the presence of a deficient PCL): contralateral harvest of the quadriceps tendon or ipsilateral/contralateral harvest of the semi-tendinosus. Use of a five or six strand construct is preferable in using hamstrings for the ACL reconstruction. If MCL or PLC is injured then use of the contralateral hamstrings is required to reconstruct both the ACL and the associated collateral. Injury to both corners and both cruciates requires either the use of a biceps femoris tenodesis laterally (and both pairs of hamstrings, each for the ACL and MCL-corner) or both pairs of hamstrings (ipsilateral and contralateral) with a contralateral quadriceps harvest for the ACL (Fig. 3).

Neglected knee dislocations

The neglected KD is an extremely rare but challenging condition to treat, without consensus regarding the optimal treatment and literature limited to small case reports. No clear definition for neglect or chronicity of a KD exists, with case reports describing a time frame ranging from 4 months to 30 years post initial injury [47, 48]. Delayed presentation or neglected KD's are sometimes seen in rural areas or in LRS. Patients with limited access to care attempt to manage the problem with a brace so that they can continue to work to support their family. When the patient reaches the provider, there is often significant disability such that a non-surgical approach is rarely suitable. The main treatment goals should be to achieve a stable reduction, adequate range of motion, and acceptable function all while minimizing potential complications and disability. There are three significant presentations: a subacute locked PL-KD, a chronically subluxed knee, or a knee with functional instability that requires ambulatory aid such as a cane and a makeshift brace.

The presence of a delayed PL-KD is often fraught with complications with ligament reconstruction. The MCL complex is often completely necrotic and frequently extensive releases are required to realign the tibiofemoral and patellofemoral joints, often with resultant loss of reduction or infection. If the neglected dislocation is associated with significant shortening, care should be taken during reduction and surgery to avoid excessive stretching of vascular structures. Two of the authors treated an unpublished case with corrective knee arthrodesis after which the patient developed vascular compromise which resulted in limb loss. According to a post-operative angiogram, this was due to a partial occlusion of stretched popliteal vessels rather than an intraoperative vascular injury

In many scenarios and depending upon patient requirements and financial obligations the decision often is between total knee arthroplasty (TKA), knee fusion or amputation (Fig. 4). In most HRS, knee fusion is unacceptable in the patient's mind and TKA is performed. In LRS, TKA can be performed in middle-aged patients with chronic painful subluxation, but the cost and lack of availability of higher constrained prostheses to reduce the high rates of redislocation following

Table 2: Indications for external fixation in knee dislocations

Open knee dislocation
Vascular repair (or injury)
Compartment syndrome
Failure to maintain joint reduction
Inability to brace extremity
Multitrauma

arthroplasty present challenges [49, 50]. In the LRS, knee fusion is an extremely useful single reconstructive effort that limits infection and creates a painless functional limb with one single operation. The authors preferred method of fixation with arthrodesis is a long intramedullary interlocking nail due to the advantageous biologic and rigid fixation (Fig. 5 & 6). Above knee amputation should be avoided in LRS because of limited access to prosthetic wear and the resulting functional limitations. In those scenarios with concomitant infection, curing the infection followed by fusion is best recommended. There are the rare scenarios where the neglected PL-KD complicated by infection can be cured of the osteomyelitis and get long-term functionality with a total knee replacement (Fig. 7 & 8).

Conclusion

The KD in the LRS is an important challenge for looking at injuries from a global perspective. The identification of vascular injuries with clinical examination (absent pulses) and simple angiography are critical for limb salvage. Use of plain radiographs without access to MRI is often required and identification of injuries must be made using physical exam. Non-operative treatment can provide functional stability for some patients. A small number of patients benefit from early surgical intervention. Most patients are best treated in a staged fashion. In the setting where reconstructions can be performed, reconstructions using all autograft tissue can be rewarding to the patient and the surgeon with careful preoperative planning. The neglected KD with chronic subluxation is difficult to reconstruct and often results in a knee fusion.

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