CURRENT CONCEPTS REVIEW

Ultra-low velocity knee dislocation in obese and morbidly obese patients: a current concepts review

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Abstract

As the prevalence of obesity continues to rise, there has been an increase in the number of ultra-low velocity knee dislocations within the obese population reported in the literature. These injuries are often referred to as 'ultra-low velocity knee dislocation' since they commonly occur during activities of daily living (e.g., same-level fall, stepped off curb, tripped on carpet). As a result, these injuries are often underappreciated and initially misdiagnosed. Even though these injuries are regarded as low velocity, a high magnitude of force is still transferred through the knee joint to dislocate the knee. Knee dislocation in obese and morbidly obese patients is associated with a particularly high rate of neurovascular injury. A low velocity knee dislocation is an orthopaedic emergency; therefore, evaluating physicians should maintain a high index of suspicion for a knee dislocation in any obese or morbidly obese patients who present with knee pain following a seemingly innocuous injury. Vascular injuries must be managed by a vascular team. Orthopaedic management of these injuries is still controversial. There is currently no consensus on the ideal orthopaedic treatment of the knee dislocations in the obese and morbidly obese patient. Operative management may be associated with more complications, such as a higher rate of neurovascular injury, increased surgical complications, and poor subjective patient outcome scores compared with non-obese patients sustaining a high velocity knee dislocation.

Level of evidence: 5

Keywords: knee dislocation, low velocity, obese, diagnosis, ultra-low velocity, neurovascular injury, management, outcomes, complications, multi-ligament knee injury

Introduction

Knee dislocation is defined as the disruption of the integrity of the tibiofemoral joint, while a multi-ligamentous injured knee (MLIK) is defined as the rupture of at least two of the main four knee ligament stabiliser group.[1,2] Historically, knee dislocations have been classified as high velocity or low velocity injuries.[3] High velocity injuries result from high energy such as motor vehicle accidents, pedestrian vehicle accidents and falls from heights, while low velocity injuries are reported most commonly during sports and, occasionally, low falls. More recently, a trend has been noted for knee dislocations in obese and morbidly obese patients resulting from a low velocity injury mechanism. The first case report of such an injury was published in 1990 by Marin et al., comprising two morbidly obese females who sustained a knee dislocation after a simple fall.[4] Since this initial report, several small case reports have emerged. The largest case series of 17 patients by Azar et al. in 2011 was the first to coin the term 'ultra-low velocity (ULV) knee dislocation', separating them from sporting injuries and high velocity trauma mechanisms.[5] All these dislocations occurred during activities of daily living (e.g., same level fall, stepped off curb, tripped on carpet) and all were in patients with a body mass index (BMI) ranging from 30 to 68. As the prevalence of obesity continues to rise and has reached the younger population, so has ULV knee dislocation become more frequent in this patient population.[6] BMI is an indirect calculation of body fatness. It is the ratio of a person's weight in kilograms divided by height in metres squared.[6-8] A BMI of less than 25 is considered normal, 25–29 is considered overweight, over 30 is considered obesity, and 40 or more is considered extreme obesity. This has also been called class 3 obesity, 'severe' or 'extreme' obesity, and 'morbidly' obese. Obesity definitions continue to expand and now a BMI of more than 50 is known as 'super obese'.[8,9] These injuries may have devastating neurovascular complications due to the proximity of crucial anatomical structures, and the significant magnitude of trauma required to dislocate a knee joint. As a result, physicians must maintain a high index of suspicion for concomitant limb-threatening injuries when evaluating a patient with a possible knee dislocation. The aim of this article is to review the existing literature on low velocity knee dislocations in obese and morbidly obese population groups, inclusive of diagnosis, management and outcomes (*Figures 1a and b*).

Epidemiology

Knee dislocation is a rare injury, comprising less than 1% of all orthopaedic injuries.[10] It occurs in younger patients with a male to female ratio of 4:1.[11] Approximately 50% are secondary to road traffic accidents (high velocity dislocations), approximately a third are sports injuries (low velocity dislocations) and nearly 10% are from simple falls (ULV dislocations).[12,13] Bilateral knee dislocations are rare, occurring in approximately 5% of patients. Isolated open knee dislocations have been reported as 5–17%, while 14–44% of cases are recorded in polytrauma patients.[10,12,13]

Mechanism of injury

Despite the increase in case reports published, no consistent definition for different mechanisms has emerged, and overlapping terminology has added to the confusion. Spontaneous, spontaneous non-traumatic, pathological, low velocity and ULV have all been used to describe knee dislocations in obese and morbidly obese patients.[5,14]

Even though ULV knee dislocations occur after a common daily activity, a large amount of force is still transferred through the knee joint to dislocate the knee.[3] This can be accomplished by increasing the velocity or mass. The laws of physics dictate that energy is proportional to mass times velocity squared ($E \propto MV^2$). Although obese patients have a low velocity injury, the large mass of the patient makes it a high energy injury, equivalent to that of a motor vehicle collision where the velocity is high but the patient mass is moderate or low. Furthermore, obese patients have been found to have displaced centres of mass and altered gait kinematics, placing them at increased risk of falls.[4,15,16] Therefore, a simple fall that results in a hyperextension moment can be sufficient to generate a large force vector to cause an anterior knee dislocation in an obese or morbidly obese patient. Stewart et al. 2014, demonstrated in their study that obese individuals are significantly more likely to sustain knee dislocations caused by a low energy mechanism, and with an associated increased complication rate of 9.2% for every one unit increment in BMI.[17] Laxity of the uninjured knee has been reported in these patients, suggesting that hyperlaxity also plays a role in knee dislocations in obese patients. The direction of dislocation is an indication of the force of the dislocation mechanism and has implications for concomitant injuries. Most reported ULV knee dislocations are anterior, likely caused by supraphysiologic loads and failure of the ligamentous and capsular restraints around the knee.[11,18]

Figure 1a. AP view of the left knee joint in a 38-year-old morbidly obese female with a low velocity knee dislocation

Figure 1b. Lateral view of the left knee joint of the same patient

Classification

Kennedy classification

An anatomical classification was proposed by Kennedy in 1963, based on the direction of tibial dislocation in relation to the femur, as follows:[19]

- anterior
- posterior
- lateral
- medial
- rotatory – anteromedial, posteromedial, anterolateral, and posterolateral

Although well established and attractive by virtue of its simplicity, this is an unreliable guide to specific patterns of injury and provides no guidance in terms of management.[20]

Anterior knee dislocations are the most common type of knee dislocation from this classification, with an incidence of around 40%, and are due to a forced hyperextension. Kennedy's cadaveric research demonstrated that at least 30° of forced hyperextension was required before an anterior dislocation occurred, with the mechanism being capsular rupture followed by rupture of the anterior cruciate ligament.[19,21] Anterior dislocations are associated with a higher likelihood of an intimal tear to the popliteal artery and subsequent arterial thrombus.

Schenck classification

Schenck proposed an alternative classification in 1994, which focused on the pattern of ligament injury with the presence or absence of an associated fracture.[22] The anatomic information provided by the classification was intended to guide treatment and assist clinicians preparing for ligament reconstruction or repair. Finally, the classification system was designed to better predict neurovascular complications associated with knee dislocations. A systematic review by Medina et al. found the highest rates of vascular injury in patients with knee dislocation (KD) IV injuries,[23] while Green et al. found the highest rates of vascular injury in KD III injuries.[24] Neither study found evidence of popliteal artery injuries in KD I or KD II injuries.[23-25]

Pattern of injury

The most common directions for a knee dislocations are anterior, posterior, medial and lateral.[2,26] Other rotatory combinations are less common and include anteromedial, anterolateral, posteromedial and posterolateral dislocations.[2] Medial (4%) and lateral (18%) dislocations are very rare and occur due to varus/valgus stresses.[2,26] Posterior dislocations (33%) are caused by application of a posterior force to the tibia as in a 'dashboard' type injury. Varus or valgus loads may produce medial (4%) and lateral (18%) dislocations.[27] KD III injuries are the commonest in terms of the Schenck classification system.[11]

Associated injuries

Vascular injury

The reported rate of associated vascular injuries with knee dislocations is variable, ranging from 25–30% of all knee dislocations.[10,24,28,29] Vascular injuries requiring surgical treatment occurred in 26–41% of ULV knee dislocations.[25] Azar et al. noted that patients with vascular injuries had a higher BMI than those

Figure 2. CT angiography of a 38-year-old morbidly obese female with a low velocity knee dislocation, associated with left popliteal artery injury

without, but did not reach statistical significance.[5] Morbidly obese patients have a higher odds ratio of vascular injury than non-obese patients, and obese patients had higher rates of open vascular repair (39%) than patients with high energy mechanisms (6%).[24,30] Georgiadis et al. reported that a greater percentage of obese patients sustained vascular injuries (33%) compared to non-obese patients (9%)[10,17] and were also more likely to have a popliteal artery injury requiring repair: vascular repair was required in 28% of patients with BMI > 30 kg/m^2 and in 39% of those with a BMI > 40 kg/m.[2,10] (*Figure 2*).

Neurologic injury

Reported rates of neurologic injury with knee dislocation have also varied widely, from 9–49%. Common peroneal nerve or tibial nerve injuries are reported in 39–41% of knee dislocations, with approximately half having return to normal function.[25] Obese patients and morbidly obese patients have higher rates of nerve injury (42% and 41%, respectively) than non-obese patients.[31] The highest reported rate of nerve injury occurred among morbidly obese patients with a low-energy mechanism, with seven of 13 (54%) having a nerve injury.[17] Common peroneal nerve injury is quoted as having an overall incidence of between 14% and 25%; less commonly, the tibial nerve may also be injured.[23,26,32] In dislocations with disruption of the posterior cruciate ligament (PCL) and posterolateral corner (PLC), the incidence of peroneal nerve injury may be as high as 45%. It occurs because of traction along the posterior aspect of the lateral femoral condyle.

Clinical evaluation and diagnosis

ULV knee dislocation is an orthopaedic emergency. These patients usually present with a chief complaint of knee pain after seemingly innocuous trauma, and the presence of obesity can often mask any obvious deformity around the knee (*Figure 3*). Knee dislocations are also difficult to diagnose because approximately 20–50% will spontaneously reduce before presentation.[10,13] Therefore, a thorough ligamentous examination is important when assessing an obese patient with knee pain after low energy trauma, and radiographs should be obtained on all patients. There is still significant controversy about the role of arteriography versus less invasive measures such as ankle-brachial index (ABI) to determine the vascular status of a patient after an ULV knee dislocation.[33] The first line in diagnosis should be a thorough physical examination with ABI measurements. McKee et al. reported 100% sensitivity, specificity, and positive predictive value for significant arterial injury

Figure 3. Clinical picture of the left knee joint in a morbidly obese patient. The presence of obesity can often mask any obvious deformity around the knee.

when patients were found to have an ABI less than 0.9.[1,4,11] ABI is a useful tool for the initial evaluation of suspected vascular injury in low velocity knee dislocation. However pre-existing peripheral vascular disease may render it less reliable; thus, positive results must always be confirmed with additional imaging.[8,9] Duplex sonography (DUS) is widely used in the setting of trauma. Accessibility, low cost, easy mobility, non-invasiveness and lack of ionising radiation are its advantages.[8,20] Luminal narrowing, hypoechoic intramural haematoma, dissected arterial wall, haemodynamic relevant stenosis, the 'yin-yang' sign (pseudoaneurysm) and occlusion are the features consistent with vascular injury.[8] With the addition of colour Doppler, the sensitivity, specificity and accuracy are up to 95%, 99% and 98%, respectively, in assessment of vascular injuries in knee dislocations.[8,20] Observation for 48 hours with routine examinations without arteriography has been shown to be safe in patients with a normal neurovascular examination and an ABI > 0.9. The selective use of arteriography has been recommended because of a potential delay in treatment of popliteal artery injuries, and many algorithms have been proposed to determine the necessity of arteriography after knee dislocation. Smith et al. proposed a selective arteriography protocol that begins with reduction of the dislocation and physical examination after reduction.[14] If hard signs of a vascular injury are present (e.g., active haemorrhage, distal ischaemia or expanding pulsatile haematoma), immediate surgical exploration is performed with or without preceding arteriogram at the discretion of the surgeon. If a distal pulse is present and the limb is well perfused with an ABI > 0.9, the patient is admitted for close observation and serial physical examinations by the physician for at least 24 hours. If asymmetric pulses and a well-perfused limb with an ABI of < 0.9 are present, an angiogram is obtained.[21,33]

Management

Initial treatment

Once a patient has been diagnosed with an ULV knee dislocation, a closed reduction should be performed immediately under conscious sedation. A neurovascular examination should be completed and documented before and after reduction of the knee joint. Ligamentous examination should be performed once the knee is reduced, and a brace or well-padded splint is fitted with the knee in 30–40° of flexion. If the reduction cannot be maintained in a splint or brace, an external fixator (knee spanning) should be applied in the operating room. The main indications for initial spanning external fixation were significant vascular injury, gross instability on examination with failure to maintain joint reduction, and open knee dislocation.[1,2,15] The timing between vascular reconstruction and the placement of an external fixator remains controversial. Some authors recommend the placement of an

Figure 4. Clinical picture of the left knee joint in a morbidly obese patient, with a knee-spanning external fixator of the knee joint

external fixator after vascular exploration or repair. This reduces the ischaemic time and allows knee flexion, which is critical for medial popliteal exposure by the vascular surgery team. However, other authors recommend the use of external fixation before definitive arterial repair and the presence of a vascular surgeon to assist with planning the placement of external fixation. There are currently no recommendations regarding the optimal timing pertaining to the removal of the external fixator in cases with an associated vascular injury (*Figures 4 and 5*).

Definitive treatment

There has been considerable debate regarding the most appropriate technique to manage these difficult injuries. The recent literature has provided some solutions. However, there remain several unresolved considerations.

Operative versus nonoperative management

Several studies have compared operative and nonoperative management of ULV knee dislocations. Azar et al. reported that patients who underwent ligament reconstruction demonstrated better Hospital for Special Surgery scores (HSS), than those treated without reconstruction.[5] Operative treatment of these cases has been shown to result in a better range of motion, decreased flexion contracture, and better Lysholm scores; however, patients may still have a significant disability.[4,16,34] Multiligamentous reconstruction in the obese or morbidly obese population is associated with several challenges including longer operative procedures, need for special equipment (e.g., bariatric table), and difficulty with positioning. Operative times have been reported to be significantly longer (5 hours compared to 2.5 hours) when obese and morbidly obese patients were matched to patients with similar surgery and BMIs between 20 and 30 kg/m,[2,34] respectively.

Timing of surgery

Timing of surgery is often determined by the severity of ligamentous injury, the vascular status of the extremity, the overall degree of instability, post-reduction stability, and status of the skin and soft tissue.[2,35] There is increasing consensus that surgical intervention for isolated knee dislocation injuries should be performed early (within two to three weeks), compared with delayed reconstruction (greater than three weeks from the initial

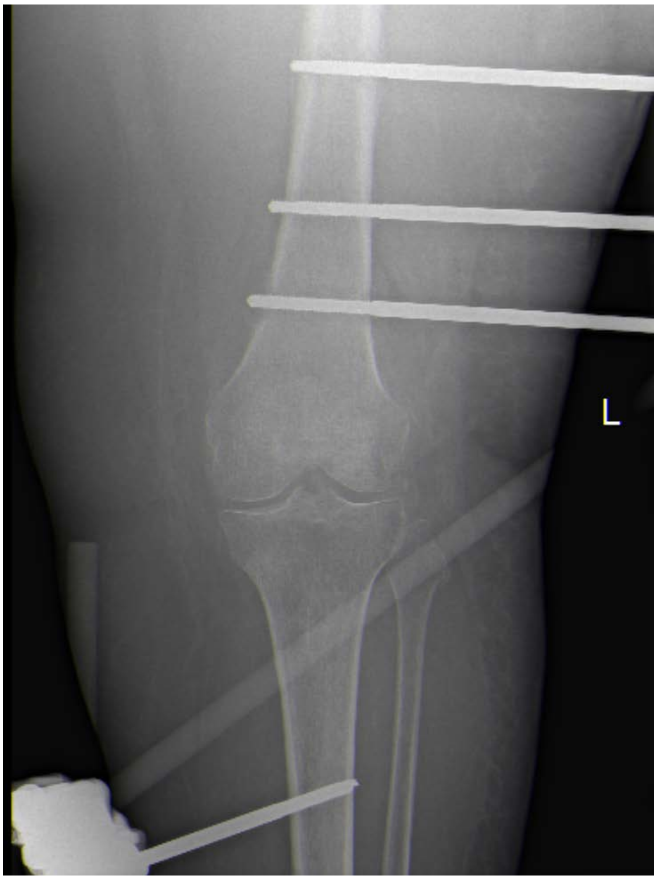

Figure 5a. AP view of the left knee joint in an obese patient; postoperative image of a knee-spanning external fixator

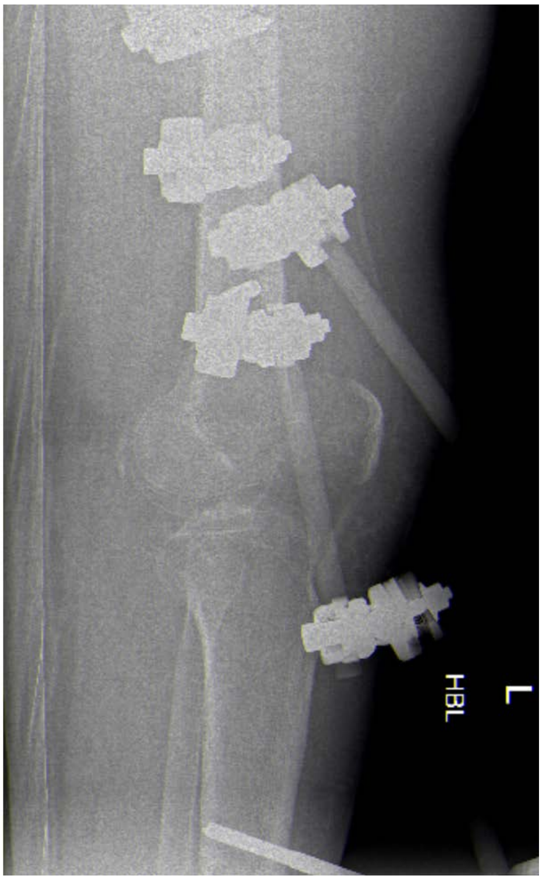

Figure 5b. Lateral view of the left knee joint; postoperative image of a knee-spanning external fixator

injury).[27,35-37] Recent systematic review of early versus delayed surgery found significantly better outcomes for early intervention, regarding range of motion, standardised knee function scores, and patient satisfaction.[31] However, these studies did not differentiate between obese and non-obese patients, and it is likely that the patients treated in a delayed fashion had more severe concomitant injuries that dictated a delayed intervention.

Surgical technique

The selection of arthroscopic versus open reconstruction in ULV knee dislocation depends on the timing of surgery as well as the structures involved. PLC, MCL and PMC require open reconstruction given their subcutaneous nature and proximity to neurovascular structures.[15,34] No randomised trials have compared open versus arthroscopic reconstruction after knee dislocation, thus the advantages of either are theoretical. Coexisting injuries that require open repair, such as fractures, popliteal artery injuries and compartment syndrome, may dictate a more aggressive open approach. Arthroscopy allows for evaluation and treatment of concomitant intra-articular pathology, including cartilage damage and meniscal tears. Arthroscopic management may also allow for a smaller infection rate compared with open knee reconstruction. Open reconstruction is usually reserved for lateral collateral ligament/PLC and MCL/PMC reconstructions. A wide variety of surgical techniques have been described in the management of these injuries. The most important principle is to define the components contributing to the instability and to reconstruct the primary restraints as anatomically and isometrically as possible.[35] Specific attention to reconstruction of the PLC may be most important in improving outcomes in this population.[5,15,34]

Postoperative external fixation versus hinged knee bracing

Prior to surgery, there may be difficulty in obtaining braces or stabilising the knee without external fixation, while postoperatively there may be difficulty in fitting custom braces to patients. The benefits of postoperative reconstructive spanning external fixation have been described by many authors. The postoperative external fixator helps to protect the graft tissue from excessive force. The Compass Knee Hinge (CKH) (Smith & Nephew, Memphis, TN) is a hinged, multiplanar, external fixator that can be applied at the isometric point of the knee joint.

Outcomes

Surgical reconstruction leads to improved subjective and objective results in patients with ULV knee dislocation. These patients may have low postoperative activity scores, reflective of their preoperative activity status. Despite improved objective outcomes with surgery, many patients with ULV knee dislocation do poorly overall, with 71% in one study describing themselves as 'dissatisfied' or 'extremely dissatisfied' with their results after ligamentous reconstruction.[16] There are three recent studies that have analysed outcomes in a relatively large cohort of patients following ULV knee dislocations.[5,10,16] Azar et al. published the first large case series of ultra-low velocity knee dislocations in 17 patients.[5] Less than half of their patients underwent ligamentous reconstruction (8 of 17 patients). Most patients reported 'poor' or 'fair' outcomes scores. However, those who underwent reconstruction had higher standardised knee outcome scores at an average follow-up of 28.5 months. Many complications were noted within the cohort, occurring in 47% of the patients. These included deep and superficial infection, surgical incision breakdown, postoperative arthrofibrosis, above-knee amputation in two patients, and mortality in one patient within seven days postoperatively.[5] Werner et al. also published a large cohort of 215 patients who experienced knee dislocations, of which 23 patients met the criteria for ULV knee dislocation. All patients underwent ligamentous reconstruction with no amputations or mortalities, yet there was a high rate of complications, which included knee stiffness, wound infection, persistent instability, deep vein thrombosis, vascular claudication, and pulmonary embolism.[16] Georgiadis et al. also compared the presentation and outcomes in obese patients experiencing low velocity knee dislocation versus those experiencing high velocity knee dislocation over a 17-year period.[10] A total of 53 patients were analysed, with 28 patients sustaining high velocity knee dislocation and 25 patients sustaining a low velocity knee dislocation. Eighteen of 25 patients in the low velocity knee dislocation group experienced an ULV knee dislocation. These ULV knee dislocation patients were more likely to have nerve injuries (50 vs 6%) and vascular surgical repairs (28 v 6%) than patients with high velocity knee dislocations.[10,16]

Complications

Despite improved outcomes with surgery, most patients with ULV knee dislocations do poorly overall. Reported complication rates can be as high as 47%.[4]

- Arthrofibrosis and loss of motion – Arthrofibrosis and loss of motion are frequently up to 40% after ULV knee dislocations in obese patients.[5,16]
- Recurrent instability – Werner et al. reported graft failure and instability in two of 17 patients with ULV knee dislocations,[16] and Vaidya et al., in a report of 18 patients, described late anterior cruciate ligament (ACL) reconstruction because of ongoing instability.[34]
- Thromboembolic complications – Rates of deep vein thrombosis (DVT) in ULV knee dislocations are infrequently reported; an incidence of 3.5% has been reported in studies that include all mechanisms of knee dislocations.[5] Postoperative thromboprophylaxis has been shown to be effective in patients with knee dislocations.[5,14]
- Amputation – Like other complications, amputation rates after ULV knee dislocations vary significantly. Among all knee dislocations in a large case series, the rate of amputations was reported to be 9.2%, with an increased risk following open or high energy injury. Smaller case series of ULV knee dislocations in obese patients report amputation rates of 12–28%.[14,16]

South African context

Little doubt exists of a rising trend in BMI and consequently, in the prevalence of overweight and obesity in the South African population. In 2008, the average BMI at population level was estimated at 26.9 kg/m^2 among males (versus a world average of 23.8 kg/m^2), and 29.5 kg/m^2 among females (versus a world average of 24.1 kg/m^2). The rate of growth, calculated over the period between 2000 and 2008, was 2.9 kg/m^2 per decade for males and 1.6 kg/m^2 per decade for females. These high values of BMI and seemingly increasing growth rates have an obvious correspondence with a large and rapidly increasing proportion of people becoming overweight or obese. As the rate of obesity continues to increase, it has been postulated that the incidence of these ULV knee dislocations will also continue to increase. There is a paucity of research on the incidence and management of ULV knee dislocation injuries in South Africa. Held et al. looked at the frequency of popliteal artery injuries and incidence of early limb loss in 96 cases of knee dislocation in a single trauma unit at a tertiary care hospital in South Africa over a period of 12 years (2000–2012).[38] In their study, the incidence of vascular injuries in knee dislocations reached nearly 30%. The risk of amputation in knee dislocations with an associated popliteal artery injury was approximately 25%, and greater than 50% in patients who presented with a threatened limb.[38] A prioritised list of the most important challenges in the management of acute knee dislocations was established through a modified Delphi consensus study.[37] From the list of challenges generated, consensus was reached for postoperative stiffness, obesity, delayed presentation and associated common peroneal nerve injuries.[37]

Conclusion

ULV knee dislocations frequently occur after innocuous trauma, yet these injuries should still be considered high energy. Given the high frequency of associated neurovascular injuries, these injuries must be treated as an emergency to minimise the risk of limb-threatening complications. There is evidence that increasing BMI correlates with a significant risk of neurovascular injuries as well as other complications. Given the size of the limb, maintenance of reduction in these patients almost always requires external fixation. While surgery may be technically challenging, surgical reconstruction leads to improved subjective and objective results. Discussion with the patient should focus on limited expectations of an optimistic outcome and the high complication rates because of the nature of their injury. Randomised, prospective studies for surgical timing and surgical techniques are currently lacking and further research into this specific entity is required.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010. Ethics approval was not obtained (review article).

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

SM: literature review, epidemiology, technical and surgical factors, external knee spanning fixator, outcomes, complications, South African context, first draft preparation, manuscript preparation

PR: contributed to conceptualisation, literature review, technical and surgical factors, first draft preparation

BP: literature review, epidemiology, technical and surgical factors, outcomes, first draft preparation, manuscript preparation

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