

# Practical Management of Knee Dislocations: A Selective Angiography Protocol to Detect Limb-Threatening Vascular Injuries

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**Abstract:** Knee dislocations are relatively uncommon but potentially catastrophic injuries. In athletes, these injuries generally result from high-energy traumatic mechanisms such as collisions in football and rugby, high-velocity falls in skiing, and falls from heights in gymnastics and extreme sports. Knee dislocations are frequently associated with coincident neurological or vascular injuries. Recognition of vascular injury is particularly challenging because vascular compromise may not be immediately associated with clinical signs of ischemia and may result from injuries without complete or evident dislocation. This article reviews the rationale behind selective angiography, adjunctive vascular testing, and the need for observation after multiligament knee trauma. An algorithm for the diagnosis of vascular injuries is presented.

**Key Words:** knee dislocation, multiple ligament knee injury, popliteal injury, selective arteriography

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## INTRODUCTION

Traumatic knee dislocations are relatively uncommon orthopedic injuries and are often the result of high-velocity trauma. The most frequently reported mechanism of injury is motor vehicle accidents. No detailed data regarding the incidence and mechanism of this injury in athletes has been reported in a large series. However, many believe that the prevalence of this injury is increasing in the athletic population.<sup>1</sup> This may be a result of an increase in the size, strength, and speed of the modern athlete leading to higher collision forces or an increase in the popularity of extreme sports that places participants at risk for sustaining high-velocity falls from heights.

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Multiple ligament knee injuries may have devastating consequences, particularly in the setting of unrecognized vascular compromise. The incidence of popliteal artery injury after knee dislocation has been estimated as high as 40%,<sup>2</sup> a concerning statistic given that studies have shown that delayed recognition of an occlusive injury beyond 8 hours is likely to result in above the knee amputation.<sup>2,3</sup> Traditionally, the liberal use of angiography was recommended in any patient with known or suspected knee dislocation in an effort to avoid missing or delaying the diagnosis of an associated vascular injury.<sup>4–10</sup> Currently, many authorities advocate for the use of selective angiography protocols based on physical examination findings. Though these protocols vary with respect to the time of observation required, frequency of physical examination, and whether adjunctive tests such as ankle brachial indices (ABIs) or duplex ultrasonography are used, they have been generally successful in their ability to rule out clinically significant vascular injury.<sup>11–19</sup> Despite the reported success of these protocols, delays in the diagnosis of surgically significant vascular injury continue to occur, and many patients with knee dislocations are not receiving an adequate vascular evaluation. The aim of this article was to review the basis for selective angiography after multiligament knee injury and present a simple protocol for detecting limb-threatening vascular injury in patients with knee dislocation based on the current best evidence.

## MULTILIGAMENT DISRUPTION AND VASCULAR INJURY

Knee dislocation is defined as a complete loss of the tibiofemoral articulation. However, an unknown number of these injuries spontaneously reduce, making the clinical diagnosis difficult.<sup>20</sup> In fact, it is unnecessary for the knee to have completely dislocated for an injury to the intimal wall of the popliteal artery to develop. In the senior author's (CJW) experience with 86 multiligament knee injuries treated between August 2004 and October 2008, vascular compromise occurred in 6% of traumatic injuries in which only 2 ligaments were torn. Specifically, vascular injuries can occur in patients with bicruciate injuries or simultaneous tears of the anterior cruciate ligament (ACL) and lateral collateral ligament (LCL). Of all magnetic resonance imaging–documented 2-ligament injuries treated, the only pattern not associated with a vascular injury was concomitant tears of the ACL and medial collateral ligament (MCL).<sup>21</sup> With 2 ligaments disrupted, the knee can be

difficult to examine due to patient discomfort and gross rotational and coronal plane instability that can be difficult to isolate to the lateral or medial side. Therefore, when substantial laxity of 2 or more of the major ligaments of the knee is found, a presumptive diagnosis of knee dislocation should be made.<sup>8</sup>

The most devastating consequence of multiligament knee injury is popliteal artery damage, which may occur in 10%–40% of knee dislocations.<sup>18</sup> The high incidence of popliteal artery injury is due to its proximity to the knee joint and its anchored attachments at the adductor canal cephalad and by the fibrous arch of the soleus muscle caudad, restricting its ability to stretch.<sup>18</sup> Timely diagnosis of an associated vascular injury is of the utmost importance in patients with knee dislocations, as previous studies have shown that recognition of an occlusive injury beyond 8 hours is likely to result in irreversible limb ischemia and above the knee amputation.<sup>2,3</sup>

## MAKING THE DIAGNOSIS OF VASCULAR INJURY ASSOCIATED WITH MULTILIGAMENT DISRUPTION

### Physical Examination

When substantial laxity of 2 or more of the major ligaments of the knee is found, a diagnosis of knee dislocation should be considered and careful examination of the vascular status of the limb must be undertaken. Palpation of the dorsalis pedis and posterior tibial pulses are an essential part of this examination, and any asymmetry detected between limbs should alert the practitioner to the possibility of vascular injury. The palpation of pedal pulses when used as part of a protocol that includes serial physical examination performed by a physician over a period of observation of 23–48 hours has been shown to be highly sensitive and specific in detecting vascular injury associated with knee dislocation.<sup>17,18</sup> It must be emphasized, however, that an initial palpation of pedal pulses alone is inadequate to rule out limb-threatening vascular injury in this group of patients.<sup>20</sup> Numerous reports exist in which patients who had initially normal pulses after a knee dislocation were ultimately diagnosed with an associated limb-threatening vascular injury. In fact, estimates suggest that this may occur in as many as 5%–15% of knee dislocations through delayed expansion of an intimal tear.<sup>5,6,20,22–24</sup>

### Selective Arteriography

Arteriography has long been considered the gold standard for detecting any limb-threatening vascular injury after knee dislocation and historically has been performed in all patients suspected of having sustained this injury.<sup>4,5,7–9</sup> However, this diagnostic test is costly, invasive, and carries the risk of contrast dye allergic reactions and renal toxicity and may delay surgical intervention. Consequently, its value has recently been challenged by a number of authors who promote selective angiography protocols with use of the physical examination as the primary screening tool for vascular injuries in patients with a knee dislocation.<sup>11–19</sup> Though these protocols vary somewhat with respect to the time of observation

required and frequency of physical examination and whether adjunctive tests such as ABIs or duplex ultrasonography are used, they have been successful in their ability to rule out clinically significant vascular injury. Traditional selective angiography protocols require admission to the intensive care unit for frequent neurovascular checks.<sup>17,18</sup> In the largest such study to date, Stannard et al<sup>18</sup> applied a selective angiography protocol to 126 patients with knee dislocation. Patients with hard signs of arterial injury, such as distal ischemia, active hemorrhage, or an expanding pulsatile hematoma, received an immediate arteriogram. Those without hard signs on physical examination were admitted for serial examinations over a 24-hour period. This protocol had a positive predictive value of 90%, a negative predictive value of 100%, a sensitivity of 100%, and a specificity of 99% for detecting surgically significant vascular injury in their group of patients.

### Ankle Brachial Index

The ABI is calculated after obtaining the systolic blood pressure values from all 4 extremities using a Doppler probe and a standard blood pressure cuff. The highest measured arterial pressure from the dorsalis pedis or posterior tibial artery is divided by the higher of the brachial arterial pressures from both upper extremities. This noninvasive, easily performed test provides an objective tool for practitioners to use when determining whether to obtain an arteriogram and may increase the accuracy of physical examination.<sup>24</sup> Mills et al<sup>24</sup> prospectively evaluated the value of ABI for diagnosing arterial injury after knee dislocation. In their study, they found 11 of 38 patients who required vascular surgical intervention had ABIs <0.90. No patients with an ABI >0.90 required intervention during their hospital stay. Importantly, they diagnosed 1 patient with surgically significant vascular injury who had normal pulses and no hard signs of vascular injury who would not have undergone arteriogram had ABI evaluation not been performed. In this study, the negative predictive value of having an ABI >0.90 was 100%. They also identified 3 patients who would have undergone unnecessary arteriography. This study is limited by its small number of patients and lack of long-term follow-up; however, it is currently the only study that prospectively evaluates the use of ABI in knee dislocation. The reader is cautioned that there have been reports of the delayed presentation of popliteal artery injury even with normal systolic ankle pressures after penetrating trauma,<sup>25</sup> and more studies are required to determine the effectiveness of ABIs to diagnose arterial injury in patients with knee dislocations.

### Duplex Ultrasonography

Occlusion of the popliteal artery occasionally has been reported immediately after ligament reconstruction.<sup>22,26</sup> This is thought to be the result of an unrecognized non-flow-limiting intimal tear, which occurred at the time of the injury, that either progressed to a flow-limiting tear or resulted in thrombosis. Duplex ultrasonography offers another noninvasive and less expensive alternative to arteriography with a comparable accuracy in detecting traumatic vascular injury, though no study specific to knee dislocations has been performed.<sup>27–29</sup> It

seems plausible, however, that duplex ultrasonography may be able to detect injury that may be non-flow limiting, which may go undetected by pedal pulse examination and/or ABI examination, and therefore may increase the sensitivity of a selective angiography protocol. Though every effort is made to avoid the use of a tourniquet when operating on patients with multiple ligament knee injuries, they are occasionally required. The stasis that results from the use of a tourniquet can further increase the risk of occlusion when an unrecognized intimal tear is present or in patients who have undergone previous vascular reconstruction. For this reason, we routinely obtain arterial duplex ultrasonography on all patients who require surgical reconstruction. Ultimately, more studies are needed to determine the role of this diagnostic test in the evaluation of knee dislocations.

**Authors' Recommended Protocol**

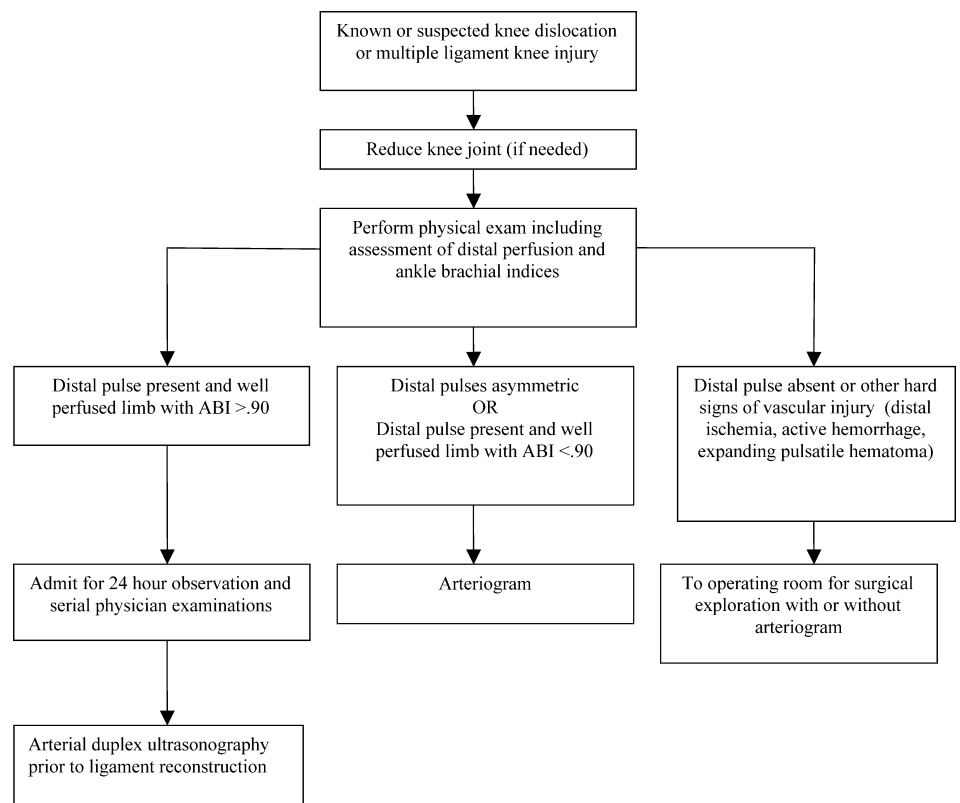
We recommend a simple to use algorithm to detect limb-threatening vascular injury after known or suspected knee dislocations (Figure 1). With the recommended protocol, patients with hard physical signs of vascular injury (expanding hematoma, absent pulses, hemorrhage, and bruit) receive an immediate intraoperative angiogram by the vascular surgeons. In the absence of hard physical signs of vascular injury, ABIs are performed. Those with ABIs <0.90 undergo emergent angiography to evaluate for vascular compromise. Conscious patients without hard signs and with normal ABIs (>0.90) can be observed for 24 hours outside the intensive care unit setting. If operative intervention of the extremity is anticipated, duplex

arterial ultrasonography is employed to confirm arterial patency and normal flow velocities. Intimal tears with no flow limitation identified with these noninvasive tools require observation.<sup>13,14,19,30,31</sup> For patients who present with a sub-acute knee dislocation (>24 hours after injury), vascular assessment including palpation of popliteal, posterior tibial, and pedal pulses, as well as obtaining ABIs is indicated; however, a period of further observation is likely not necessary. A table outlining the key management points for identifying and treating vascular injury associated with knee dislocation based on time of presentation is included (Table 1).

The reader is cautioned that conclusive evidence demonstrating that any selective angiography protocol is adequate for detecting all surgically significant vascular injury has yet to be presented. Given the disastrous consequences that may result should a delay in diagnosis occur, we continue to recommend formal angiography be considered in any patient with a knee dislocation who has an equivocal exam, and it is definitely warranted at institutions where evidence-based selective angiography protocols are unable to be followed.

**CONCLUSIONS**

Physicians must maintain a high degree of suspicion for arterial injury after any knee dislocation. Even if the initial physical examination is normal, the physician must take further measures to objectively rule out occult injury, such as ABIs or arterial duplex ultrasonography. Observation for a 24-hour period is warranted in all cases of knee dislocation



**FIGURE 1.** Recommended algorithm for the diagnosis of vascular injury following multiple ligament knee injuries. \*Modified from the University of Washington/Harborview Medical Center (Seattle, WA).

**TABLE 1.** Key Management Points for Identifying and Treating Vascular Injury Associated With Knee Dislocation Based on Time of Injury Presentation

Injury Presentation	Management Principles	Actions
On the field	<ol style="list-style-type: none"> <li>1. Stabilize the patient</li> <li>2. Diagnose the vascular injury</li> <li>3. Diagnose the knee dislocation</li> </ol>	<ol style="list-style-type: none"> <li>1. Activate EMS                             <ul style="list-style-type: none"> <li>● If a knee dislocation is known to have occurred or is suspected, the patient must be expeditiously transferred to a hospital equipped to deal with knee dislocations and their associated injuries. <b>Even if the vascular examination is normal, these patients require further evaluation in the emergency department and need to be observed for at least 24 h.</b></li> </ul> </li> <li>2. Assess ABC's                             <ul style="list-style-type: none"> <li>● Knee dislocations are commonly the result of high-energy trauma and are often associated with other severe injuries. These must be identified and treated primarily.</li> <li>● Palpation of bilateral posterior tibial and dorsalis pedis pulses must be performed. Any asymmetry should alert the provider to possible vascular injury.</li> <li>● <b>If no pulse is palpated and the knee is grossly dislocated an attempt at reduction is warranted.</b> This may result in re-perfusion of the extremity.</li> </ul> </li> <li>3. Knee examination                             <ul style="list-style-type: none"> <li>● Often knee dislocations spontaneously reduce and may not present with a large effusion. This is due to the capsular disruption that occurs as a result of the injury.</li> <li>● Any combined ligamentous injury detected on physical examination should raise concern for knee dislocation and should be treated as such until proven otherwise. <b>Varus or valgus instability in full extension and exaggerated hyperextension of the knee generally only occur with combined ligament injuries and knee dislocation should be suspected in these cases.</b></li> </ul> </li> </ol>
Acute (<24 h) with obvious associated vascular injury	<ol style="list-style-type: none"> <li>1. Expedient reperfusion of the injured extremity</li> </ol>	<ol style="list-style-type: none"> <li>1. Reduction                             <ul style="list-style-type: none"> <li>● Reduction is performed by stabilizing the distal femur and applying longitudinal traction on the tibia. A medial skin dimple is indicative of a posterior lateral dislocation which is often irreducible by closed methods. This is a result of the medial femoral condyle becoming trapped in the capsule or extensor mechanism. After reduction, the knee should be immobilized in 15 degrees of flexion to prevent resubluxation or dislocation.</li> </ul> </li> <li>2. Facilitate surgical management                             <ul style="list-style-type: none"> <li>● If the patient continues to have no palpable distal pulses despite reduction or has hard signs of vascular injury (active hemorrhage, expanding pulsatile hematoma), care must be coordinated to avoid a delay in revascularization. Ischemic injury of greater than 8 h leads to a high likelihood of above the knee amputation. <b>Emergency department evaluation must be efficient and angiography, if necessary, should be performed in the operating room. Formal arteriography may delay surgical intervention.</b></li> </ul> </li> </ol>
Acute (<24 h), without obvious associated vascular injury	<ol style="list-style-type: none"> <li>1. Reduce knee joint if dislocated</li> <li>2. Evaluate for occult vascular injury</li> </ol>	<ol style="list-style-type: none"> <li>1. Reduction                             <ul style="list-style-type: none"> <li>● As above.</li> </ul> </li> <li>2. Vascular examination                             <ul style="list-style-type: none"> <li>● A thorough vascular assessment must be performed. This includes palpation of popliteal, posterior tibial, and pedal pulses, as well as obtaining Ankle-Brachial-Indices (ABI). <b>Patients with normal findings and an ABI &gt;0.90 should be admitted for observation for 24 h.</b> Patients with abnormal findings or an ABI &lt;0.90 require arteriography. (Figure 1).</li> </ul> </li> </ol>
Subacute (>24 h from injury), without obvious associated vascular injury	<ol style="list-style-type: none"> <li>1. Diagnose knee dislocation</li> <li>2. Evaluate for occult vascular injury</li> </ol>	<ol style="list-style-type: none"> <li>1. Diagnosis                             <ul style="list-style-type: none"> <li>● The diagnosis of knee dislocation and multiligament trauma is difficult, and, occasionally, these patients present days or weeks after their injury.</li> </ul> </li> <li>2. Vascular examination                             <ul style="list-style-type: none"> <li>● Vascular assessment including palpation of popliteal, posterior tibial, and pedal pulses, as well as obtaining ABIs is indicated. If examination and ABIs are normal, these patients do not require a period of further observation as most occult vascular injuries present within the first 24 h.</li> <li>● Arterial duplex ultrasonography should be obtained prior to any surgical intervention.</li> </ul> </li> </ol>

EMS, emergency medical services.

or multiligament injury in which a negative arteriogram has not been documented.

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### REFERENCES

- Brautigan B, Johnson DL. The epidemiology of knee dislocations. *Clin Sports Med*. 2000;19:387–397.
- Green NE, Allen BL. Vascular injuries associated with dislocation of the knee. *J Bone Joint Surg Am*. 1977;59:236–239.
- Patterson BM, Agel J, Swiontkowski MF, et al. Knee dislocations with vascular injury: outcomes in the Lower Extremity Assessment Project (LEAP) study. *J Trauma*. 2007;63:855–858.
- Bryan T, Merritt P, Hack B. Popliteal arterial injuries associated with fractures or dislocations about the knee as a result of blunt trauma. *Orthop Rev*. 1991;20:525–530.
- Gable DR, Allen JW, Richardson JD. Blunt popliteal artery injury: is physical examination alone enough for evaluation? *J Trauma*. 1997;43:541–544.
- McCutchan JD, Gillham NR. Injury to the popliteal artery associated with dislocation of the knee: palpable distal pulses do not negate the requirement for arteriography. *Injury*. 1989;20:307–310.
- Melton SM, Croce MA, Patton JH Jr, et al. Popliteal artery trauma. Systemic anticoagulation and intraoperative thrombolysis improves limb salvage. *Ann Surg*. 1997;225:518–527; discussion 527–519.
- Rihn JA, Groff YJ, Harner CD, et al. The acutely dislocated knee: evaluation and management. *J Am Acad Orthop Surg*. 2004;12:334–346.
- Rose SC, Moore EE. Trauma angiography: the use of clinical findings to improve patient selection and case preparation. *J Trauma*. 1988;28:240–245.
- Welling RE, Kakkasseril J, Cranley JJ. Complete dislocations of the knee with popliteal vascular injury. *J Trauma*. 1981;21:450–453.
- Abou-Sayed H, Berger DL. Blunt lower-extremity trauma and popliteal artery injuries: revisiting the case for selective arteriography. *Arch Surg*. 2002;137:585–589.
- Atteberry LR, Dennis JW, Russo-Alesi F, et al. Changing patterns of arterial injuries associated with fractures and dislocations. *J Am Coll Surg*. 1996;183:377–383.
- Dennis JW, Jagger C, Butcher JL, et al. Reassessing the role of arteriograms in the management of posterior knee dislocations. *J Trauma*. 1993;35:692–695; discussion 695–697.
- Kaufman SL, Martin LG. Arterial injuries associated with complete dislocation of the knee. *Radiology*. 1992;184:153–155.
- Kendall RW, Taylor DC, Salvian AJ, et al. The role of arteriography in assessing vascular injuries associated with dislocations of the knee. *J Trauma*. 1993;35:875–878.
- Martinez D, Sweatman K, Thompson EC. Popliteal artery injury associated with knee dislocations. *Am Surg*. 2001;67:165–167.
- Miranda FE, Dennis JW, Veldenz HC, et al. Confirmation of the safety and accuracy of physical examination in the evaluation of knee dislocation for injury of the popliteal artery: a prospective study. *J Trauma*. 2002;52:247–251; discussion 251–242.
- Stannard JP, Sheils TM, Lopez-Ben RR, et al. Vascular injuries in knee dislocations: the role of physical examination in determining the need for arteriography. *J Bone Joint Surg Am*. 2004;86-A:910–915.
- Treiman GS, Yellin AE, Weaver FA, et al. Examination of the patient with a knee dislocation. The case for selective arteriography. *Arch Surg*. 1992;127:1056–1062; discussion 1062–1063.
- Barnes CJ, Pietrobon R, Higgins LD. Does the pulse examination in patients with traumatic knee dislocation predict a surgical arterial injury? A meta-analysis. *J Trauma*. 2002;53:1109–1114.
- Nicandri G, Dunbar RP, Wahl CJ. Are appropriate protocols being utilized to identify vascular injury associated with knee dislocation? Paper presented at: AAOS Annual Meeting; February 25–28, 2009; Las Vegas, NV.
- Lohmann M, Lauridsen K, Vedel P. Arterial lesions in major knee trauma: pedal pulse a false sign of security? *Arch Orthop Trauma Surgery*. 1990;109:238–239.
- McCoy GF, Hannon DG, Barr RJ, et al. Vascular injury associated with low-velocity dislocations of the knee. *J Bone Joint Surg Br*. 1987;69:285–287.
- Mills WJ, Barei DP, McNair P. The value of the ankle-brachial index for diagnosing arterial injury after knee dislocation: a prospective study. *J Trauma*. 2004;56:1261–1265.
- Graham AN, Henderson SA, McCoy GF, et al. Delayed presentation of bilateral popliteal artery injury. *Eur J Vasc Surg*. 1992;6:673–676.
- Chapman JA. Popliteal artery damage in closed injuries of the knee. *J Bone Joint Surg Br*. 1985;67:420–423.
- Fry WR, Smith RS, Sayers DV, et al. The success of duplex ultrasonographic scanning in diagnosis of extremity vascular proximity trauma. *Arch Surg*. 1993;128:1368–1372.
- Bynoe RP, Miles WS, Bell RM, et al. Noninvasive diagnosis of vascular trauma by duplex ultrasonography. *J Vasc Surg*. 1991;14:346–352.
- Perron AD, Brady WJ, Sing RF. Orthopedic pitfalls in the ED: vascular injury associated with knee dislocation. *Am J Emerg Med*. 2001;19:583–588.
- Sawchuk AP, Eldrup-Jorgensen J, Tober C, et al. The natural history of intimal flaps in a canine model. *Arch Surg*. 1990;125:1614–1616.
- Wascher DC. High-velocity knee dislocation with vascular injury. Treatment principles. *Clin Sports Med*. 2000;19:457–477.