Vascular Injuries in Knee Dislocations: The Role of Physical Examination in Determining the Need for Arteriography

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Background: Popliteal artery injury is frequently associated with knee dislocation following blunt trauma, an injury that is being seen with increasing frequency. The primary purpose of the present study was to evaluate the use of physical examination to determine the need for arteriography in a large series of patients with knee dislocation. The secondary purpose was to evaluate the correlation between physical examination findings and clinically important vascular injury in the subgroup of patients who underwent arteriography.

Methods: One hundred and thirty consecutive patients (138 knees) who had sustained an acute multiligamentous knee injury were evaluated at our level-1 trauma center between August 1996 and May 2002 and were included in a prospective outcome study. Four patients (four knees) were lost to follow-up, leaving 126 patients (134 knees) available for inclusion in the study. The results of the physical examination of the vascular status of the extremities were used to determine the need for arteriography. The mean duration of follow-up was nineteen months (range, eight to forty-eight months). Physical examination findings, magnetic resonance imaging findings, and surgical findings were combined to determine the extent of ligamentous damage.

Results: Nine patients had flow-limiting popliteal artery damage, for an overall prevalence of 7%. Ten patients had abnormal findings on physical examination, with one patient having a false-positive result and nine having a true-positive result. The knee dislocations in the nine patients with popliteal artery damage were classified, according to the Wascher modification of the Schenck system, as KD-III (one knee), KD-IV (seven knees), and KD-V (one knee).

Conclusions: Selective arteriography based on serial physical examinations is a safe and prudent policy following knee dislocation. There is a strong correlation between the results of physical examination and the need for arteriography. Increased vigilance may be justified in the case of a patient with a KD-IV dislocation, for whom serial examinations should continue for at least forty-eight hours.

Level of Evidence: Diagnostic study, Level II-1 (development of diagnostic criteria on basis of consecutive patients [with universally applied reference "gold" standard]). See Instructions to Authors for a complete description of levels of evidence.

Knee dislocation or multiligamentous knee injury following high-energy trauma represents one of the most challenging injuries encountered by orthopaedic surgeons. Knee dislocations previously were described as rare injuries[1-7] but are being recognized with remarkably increasing frequency[1,4,5,8,9]. The reasons for this increase in diagnosis include a change in the definition of knee dislocations to include knees that have spontaneously reduced[4,5,8,9], the increased general speed of motor vehicles[1], and the routine use of magnetic resonance imaging to evaluate soft-tissue injuries about the knee. In addition to the obvious ligamentous damage, patients with knee dislocations frequently have many associated injuries. Wascher, in a report on patients with high-velocity knee dislocations, reported that the rate of life-threatening injuries involving the head, chest, or abdomen was 27%; the rate of associated fractures was 50% to 60%; and the rate of multiple fractures was 41%[9].

Injury to the popliteal artery is another problem that is frequently associated with knee dislocation. Our review of the literature demonstrated that the reported rate of popliteal ar-

TABLE I Revised Classification of Knee Dislocations Associated with Periarticular Fractures Based on Magnetic Resonance Imaging and Surgical Findings

Classification	Number of Knees
V.1	0
V.2	1
V.3M	4
V.3L	22
V.4	12

tery injury has ranged from 10% to 40%[2,3,7-12]. Many authors have advocated routine arteriography for any patient who is found to have a knee dislocation[2,4,5,13-19]. However, recent articles have questioned the routine use of arteriography and have made a case that it should be used selectively on the basis of the results of the physical examination[1,7-10,12,20,21]. Many of those articles represented small series in which angiograms were made for all patients and their findings were correlated with the results of the physical examination. The controversy surrounding the appropriate evaluation of the vascular status of patients who have a knee dislocation leaves the treating surgeon in a difficult situation, with the potential for a disastrous result if the diagnosis is missed.

The primary purpose of the present study was to evaluate the use of selective arteriography in a prospective series of patients with knee dislocation. The secondary purpose was to evaluate the correlation between physical examination findings and arteriographic findings. Our hypothesis was that the results of physical examination would accurately predict the occurrence of clinically important arterial injury.

Materials and Methods

One hundred and thirty consecutive patients (138 knees) who had sustained an acute multiligamentous injury were evaluated at our level-1 trauma center between August 1996 and May 2002 and were included in a prospective cohort study. In order to be included in this study and to be defined as having a knee dislocation, a patient had to have presented with a dislocated or a grossly unstable knee with tears of at least both the anterior and the posterior cruciate ligament as documented on a magnetic resonance imaging scan, with surgical confirmation of the pathology. All of the patients in this series were treated with surgical repair (if osseous avulsion had occurred) or reconstruction of the torn knee ligaments. The mean duration of follow-up was nineteen months (range, eight to forty-eight months). Four patients (four knees) were lost to follow-up, leaving 126 patients (134 knees) available for inclusion in the study. Eight patients had sustained a bilateral knee dislocation. Sixty-nine left knees and sixty-five right knees were involved. The study group included ninety male and thirty-six female patients with a mean age of 34.1 years (range, sixteen to seventy years). High-energy mechanisms of injury were very common, with the dislocation (or dislocations) resulting from a motor-vehicle accident in sixty-five patients, a motorcycle accident in twenty-one, a motor-vehicle-pedestrian accident in twenty, a high-energy fall in seven, an athletic injury in six, an equestrian injury in three, an assault in one, a crush injury in one, a boating accident in one, and a low-energy fall in one.

During the course of the study, the senior author (J.P.S.) utilized a protocol of selective arteriography for patients with multiligamentous knee injuries. The term selective arteriography is defined as the use of physical examination as the primary screening tool for vascular injuries in patients with a knee dislocation. Arteriography is selected only for patients with physical findings that are consistent with a vascular injury. Patients with (1) any decrease in pedal pulses, lower extremity color, or temperature on physical examination, (2) an expanding hematoma about the knee, or (3) a history of an abnormal physical examination prior to presentation in the emergency department underwent arteriography. In all cases, the initial vascular examination was performed by the orthopaedic resident on call, with subsequent serial examinations performed by orthopaedic residents and attending surgeons. The choice to follow this protocol or to perform arteriography in addition to the protocol was made at the discretion of the attending orthopaedic surgeon on call. The results of physical examination and arteriography (if performed) were recorded in a database. All patients underwent serial vascular examinations and were followed to identify vascular sequelae. Patients with normal vascular findings were admitted to the hospital for at least forty-eight hours. Serial examinations included neurovascular checks performed by nursing personnel every two to four hours, with a documented repeat examination by a surgeon at four to six, twenty-four, and forty-eight hours. Any deterioration in vascular status mandated immediate arteriography or surgical intervention. Patients with a bilateral knee dislocation were evaluated and were required to have symmetric and easily palpable pulses in order to qualify for serial examinations rather than arteriography.

The knee dislocations were classified, according to the anatomic system proposed by Schenck and modified by Wascher[9], as KD-I (dislocations associated with multiple-ligament injuries that did not include both cruciate ligaments), KD-II (dislocations associated with a bicruciate ligament injury only), KD-III (dislocations associated with a bicruciate ligament injury and a tear of either the posteromedial or posterolateral knee ligaments), KD-IV (dislocations associated with tears of both cruciate ligaments and both posteromedial and posterolateral ligaments), or KD-V (dislocations associated with a periarticular fracture and multiple-ligament injuries). We modified the classification further to delineate the ligament damage in patients with a KD-V dislocation by adding a number (1 through 4) to indicate which classification would be appropriate if the fracture were not present. Thus, the classification KD-V.2 would indicate the presence of a bicruciate injury in association with a periarticular fracture, and the classification KD-V.3M would indicate the presence of tears of the anterior cruciate ligament, posterior cruciate liga-

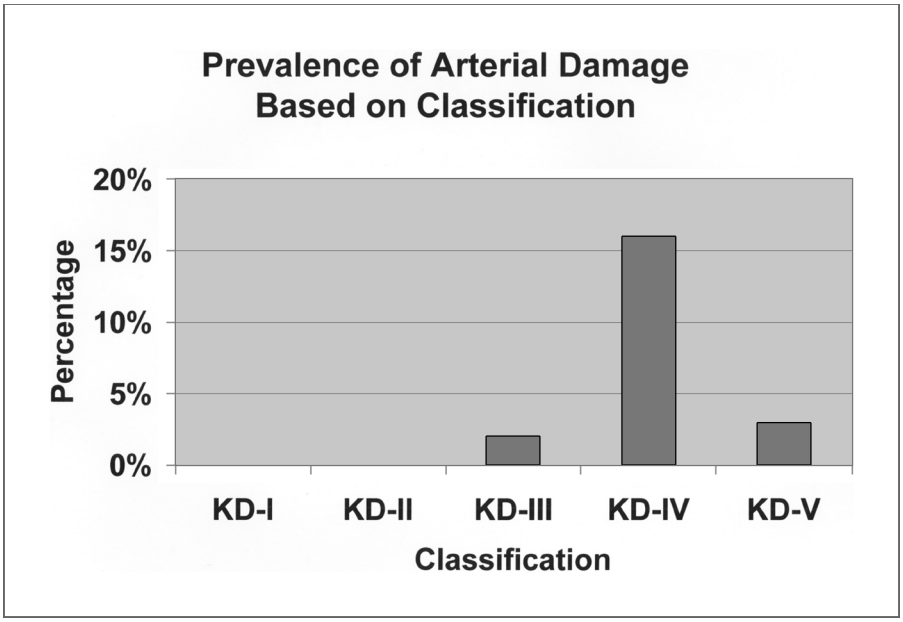

Fig. 1
Illustration showing the prevalence of clinically important popliteal artery damage based on anatomic classification of knee dislocation.

ment, and the posteromedial corner in association with a periarticular fracture (Table I). The injuries in the present study included three KD-I, one KD-II, forty-six KD-III, forty-five KD-IV, and thirty-nine KD-V dislocations. The three patients with a KD-I injury all presented to the emergency room with a dislocation of the knee. Table I shows the subclassification of the KD-V injuries with periarticular fractures.

Fisher's exact test was used to evaluate the statistical association between the results of physical examination and an adverse clinical outcome. A p value of <0.05 was considered significant.

Results

Nine patients had clinically important artery damage, for a prevalence of 7%. Ten patients had abnormal findings on physical examination, with one patient having a false-positive result. Of the nine patients with popliteal artery damage, one had a KD-III dislocation, seven had a KD-IV dislocation, and one had a KD-V dislocation. The prevalence of arterial damage associated with each classification was 0% for patients with a KD-I dislocation, 0% for those with a KD-II dislocation, 2% for those with a KD-III dislocation, 16% for those with a KD-IV dislocation, and 3% for those with a KD-V dislocation (Fig. 1).

As a result of the high-energy mechanisms of injury in our patients, associated ipsilateral extremity trauma was common. Seventy patients had a total of eighty-five ipsilateral fractures, including thirty-eight fractures involving the tibial plateau, nineteen involving the acetabulum, nineteen involving the femoral shaft, six involving the tibial shaft, one involving the supracondylar region of the femur, one involving the patella, and one involving the calcaneus. The tibial plateau fractures, when classified according to the system of Schatzker et al.[22], included twenty-five type-VI, six type-V, three type-IV, and four low-energy (type I, II, or III) fractures.

One hundred and twenty-four knees (116 patients) with a minimum of six months of follow-up had normal findings on serial examinations when the affected side was compared with the normal side. Patients with bilateral knee dislocation had completely normal findings on vascular examination. None of the patients had subsequent development of any acute vascular complications or problems.

Seventeen patients had an arteriographic examination as ordered by the attending orthopaedic surgeon despite having normal findings on physical examination. None of these patients had angiographic findings that required vascular surgical treatment. Fourteen had completely normal findings, two had mild spasm, and one had a small intimal tear. All seventeen patients had had serial physical examinations for forty-eight hours, consistent with our physical examination protocol, and all did well, with no acute vascular complications.

A statistical analysis of all 126 patients demonstrated a significant association between the findings on physical examination and a clinically important arterial injury ($p < 0.001$). Physical examination had a positive predictive value of 90%, a negative predictive value of 100%, a sensitivity of 100%, and a specificity of 99%.

Discussion

Popliteal artery damage is a considerable clinical risk following dislocation of the knee. The artery is held firmly against the femur by the adductor hiatus proximally and by the arch of the soleus muscle distally[1,3,7,9]. Kennedy noted rupture of the popliteal artery with 50° of hyperextension in a cadaveric model[4]. Rupture of the artery can lead to disastrous results and often amputation because the collateral circulation around the knee is inadequate in most individuals[1,4]. An amputation rate of 73% was reported in association with ligation

of the popliteal artery in World War II, compared with a rate of 32% when repair of the artery was adopted in the Korean War[15,20]. The risk of amputation has been noted in many series, with several investigators reporting that there is only a six to eight-hour window in which to accomplish revascularization[1,2,4]. The risk of amputation if vascular repair is not accomplished within that time window was reported to be 86% by Green and Allen[2].

The role of arteriography following knee dislocation has become controversial over the last decade. Many older articles and some more recent ones have advocated routine angiograms for patients who have sustained a knee dislocation[2,4,5,13-19]. Other authors have noted that there is a strong correlation between the results of physical examination of the injured extremity and the need for arteriography, which has led to the development of protocols of selective angiography for patients with positive physical findings[1,7-10,12,20,21,23-25]. These protocols involve the use of either a vascular physical examination (including the evaluation of dorsal pedal pulses) or the measurement of the Doppler ankle-brachial index to assess the vascular status of the limb[1,7,8-10,12,20,21]. Applebaum et al. noted that the most predictive physical finding was a pulse deficit on examination of pedal pulses, a finding that was present in all of their patients[20]. They also noted that the ankle-brachial index had excellent sensitivity but very low specificity. Lynch and Johansen compared the use of the ankle-brachial index with that of arteriography following blunt and penetrating trauma[26]. They reported that an ankle-brachial index of <0.9 had a sensitivity of 87% and a specificity of 97% for the diagnosis of arterial disruption when compared with the results of arteriography. Clearly, use of the ankle-brachial index presents a noninvasive clinical test that can be used to assess patients for arterial disruption. The rationale for routine arteriograms is based on the concern that complete disruption of the popliteal artery can be present with normal pulses initially and that intimal flap tears can produce thrombi that can lead to complete occlusion[9]. There have been case reports of such occurrences[12,13,16,18].

We are aware of six retrospective studies in the general surgery trauma literature, involving a total of 283 knee dislocations, that have utilized protocols involving selective arteriography[3,10,12,21,23,24]. No cases of clinically important vascular injuries that failed to be detected were reported in any of those studies. The problem with those studies was that they were retrospective and small (involving nineteen to fifty-three knees) or had either no follow-up[3,10,23] or short follow-up[12,24]. Those studies leave room for concern that vascular injuries that became occluded on a delayed basis may have been missed. Miranda et al. recently reported the results of a prospective study of thirty-five patients (thirty-five knee dislocations) in which the use of selective arteriography was based on the findings of a vascular examination of the lower extremity[25]. All six patients with flow-limiting vascular injuries were correctly identified with use of a physical examination alone. The weak points of that study were the small sample size and the fact that long-term follow-up data were available for only sixteen patients (46%). When the results of the six retrospective studies[3,10,12,21,23,24] are combined with those of the study by Miranda et al.[25] and the present series, 449 patients have been involved in treatment protocols involving selective arteriography (three patients in the study by Miranda et al.[25] had already been described in the report by Dennis et al.[21]). While we recognize the limitations of retrospective cohort studies, it is notable that there were no cases in any of those studies in which a physical examination failed to detect a clinically important vascular injury. The results of those studies are summarized in the Appendix.

Selective angiography following knee dislocation has been proposed because the recommended treatment for intimal flap tears has changed. Intimal flap tears are injuries to the endothelial lining of the arterial wall. They are normally not flow-limiting and are identified only with arteriography[9]. Previously, it was believed that most intimal tears would progress to complete occlusion by forming a thrombus at the site of the arterial wall damage. Therefore, the previously recommended treatment involved surgical exploration and excision of the arterial segment containing the intimal damage[9]. Sawchuk et al., in a canine study, found that only 3% of intimal tears that were not associated with hemodynamically important stenosis (defined as stenosis involving ≥50% of the lumina) were associated with the development of thrombosis[27]. Clinical studies have confirmed this finding. The vast majority of intimal tears seen on the angiograms of patients with normal findings on physical examination do not progress to popliteal artery occlusion[19,28]. The most commonly employed treatment for intimal tears with no flow limitation is observation[3,8,9,12,21].

Arteriography is an invasive procedure with substantial risks and cost. The overall complication rate is approximately 1.7%[12]. Reported complications have included bleeding, thrombosis, arteriovenous fistulae, pseudoaneurysms, reactions to contrast medium, and renal failure[9,10,12,20]. Another important problem with angiography following knee dislocation is the possibility of a false-positive result, leading to unnecessary surgical exploration. The reported rate of false-positive results has ranged from 2.4% to 7%[9,12,20]. Finally, arteriography represents an expensive screening test. The cost (in 1990 dollars) has been reported to range from $750 to $1500 per study[12,20]. The mean cost at our institution for nine single-leg arteriograms that were made in 2003 (including the fees for the arteriograms, the use of the arteriography suite, and the radiologist interpretation) was $5240 per study. Despite these issues, arteriography clearly has a major role to play in the treatment of patients who have knee dislocations. Any patient with a vascular abnormality on physical examination should undergo arteriography or emergent surgery to exclude a clinically important injury to the popliteal artery.

Numerous articles in the literature have mentioned patients who have had normal findings on the initial physical examination but positive findings on arteriograms. A careful evaluation of those reports demonstrates that most of the positive findings were intimal tears that would now be treated with observation alone[3,5,7-10,12,20]. There also have been reports of

intimal injuries that went on to occlusion after a substantial delay[12] as well as of late occlusion after redisplacement of a dislocation[11]. In both cases, the patients would have been treated with observation only if arteriograms had been made. Gable et al. reported the case of a patient who had a pseudoaneurysm with late rupture at five weeks[15]. This complication was recognized when symptoms developed at the time of the rupture. The patient was treated surgically and did well. Serial pedal pulse examinations should provide an effective screen for patients in whom an occlusive thrombus develops in the period immediately following the knee dislocation. The risks and costs of arteriograms are not justified to identify the rare case that might be missed by physical examination.

The algorithm that we developed for the evaluation of the vascular status of patients with knee dislocations was successfully used to diagnose all clinically important vascular injuries in a large series of patients. The first step in this algorithm is to perform a physical examination of the dorsalis pedis and posterior tibial arteries as well as a gross evaluation of color and temperature. If there is any asymmetry between the two lower extremities, the patient should have an arteriogram made either in the angiography suite or on the operating-room table. If there is any history of an abnormal vascular examination in the prehospital setting, the patient should also undergo arteriography. In the absence of these findings, the patient should be admitted for careful observation. Neurovascular checks should be performed by the nursing staff every two to four hours for the first forty-eight hours. The vascular examination should be documented by a surgeon at the time of admission, four to six hours after admission, and again twenty-four and forty-eight hours after admission. If any clinical abnormalities are detected, an arteriogram should be made.

The algorithm of selective arteriography as described above is a safe and prudent policy to follow when treating a patient who has a knee dislocation. The use of arteriography only for patients who have physical findings that are consistent with a clinically important vascular injury eliminates the need for an invasive vascular study in most cases. If there is any doubt in the surgeon's mind, it is clearly wise to err on the side of performing an arteriographic or other vascular study. Increased vigilance may be justified when treating a patient who has a KD-IV dislocation, and the data in the present series indicate that serial examinations should last for at least forty-eight hours. All patients with knee dislocations, even those with completely normal findings on the initial vascular physical examination, should be admitted for serial examinations.

Appendix

eA A table showing data from published reports in which a physical examination was used to determine the need for arteriography following knee dislocation is available with the electronic versions of this article, on our web site at www.jbjs.org (go to the article citation and click on "Supplementary Material") and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM). ■

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