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Systematic Review

Popliteal Artery Injury Following Knee Dislocation: Anatomy, Diagnosis, Treatment, and Outcomes

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Abstract: Background/Objectives: Popliteal artery injury is a rare but devastating complication of knee dislocations, significantly increasing the risk of limb ischemia, amputation, and poor functional outcomes if not promptly managed. This systematic review primarily evaluates the functional outcomes associated with this injury but also reviews current research on diagnostic modalities and treatment strategies to provide a comprehensive understanding of this severe orthopedic and vascular injury. **Methods**: A systematic search of PubMed, in accordance with PRISMA Guidelines, identified 144 studies, of which 13 full-text articles were assessed for eligibility after excluding 131 during the title and abstract screening. Six studies were excluded due to missing vascular injury or functional outcome data or being written in a foreign language, leaving seven studies for inclusion. These studies were predominantly retrospective, focusing on knee dislocations with popliteal artery injury and reporting validated functional outcomes such as the Lysholm and International Knee Documentation Committee (IKDC) scores. The data were synthesized narratively due to heterogeneity in the study designs, interventions, and outcome reporting. **Results**: Patients with vascular injuries consistently demonstrated poorer functional outcomes compared to those without, with mean or median Lysholm and IKDC scores consistently being lower than non-vascular injury patients. Increased BMI, delayed intervention, and multi-ligamentous injury were associated with worse outcomes, highlighting the importance of timely surgical management. Early repair and grafting techniques improved functional recovery, while diagnostic modalities such as Doppler ultrasound and CT angiography showed high sensitivity in detecting vascular injury. Complications included limb ischemia, prolonged rehabilitation, and amputation, often linked to delayed diagnosis. **Conclusions**: Knee dislocations with popliteal artery injury require rapid diagnosis and early surgical intervention to optimize functional outcomes and reduce complications. Standardized outcome measures and high-quality prospective research are needed to refine management strategies and address patient-specific factors like BMI.

Keywords: popliteal; popliteal artery; tibiofemoral; knee; knee trauma; knee dislocation; orthopedic surgery; orthopedic

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1. Introduction

The popliteal artery is a direct continuation of the superficial femoral artery. It is located on the posterior side of the knee, and its branches supply the distal portion of the leg [1]. Its proximity to the knee puts this artery in a vulnerable position in the event of a high-energy injury, including a tibiofemoral (knee) dislocation, tibial plateau fracture, or distal femur fracture. High-speed motor vehicle accidents, contact sports, or falls have been shown to cause tibiofemoral dislocations [2–4]. These injuries can result in complex diagnoses with associated complications.

These complications include damage to the popliteal artery, which can lead to limb ischemia, necrosis, and amputation when not treated or diagnosed right away [5]. The rate of amputation rises when this injury is left undiagnosed for as little as 6 h without revascularization [6]. According to a study published in 2021, blunt popliteal artery injury (BPAI) ranged from 2–40% of patients who suffered tibiofemoral dislocations, with 10–50% of those cases resulting in amputation [7]. About 30% of knee dislocations resulting from high-energy injuries involve popliteal artery disruption [3]. In regards to popliteal artery injury, timely diagnosis is the most crucial aspect in mitigating detrimental complications and the possible amputation of the distal extremity.

The current literature contains gaps in terms of recommendations for standardized approaches in diagnosing and treating popliteal artery injury as a result of knee dislocation. Previous recommendations for diagnosis include checking for active pulsatile bleeding, absent distal pulses, and distal limb ischemia [8]. When there is suspicion of these injuries, bedside Doppler ultrasound has also been shown to be useful [8]. In the more recent literature, diagnosis via CT angiography with vascular injury provides rapid diagnostic material when paired with timely consults to vascular surgery [9]. Due to the current sparsity of a standardized diagnostic approach to popliteal artery injury, we aim to review and determine the efficacy of current popliteal artery injury protocols. Additionally, we aim to provide a supplementary literature review on the popliteal artery and surrounding knee anatomy while including relevant outcomes regarding popliteal artery repair.

1.1. Anatomy

The vascular anatomy relevant to the popliteal artery begins with the aorta, which branches to form the common iliac artery. This then branches into the external iliac artery before transitioning into the common femoral artery. The common femoral artery then bifurcates into the superficial and deep femoral arteries. The superficial femoral artery continues down the thigh and, upon reaching the adductor canal, is named the popliteal artery, the primary blood supply to the distal lower extremity [10]. The proximal tethering of the popliteal artery to the adductor hiatus and distal passage behind the soleal arcade increases its risk of disruption, as it is unable to handle the increased distance generated between the tibia and femur during knee dislocation [11]. Upon reaching the proximal calf region, the popliteal artery gives off branches that provide the primary blood supply to the distal lower extremity. As shown in Figure 1, the popliteal artery bifurcates into the anterior tibial artery and tibioperoneal trunk. The anterior tibial artery gives rise to the dorsalis pedis artery, among others, which provides the blood supply to the dorsum of the foot and serves as an important part of the physical exam when checking pulses in the dorsum of the foot. The tibioperoneal trunk branches further into the peroneal and posterior tibial arteries. The popliteal artery also provides genicular branches that confer collateral circulation of the knee through an anastomosis [12].

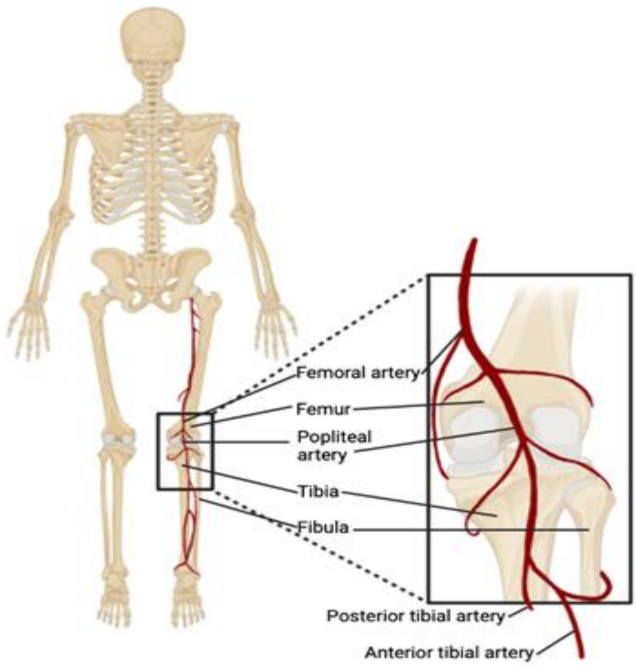

Figure 1. Anatomical course of the popliteal artery.

Analysis has been conducted on the prevalence of specific variations of the popliteal artery and their respective branching patterns. Tomaszewski et al. conducted a systematic review and meta-analysis to understand the prevalence of these variations using data from cadaveric and imaging studies [13]. By using a system first devised by Lippert and Pabst in 1985 and modified by Kim et al. [14] in 1989, they classified popliteal artery branching variants under Type I, Type II, and Type III. Type I refers to branching occurring at the level of the inferior border of the popliteus, whereas Type II refers to branching occurring superior to the knee [14]. Type III refers to any hypoplasia or aplasia of any of the branches but may follow a common branching pattern [13,14]. Type I-A, a specific subdivision of Type I, is the most commonly seen variation, with a prevalence of 92.6%, and follows the anatomy described above [13]. The second most common variation, Type I-B, with a prevalence of 2.6%, involves a trifurcation of the anterior tibial, posterior tibial, and peroneal arteries from the popliteal artery at the inferior border of the popliteus. Type II branching, across all of its subdivisions, had a combined prevalence of 3.9%. These findings suggest the importance of surgeon awareness of these variants in any vascular repair, as the anatomy of the vasculature can be drastically different if a patient falls into the Type II group.

The popliteal artery can be palpated in the posterior compartment of the knee, making it accessible for physical examination in clinical settings [1]. Additionally, the peroneal nerve, which innervates muscles in the lower leg and foot, is closely associated with the popliteal artery. Damage to this nerve can result in significant functional impairments [15].

The knee joint is a compound trochoginglymus or a gliding hinge joint [16]. This compound joint incorporates both the tibiofemoral and patellofemoral articulations. Some sources also include the proximal tibiofibular joint [17]. It is maintained by both non-contractile static stabilizers, including ligaments and fibrocartilaginous tissues such as the menisci, and contractile dynamic stabilizers, including muscles and tendons. The four primary ligaments providing stabilization to the knee are the anterior cruciate ligament (ACL), posterior cruciate ligament (PCL), medial collateral ligament (MCL), and lateral collateral ligament (LCL) [18]. The ACL and PCL provide static stabilization against anterior and posterior translation, respectively, while the MCL and LCL provide static stabilization against excessive valgus and varus forces, respectively [4]. The medial and lateral menisci disperse axial loads and rotational forces transmitted to the knee [4].

Tibiofemoral dislocation is most commonly classified utilizing two classification systems: the Kennedy classification, which is descriptive in nature, and the Schenck classification, which is based on the injury to the knee's ligaments. The Kennedy classification is based on the direction of displacement of the tibia: anterior, posterior, medial, lateral, or rotational. Anterior and posterior displacements are most commonly seen, with estimates indicating they make up 30–50% and 30–40% of all knee dislocation injuries [17]. It has been noted that posterior displacement, typically due to significant axial load to the flexed knee, is associated with the highest rate of vascular injury and the highest incidence of complete transection of the popliteal artery [17].

The utility of the Kennedy system, described by JC Kennedy in 1963 [19], is that it provides ease of use; however, it has been noted for its inadequate incorporation of other injuries to the ligamentous structure of the knee [20]. The Schenck classification, devised in 1994 by RC Schenck, incorporates ligamentous injuries into its classification, with KD (knee dislocation) I and II denoting injuries to one or both cruciate ligaments, respectively. KDIII-M and KDIII-L denote injuries to both cruciate ligaments, as well as either the MCL or LCL, respectively. KDIV denotes injuries to both cruciate ligaments and both collateral ligaments. Finally, KDV represents a multi-ligamentous injury with an associated periarticular fracture [20]. Of note, in 1997, Wascher et al. proposed a modification to denote arterial or nerve injury with a -C or -N suffix, respectively [21]. The Schenck classifications, each with their associated ligamentous injury, are presented in Table 1.

There is some variance in the literature on which Schenck classification injury has the highest prevalence of popliteal artery injury. A 2004 prospective outcome study found that 7% of 138 patients had popliteal artery damage, with seven out of those nine patients having KDIV injuries [22]. Two more recent cross-sectional studies noted that patients with KDIII-L injuries had five and nine times greater odds of popliteal artery injury than in other ligament injury types [23,24]. A systematic review incorporated data from 862 patients and found that vascular injury occurred in patients with a weighted frequency of 18% [25]. Injury solely to the popliteal artery was found in 76% of patients, with other patients having disruption to other or additional vessels, including the anterior and posterior tibial arteries and the middle genicular artery. It also found that vascular injury occurred with the highest frequency in KDIII-L and posterior dislocations, accounting for 32% and 25% of dislocations, respectively. These data show the need for heightened vigilance for vascular injury, namely popliteal artery injury, in patients with multi-ligamentous injuries of the knee, such as KDIII or KDIV injuries.

Table 1. Key Points: This table highlights the types of knee dislocations and their associated ligament injuries, with KD-IV having the most complex injuries involving all major ligaments and KD-V indicating fracture-dislocation. Awareness of these classifications may assist clinicians in anticipating potential popliteal artery damage.

Table 1. The Schenck classification describes knee dislocations by the pattern of ligamentous injury.

Schenck Classification Criteria for Knee Dislocation	
KD Classification	**Description**
KD-I	Dislocation, including disruption of one cruciate ligament (ACL or PCL)
KD-II	Dislocation, including disruption of both cruciate ligaments (ACL and PCL)

Table 1. *Cont.*

Schenck Classification Criteria for Knee Dislocation	
KD Classification	**Description**
KD-IIIM	Dislocation, including disruption of both cruciate ligaments (ACL and PCL) and the MCL
KD-IIIL	Dislocation, including disruption of both cruciate ligaments (ACL and PCL) and the LCL
KD-IV	Dislocation, including disruption to both cruciate ligaments (ACL and PCL) and both collateral ligaments (MCL and LCL)
KD-V	Fracture-dislocation

KD = Knee dislocation; ACL = anterior cruciate ligament; PCL = posterior cruciate ligament; MCL = medial collateral ligament; LCL = lateral collateral ligament.

1.2. Presentation and Diagnosis

The presentation of popliteal artery injury can vary significantly based on several factors, including the patient's body mass index (BMI). The mechanism of injury can also involve low-velocity trauma, such as standing up from a seated position in high BMI patients (BMI > 30), as opposed to high-energy trauma seen in motor vehicle accidents [26]. Higher BMI has been associated with increased difficulty in diagnosing vascular injuries due to the challenges in palpating pulses and assessing vascular integrity [27]. Despite the presence of a pulse and the initial absence of popliteal artery injury indications in patients, this injury should be suspected in proximal tibia fractures, such as Salter-Harris III and IV fractures in pediatric patients, because collateral flow involving the anterior and posterior tibial arteries can mask symptoms upon presentation [28].

Initial diagnostic approaches typically include physical examination, focusing on signs such as bleeding, pulselessness, and distal ischemia. Doppler ultrasound utilization is the established method for assessing blood flow in the popliteal artery. Early studies demonstrated its effectiveness in detecting vascular injuries [29]. Over time, advances in ultrasound technology have improved the accuracy and reliability of this diagnostic tool, though it is subject to operator experience, and the quality of imaging may be diminished in high BMI patients [30]. One study found Doppler ultrasound to have a sensitivity of 95% and a specificity of 99% in lower extremity vascular injury [31]. CT angiography has emerged as a preferred diagnostic modality in the recent literature. It offers a rapid and detailed assessment of vascular injuries and can be critical in the timely diagnosis and management of popliteal artery injuries [9]. This imaging technique, when paired with immediate consultation with vascular surgery, enhances the likelihood of favorable outcomes by facilitating early intervention. It should be noted that CT angiography is an expensive imaging modality, and not all hospitals have immediate access to it [32,33]. The sensitivity and specificity of lower extremity vascular injury have been cited in one study as 95.1% and 98.7%, respectively [34].

Another method of detecting vascular injury after tibiofemoral dislocation is the measurement of the ankle-brachial index (ABI). This index is a ratio of the systolic blood pressure measured at the ankle to the brachium. Mills et al. found (in a case series) that an ABI above and below 0.9 provided 100% negative and positive predictive values, respectively, for the presence of significant vascular injury after knee dislocation, and it provided 100% sensitivity and specificity [35]. Thus, it has been proposed in management algorithms that CT angiography is only indicated after first measuring the ABI [32]. It should be noted that not all clinical settings have these imaging modalities readily available for use, further underscoring the importance of the ABI. As an example, one survey from

2011 found that only 175 out of 298 respondent emergency rooms had Doppler ultrasound available for immediate use within the United States, indicative of the variable access between urban centers and rural areas [34]. Another 2014 survey found a similar divide, showing that only 15 and 25 American States had ultrasound and some form of CT imaging modalities, respectively, in 100% of their critical access hospitals [36]. Table 2 presents the sensitivities, specificities, advantages, and disadvantages of these different diagnostic modalities, necessitating a stepwise initial trauma management algorithm for clinicians. In the initial presentation, a management algorithm that incorporates diagnostic methods is presented in Figure 2.

Table 2. Key Points: CT angiography offers the best utility but may not be readily available in all clinical settings globally. Bedside Doppler ultrasound is another practical initial assessment tool with high sensitivity and specificity. The ankle-brachial index (ABI), however, remains an effective and simple screening tool for identifying vascular compromise using readily available equipment.

Table 2. Comparison of diagnostic modalities used to detect vascular injuries in the lower extremity, highlighting their sensitivity, specificity, advantages, and limitations.

Sensitivity and Specificity of Diagnostic Methods in Detecting Lower Extremity Vascular Injury				
Diagnostic Modality	**Sensitivity**	**Specificity**	**Advantages**	**Limitations**
Physical Examination	Variable	Variable	Immediate; no equipment needed	May miss occult injuries; examiner-dependent
Doppler Ultrasound [37]	95%	99%	Non-invasive; bedside availability	Operator-dependent; limited by obesity
CT Angiography [31]	95.10%	98.70%	Rapid; detailed vascular imaging; gold-standard	Radiation exposure; contrast nephropathy
Magnetic Resonance Angiography [38]	>80%	>90%	No radiation; detailed soft tissue imaging	Time-consuming; limited availability
Ankle-Brachial Index [35]	100%	100%	Simple; quick screening tool	May be affected by distal injuries

CT = Computed tomography.

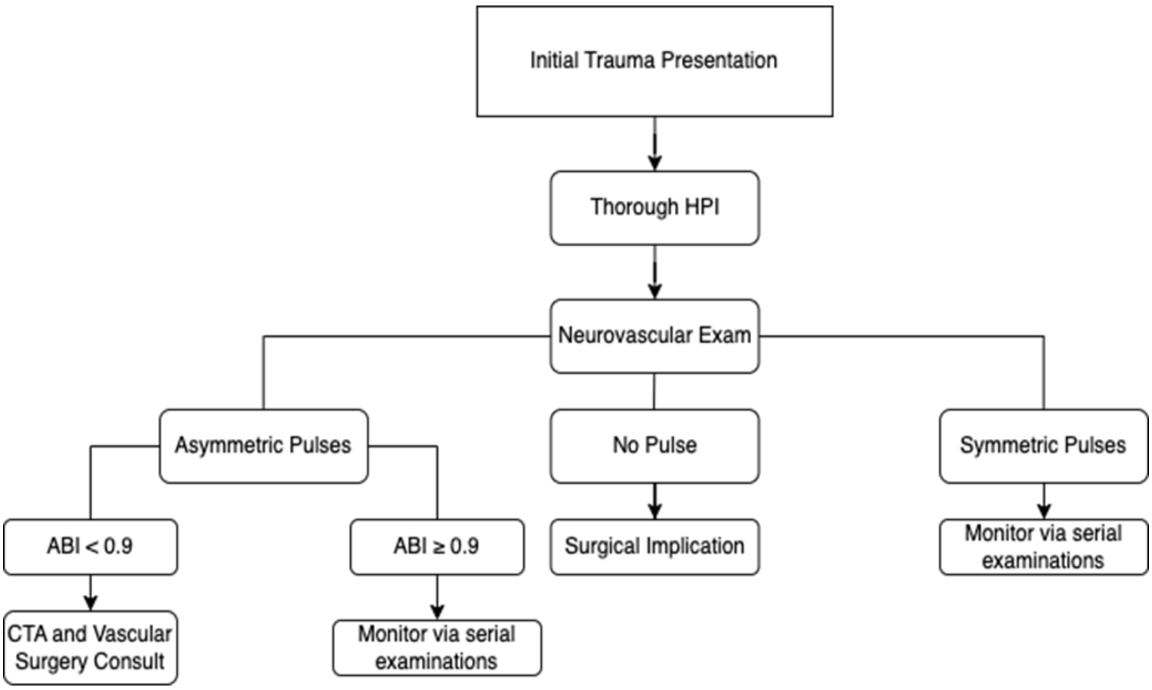

Figure 2. Management algorithm in setting of knee dislocation.

A new scoring methodology to determine a patient's risk of amputation specific to popliteal injury was described by O'Banion et al. in response to a perceived lack of specificity in the Mangled Extremity Severity Score (MESS). This methodology is known as the POPSAVEIT score and assigns one point for a systolic blood pressure less than 90 mmHg, two points for associated orthopedic injury, and either two points for a lack of pre-operative pedal Doppler signal or one point for a lack of palpable pre-operative pedal pulses if Doppler is not available for use. A calculated POPSAVEIT score greater than or equal to three was positively associated with amputation of the limb [39].

2. Methods

2.1. Study Selection

A systematic review was conducted to evaluate the functional outcomes and management of knee dislocations with associated vascular injuries following the criteria and according to the recommendations of PRISMA or 'Preferred Reported Items of Systematic Review and Meta-Analysis'. The search was performed using PubMed, yielding 144 articles.

The following search terms were used: ((“Knee Dislocation” OR “knee dislocation” OR “tibiofemoral dislocation” OR “MLKI”) AND (“popliteal artery” OR “vascular injury”) AND (“orthopedic” OR “repair” OR “reconstruction”) AND (“return to activity” OR “functional outcome” OR “rehabilitation” OR “complications” OR “Lysholm score”)), ((“Knee Dislocation” OR “knee dislocation” OR “tibiofemoral dislocation” OR “MLKI”) AND (“popliteal artery” OR “vascular injury”) AND (“return to activity” OR “return to work” OR “return to sport” OR “rehabilitation” OR “complications” OR “Lysholm score”)).

Screening was conducted by two authors (KCV and MC), and disagreements were resolved by a third author (MA). After screening the titles and abstracts, 131 articles were excluded due to wrong outcome measures, wrong publication type, or the publication being in a foreign language. Thirteen full-text articles were further assessed, and five were excluded for reasons including non-reporting of functional outcomes or failure to include vascular injury cases. One paper was excluded due to the inability to access the full text. Ultimately, seven studies [26,40–45] were included in the final review. The number of studies included and excluded after each step in the screening is presented as a flowchart in Figure 3.

2.2. Inclusion Criteria

Studies were selected if they focused on knee dislocations with some percentage of popliteal artery injuries, particularly popliteal artery damage, and reported on functional outcomes using validated scoring systems such as Lysholm, International Knee Documentation Committee (IKDC), and Hospital for Special Surgery (HSS) scores. Both case series and retrospective studies were included, with a requirement for a mean or median of at least 18 months of follow-up for inclusion.

2.3. Data Extraction

Data extraction focused on study design, sample size, patient demographics, management of vascular injuries, functional outcomes, and complications. The risk of bias and the quality of studies was assessed using a modified version of the MINORS (Methodological Index for Non-Randomized Studies) tool proposed by Slim et al. [46], with scores ranging from 0 to 12 for non-comparative studies and 0 to 20 for comparative studies. Due to the nature of the pathology and heterogeneity in surgical management, prospective studies on the topic are scant, and two specific domains of quality related to the prospective collection of data and the prospective calculation of study size were omitted, as only one of the studies contained these characteristics. This omission should be considered when analyzing these scores. These scores are presented in Table 3.

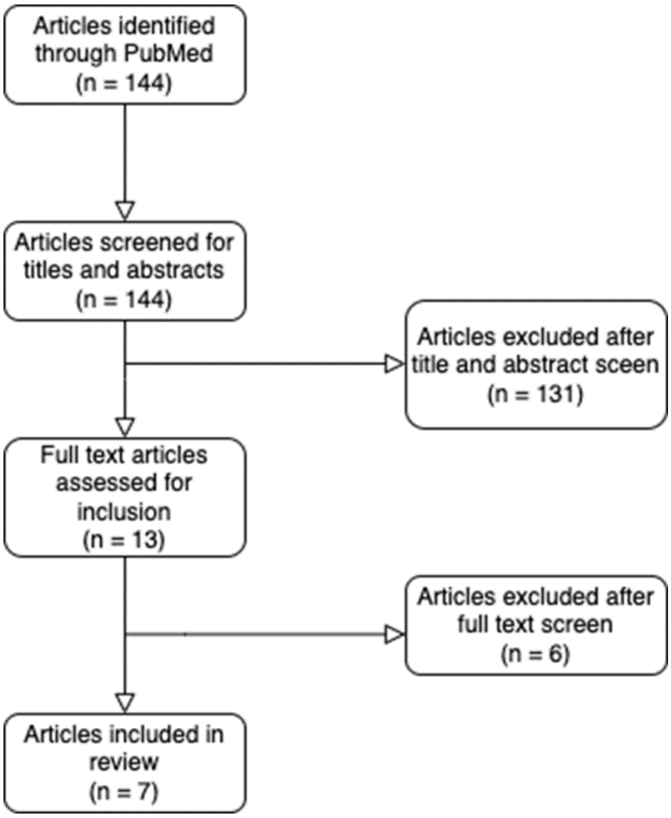

Figure 3. Flow diagram. Number of studies included and excluded after each stage of screening.

This review followed a structured, systematic approach to ensure comprehensive data capture and consistent study evaluation. The inclusion and exclusion criteria were strictly applied to maintain relevance to functional outcomes in popliteal artery injuries following knee dislocations. The data were then synthesized and organized in tables (Tables 3 and 4) to elucidate functional outcomes across different studies.

Table 3. Summarizes key characteristics of included studies, including study design, sample size, patient demographics, inclusion criteria, and details of vascular injury management. The modified MINORS score is used to assess methodological quality.

Study Characteristics								
Study	**Year**	**Study Design**	**Modified MINORS Score (Slim et al. [37]) (0–12 Non-Comparative) (0–20 Comparative)**	**Sample Size (*n*)**	**Mean Age (Years)**	**Median Age (Years)**	**Inclusion Criteria**	**Vascular Injury Management**
Kilicoglu et al. [47]	2020	Retrospective case series (comparative)	16	42	NR	34	TKD patients treated surgically	9 popliteal artery injuries surgically managed
Sanders et al. [43]	2017	Retrospective matched cohort (comparative)	17	48	31	-	MLKI patients with/without vascular injury	16 had popliteal artery bypass grafting
Vaidya et al. [45]	2015	Retrospective case series (comparative)	14	19 (21 knees)	30.3	-	Obese patients with low-velocity knee dislocations	5 popliteal artery injuries, 4 repaired

Table 3. *Cont.*

Study Characteristics								
Study	**Year**	**Study Design**	**Modified MINORS Score (Slim et al. [37]) (0–12 Non-Comparative) (0–20 Comparative)**	**Sample Size (n)**	**Mean Age (Years)**	**Median Age (Years)**	**Inclusion Criteria**	**Vascular Injury Management**
Levy et al. [43]	2015	Retrospective cohort (comparative)	17	125	NR	31	MLKI patients with ≥2 years follow-up	16 popliteal artery injuries surgically managed
Plancher et al. [44]	2008	Retrospective cohort (comparative)	15	48 patients (50 knees)	26	-	Knee dislocation with greater than 2 ligaments disrupted	12 popliteal artery injuries (8 successfully treated without knee arthrodesis or amputation)
Teissier et al. [43]	2019	Retrospective case series (non-comparative)	9	16	40.8	-	Knee dislocations with vascular injuries	All had vascular injuries surgically treated
Azar et al. [42]	2011	Retrospective case series (comparative)	14	17 (11 with complete follow-up)	28.6	-	Obese patients with ultra-low-velocity knee dislocations	7 popliteal artery injuries surgically repaired (3 with complete follow-up)

Table 4. Key Points: The data across all included studies indicate that patients with vascular injuries report lower functional outcome scores, such as Lysholm and IKDC, compared to those without vascular involvement. Additionally, patient factors such as higher BMI and age over 30 were associated with poorer recovery. Patients who did not undergo reconstruction or operative management also suffered from lower functional outcome scores.

Table 4. Functional outcomes following vascular injury.

Functional Outcome Measures					
Study	**Mean Follow-Up (Months) (Median If Specified)**	**Functional Scores Used**	**Mean Lysholm Score**	**Mean IKDC Score**	**Other Scores**
Kilicoglu et al. [47]	128	Lysholm, IKDC, KSS	68.4 (neural injury) 77.7 (vascular injury) 90.5 (no neurovascular injury)	60.6 (neural injury) 71.5 (vascular injury) 82.1 (no neurovascular injury)	KSS: 67.0 (neural injury) 72.6 (vascular injury) 89.9 (no neurovascular injury)
Sanders et al. [43]	99.6 (vascular group) 72.0 (control group)	Lysholm, IKDC	62.5 (vascular group) 86.4 (control group)	59.7 (vascular group) 83.8 (control group)	-
Vaidya et al. [45]	31	Tegner, Knee Laxity Scores	Not used	Not used	Mean Tegner Activity Score Difference: −1.5 (vascular group) −1.19 (no vascular injury group)
Levy et al. [43]	60 (median)	Lysholm, IKDC	76.9 (≤30 yrs) 68.5 (>30 yrs)	73.3 (≤30 yrs) 61.9 (>30 yrs)	-
Plancher et al. [44]	99.6	Lysholm, HSS	84.3 (operative group) 70.5 (non-operative group) 82.0 (popliteal artery injury)	Not used	HSS: 81.0 (popliteal artery injury)
Teissier et al. [43]	23 (median)	Oxford Knee Score (OKS)	Not used	Not used	Median OKS decreased from 47 to 30 (all patients with vascular injuries)

Table 4. *Cont.*

Functional Outcome Measures					
Study	**Mean Follow-Up (Months) (Median If Specified)**	**Functional Scores Used**	**Mean Lysholm Score**	**Mean IKDC Score**	**Other Scores**
Azar et al. [42]	28.5	Lysholm, HSS, IKDC, Tegner	67.2 (recon group) 53.0 (non-recon group) 34.7 (popliteal artery injury) 70.3 (no popliteal injury)	Severely abnormal	HSS: 74 (recon group) 21 (non-recon group)

IKDC = International Knee Documentation Committee Subjective Knee Form; HSS = Hospital for Special Surgery Knee-Rating Scale; KSS = Knee Society Score.

3. Results

A total of seven [26,40–45] studies met the inclusion criteria for this systematic review, with publication dates ranging from 2008 to 2020. The studies were predominantly retrospective in nature, comprising case series, cohort studies, and matched-cohort studies, as shown in Table 3. The MINORS scores, used to assess quality for the included studies, ranged from 14 to 17 in comparative studies and 9 for the single non-comparative study, reflecting moderate to high quality. While most studies were retrospective, they adhered to rigorous criteria for outcome reporting and vascular injury management, supporting the reliability of the findings despite inherent design and patient population limitations.

Each study focused on the management of knee dislocations, including data on patients with associated vascular injuries, primarily or entirely involving the popliteal artery. Functional outcomes were assessed in all studies using validated scoring systems, such as the Lysholm, International Knee Documentation Committee (IKDC), Hospital for Special Surgery (HSS) score, Knee Society Score (KSS), and Oxford Knee Score (OKS) [26,40–45]. Most studies used a combination of these scores to evaluate post-treatment knee function in patients who had undergone surgical or non-surgical management of knee dislocations with vascular injuries. Lysholm scores were consistently reported across multiple studies. Table 4 presents the mean Lysholm, IKDC, or other scores (HSS, Tegner, and OKS) along with the mean or median follow-up time for each study.

Overall, patients with vascular injuries, particularly those requiring surgical intervention, demonstrated lower Lysholm scores compared to patients without vascular involvement. For example, Sanders et al. reported a mean Lysholm score of 62.5 in the vascular injury group, which is significantly lower than the 86.4 mean score in the control group without vascular injuries [43]. IKDC scores similarly demonstrated worse outcomes in patients with vascular injuries. Kilicoglu et al. noted decreased IKDC and Lysholm scores in patients with associated vascular damage. Kilicoglu et al. found that patients with vascular injuries had a mean IKDC score of 71.5, compared to 82.1 for those without neurovascular complications [47]. Several studies also employed other functional scoring systems, such as the HSS score, KSS score, and Oxford Knee Score (OKS). Azar et al. reported a severely abnormal HSS score of 21 in non-reconstructed patients with popliteal artery injuries, compared to 74 in reconstructed patients [42]. Teissier et al. highlighted a substantial decrease in OKS, with a median pre-trauma score of 47 dropping to 30 post-trauma in patients with vascular injuries [26].

Our systematic review analyzed retrospective studies detailing knee dislocations in association with vascular injuries, focusing on the popliteal artery. The studies utilized a number of functional outcome measurements to assess the success of different vascular management plans. Overall, patients who required surgical intervention as a result of vascular injury garnered lower functionality scores as compared to those without vascular injury. The Lysholm scores remained lower for individuals with vascular injuries as compared to non-injured patients, with 62.5 in injured patients compared to 86.4 in non-injured patients [43]. Similarly, the IKDC scores were consistently lower for patients with vascular injuries as compared to those who did not have vascular injuries, with 71.5 in injured patients compared to 82.1 for non-injured patients [47]. Other measurements, namely HSS and OKS, demonstrated poor outcomes for those with vascular damage and reconstruction as compared to those with injury and no reconstruction. Azar et al. demonstrated that HSS scores were found to be 21 for non-reconstructed patients with injury to the popliteal artery as compared to 74 for those with injury and subsequent reconstruction [42]. The studies reviewed demonstrate that knee dislocations with accompanying vascular injuries consistently lead to poorer functional outcomes, with surgical intervention possibly leading to an improvement in functional scoring but not necessarily an improvement to normal function.

4. Discussion

Knee dislocations are significant injuries that require intensive recovery. There are many considerations when managing such an injury. The decision to treat operatively versus non-operatively is a major factor in how rehabilitation will look. Early operative treatment of multi-ligament knee injuries has been shown to yield better functional and clinical outcomes as opposed to non-operative treatment [48]. Plancher et al. found that the non-operative treatment group suffered from lower mean Lysholm scores (70.5) as compared to the operative group (84.3) [44]. Interestingly, patients with popliteal artery injury had Lysholm and HSS scores of 82.0 and 81.0, respectively.

Body mass index (BMI) and age were significant risk factors for poor functional outcomes, with several studies noting an association between higher BMI and increased neurovascular complications. Vaidya et al. and Azar et al. observed that patients with a higher BMI had a greater likelihood of suffering neurovascular injuries and poorer knee stability scores [41,45]. Additionally, Sanders et al. found that a BMI >30 kg/m^2 was predictive of worse Lysholm and IKDC scores [43]. This finding highlights the need for tailored management strategies in obese patients, including meticulous surgical techniques and, perhaps, modified rehabilitation protocols to accommodate the suboptimal outcomes seen in these patients. Further, Levy et al. presented a study with a large sample size and extensive follow-up data, indicating that patients older than 30 years of age had worse functional outcome scores in long-to-intermediate follow-up lengths [43].

This review highlights the complex and severe nature of knee dislocations associated with vascular injuries, particularly involving the popliteal artery. Across the included studies, surgical management was the predominant treatment approach, with most patients undergoing vascular repair or bypass grafting. Despite these interventions, long-term functional outcomes remained suboptimal, with most patients experiencing significant limitations in knee function, as reflected in the Lysholm, IKDC, and HSS scores.

A study reviewing the 24-month objective and subjective outcomes of 20 knee dislocations treated with open repair found that patients with a low pre-injury level of function were able to return to their activity level; however, only 22% of competitive athletes and 38% of patients undertaking heavy activity were able to return back to their pre-injury activity level during this span [49]. This demonstrates that returning to higher levels of activity requires more time for rehabilitation post-injury and is not always achievable.

It should be noted that in sports, knee dislocations are less associated with vascular injuries compared to car accidents [50]. Therefore, it is less likely for athletes to deal with vascular complications compared to individuals who suffer this injury in a car accident. However, in sport-related injuries, a major concern to athletes is whether a return to play is possible. There are a lot of varying factors that contribute to an athlete's ability to return to play, including but not limited to the severity of the injury, the quality and compliance of rehabilitation protocols, the type of sport, complications, and lastly, mental resilience.

A study looked exclusively at 50 National Football League (NFL) players who sustained a multi-ligament knee injury from 2000 to 2016; a total of 64% returned to play [51]. Return to a pre-injury level of play was even less evident, with only 30% of these players returning to that level after the injury [51]. The mean time for return to play for 50 players was 388.71 ± 198.52 days [51]. This study did not discuss the percentage of these players who had a vascular injury. Another retrospective study focused on elite athletes who suffered a knee dislocation and found 79% of patients (*n* = 19) returned to their previous sport after a median time of 5.5 months (range, 1.5 to 36 months), with eight of them returning to pre-injury levels [52]. This demonstrates that the rehabilitation to return to a competitive level is even more challenging for individuals who are in great shape and have top-tier medical support.

One notable case report documented the return to professional athletic performance following the successful management of a popliteal artery injury without ligament surgery, underscoring the potential for positive outcomes with appropriate treatment [41]. A 21-year-old football player was able to return to play wearing a knee joint brace two years following the injury. Despite a complete ACL tear and partial MCL and PCL tear, ligament repair surgery was not conducted due to arterial injury and intra-articular inflammation. The successful recovery and return to play were due to the prompt treatment of the vascular injury, rehabilitation with a focus on improving range of motion and controlling inflammation, and progressive strength training. This case shows that return to play could be achievable with a conservative treatment plan without ligament surgery.

Overall, outcomes vary widely among patients, with surgical treatment showing more favorable results [48]. Returning to a high level of play is possible but requires extensive rehabilitation and is dependent on many factors, as every case is different.

Study Limitations

This review has several limitations. The majority of the included studies were retrospective in nature, with inherent limitations such as selection bias, recall bias, and incomplete data reporting. In addition, the small sample sizes and heterogeneity of the study populations limit the generalizability of the findings, especially with some studies focusing on high BMI patients. Though all of the functional outcome scores measured in the included studies have been validated, a consistent scoring metric across multiple prospective studies would yield a higher-quality understanding of outcomes. These studies also inherently have subjective aspects within them that are specific to the patient and introduce self-report bias. The nature of the injury and its rarity lend this topic to low patient sample sizes, high rates of loss of follow-up due to amputation or death, and a lack of prospective studies. One of the main factors not assessed or integrated into this study is the association of partial or complete peroneal nerve injury with functional outcomes. While some studies make use of separate cohorts for peroneal palsy, the heterogeneity in study design and measured outcomes warrants further research into this specific factor and its pathology.

5. Other Considerations

5.1. Vascular Repair

Once vascular status and initial trauma have been assessed, the strategy for surgical repair depends on the nature of the injury mechanism and damage to the popliteal artery—whether it is blunt or penetrating and whether it is transected, occluded, or dissected. These strategies rely on techniques also used in the treatment of peripheral artery disease. While high- and low-velocity trauma knee dislocations in high BMI patients were associated with popliteal artery injuries, the success of revascularization was not associated with the mechanism of trauma in these patients [27].

One common strategy for the restoration of blood flow is through a femoropopliteal bypass, colloquially known as a fem-pop bypass. This procedure involves constructing, via graft or synthetic material, a bypassing connection from the proximal femoral artery to the distal popliteal artery to restore vascularization to the lower limb [53]. Another approach involves creating a conduit utilizing a graft or temporary shunt from one transected end to another to restore blood flow [54,55]. In another case report, a patient with an occluded popliteal artery secondary to posterior knee dislocation underwent this bypass procedure and saw recanalization of the occluded artery. The case report concluded that bypass graft may be the favored repair approach for the revascularization of the popliteal artery in young patients [54]. High amputation rates have been associated with delayed diagnosis and treatment [55]. Early intervention, optimally within 6 to 8 h of trauma, significantly improves outcomes and reduces the risk of complications such as limb ischemia and amputation [56,57].

The choice of graft source and the orientation of the graft are important considerations in vascular repair as well, with each option imparting different advantages and disadvantages. A reversed saphenous vein graft (RSVG) is often preferred due to its compatibility and long-term patency rates. Additionally, because the repair of the artery in the majority of cases cannot be accomplished with tension-free anastomosis [26,57], a bridging interposition graft utilizing an RSVG is also commonly employed [57]. This technique involves harvesting the saphenous vein, reversing its orientation to match the direction of arterial blood flow, and using it to create a conduit between the transected ends of the popliteal artery [53]. Sciaretta et al. only recommend bypass when significant tissue loss is also present [57]. RSVGs have shown better long-term outcomes as compared to prosthetic grafts, such as those composed of polytetrafluoroethylene (PTFE), which are typically used when the saphenous vein is disrupted or injured during the instigating trauma [57–59].

There is ongoing debate in the literature regarding the use of PTFE grafts versus autologous vein grafts. While some studies have shown comparable patency rates between prosthetic and autologous vein grafts, they have been limited in their data delineating whether the bypass was carried out above-knee or below-knee [60]. Historically, studies have suggested that PTFE grafts can achieve acceptable patency rates in below-knee bypasses, but now, some studies have demonstrated it to be a viable option in above-knee bypasses as well [61,62]. Sciarretta et al. [57], however, caution against the use of PTFE grafts, stating that it was an independent predictor of amputation traumatic popliteal injury. This distinction underscores the importance of individualized patient assessment, including the surgical anatomy of the popliteal artery branching patterns, when selecting the graft material.

In addition to RSVGs, an in situ saphenous vein graft is another technique utilized in fem-pop bypasses. The in situ approach involves leaving the vein graft in its anatomical orientation while removing the valves with a valvulotome to allow for arterial blood flow. Both a 10-year randomized prospective study and retrospective chart review comparing in situ and reversed vein grafts found that reversed grafts generally offer higher primary patency rates as compared to in situ grafts, but secondary patency rates were comparable between the two techniques [53,63]. It should be noted that the in situ technique may present challenges, including the disruption of the vein when removing the valves or utilizing veins with a smaller diameter [53,59]. While an RSVG is preferred in most cases, prosthetic grafts are an acceptable alternative if the autologous vein cannot be harvested [53,63]. Initially, it was thought that synthetic grafts like PTFE or Dacron were only suitable in below-knee bypass surgeries, but some research has shown that they are also acceptable in above-knee bypasses as well [61].

In certain scenarios where the mechanism of trauma is blunt force and imaging shows intimal lesions of the artery, endovascular repair may be possible. Hutto and Reed have described a "tacking" of the intimal flap to ensure the patency of the popliteal artery by utilizing a balloon angioplasty [64]. They have described the benefits of this approach, when indicated, as minimizing further soft tissue damage during the vascular repair as would be necessitated by an open approach, such as with an RVSG bypass. This approach is contraindicated by the presence of complete arterial transection, a delay in repair greater than 6 h, and a lack of imaging equipment necessary for the procedure [64]. Some studies have discussed that the transition of intimal tears present within the artery without disruption of blood flow to complete occlusion is rare [48,65]. Thus, in some management algorithms, when these findings are seen, surgeons opt for serial examination of the patient without vascular intervention. Even when an ABI of greater than 0.9 is achieved in diagnosis, it does not exclude the possibility of an intimal tear—thus, serial examinations of the patient are still recommended.

In situations where immediate definitive repair is not feasible, such as when significant concurrent injuries or unstable skeletal conditions are present, the use of temporary intravascular shunts can be lifesaving. These shunts allow for temporary revascularization, providing the surgical team with additional time to stabilize other injuries. Khalil et al. describe a method where a transected artery is clamped, and a shunt (e.g., with a Javid shunt, balloon-style shunt, or nasogastric tube) is applied to both ends of the artery to maintain perfusion until definitive repair can be performed [56]. This approach allows other surgical teams to provide immediate stabilization of the knee before definitive vascular repair is performed [56,57]. Table 5 provides a summary of the different graft types and surgical approaches to vascular repair after popliteal artery injury.

Table 5. Key Points: Reversed saphenous vein grafts (RSVG) are preferred due to superior long-term patency compared to synthetic grafts. In situ grafts provide comparable secondary patency but involve higher technical challenges. Temporary shunts are valuable in complex trauma settings for maintaining perfusion before definitive repair.

Table 5. Outlines various vascular surgery approaches and graft options for popliteal artery repair, detailing their indications, potential complications, and special considerations.

Comparison of Vascular Surgery Approaches and Grafts			
Procedure	**Indications**	**Complications**	**Special Considerations**
Reversed Saphenous Vein Graft (RSVG) [26,54]	Transected popliteal artery without vein injury	Thrombosis, saphenous vein injury	Better long-term patency compared to synthetic grafts; used when an autologous vein is available. Can utilize bridging interposition graft when tension-free anastomosis cannot be achieved.
In Situ Saphenous Vein Graft [37,55]	Popliteal artery reconstruction in situ	Valve disruption, especially in small-diameter veins	Lower primary patency rates than RSVG, but secondary patency rates are comparable; damage to vein possible during valve removal
Synthetic Graft (e.g., PTFE) [37,60]	Used when autologous vein unavailable or damaged	Lower long-term patency, infection risk	Viable alternative; debate in literature over patency rates in below-knee or above-knee bypasses.
Temporary Shunt Placement [56]	Delayed definitive repair, polytrauma	Shunt occlusion, limb ischemia	Useful for temporary revascularization before definitive repair
Endovascular Repair [64]	Intimal tears without complete occlusion	Stent thrombosis, incomplete repair, flexion-induced damage with covered stents [26]	Minimally invasive and preserves soft tissue, suitable for intact flow with confirmed intimal tears

In patients with severe trauma and significant tissue damage, fasciotomy may be required to prevent potential compartment syndrome and is often recommended prophylactically to relieve pressure and improve outcomes [54,56]. Prophylactic fasciotomies have been associated with decreased rates of amputation, especially when performed immediately after restoring blood perfusion [57]. In a study by Sciarretta et al., fasciotomies were performed in about 75% of cases. They describe the use of a two-incision technique in four compartments, which was preferred to a one-incision technique in complex trauma cases involving significant soft tissue disruption [57].

5.2. Orthopedic Considerations

As knee dislocations with the presence of popliteal artery injury are more commonly multi-ligamentous knee injuries (MLKI), orthopedic considerations play a pivotal role in the timing, sequence, and strategies of surgical intervention. The reduction in the dislocated knee must be achieved first before moving into other approaches; however, a minority of patients may present with an irreducible dislocation typically caused by lateral or posterolateral rotational forces. This irreducibility is a consequence of the medial femoral condyle "buttonholing" the medial capsule as it travels into the knee joint during trauma [11]. After reduction is achieved, Walker et al. [11] highlight the importance of using a diverse imaging approach, combining plain radiographs, CT angiography, and MRI to fully visualize the extent of bone and soft tissue damage.

Because patients with hard signs of vascular injury will need an angiography conducted, one study has noted the utility of conducting a magnetic resonance angiography (MRA), which provides insight into the nature of the ligamentous damage [33]. Studies have shown that MRA is as effective as conventional angiography in detecting vascular injuries [66]. This dual diagnostic approach provides an advantage in pre-operative surgeon planning in complex injuries with both vascular and ligamentous damage. However, in patients with a lack of pedal pulses and an ABI of less than 0.9, exploratory vascular surgery is emergent [32]. In combination with an emergent situation, MRA does have its drawbacks with respect to the length of time required to complete a full scan, which may not be possible in times of critical care [67]. Its sensitivity and specificity in lower limb vascular injury detection are>80% and >90%, respectively, according to one study [38].

The decision to prioritize bone stabilization or vascular repair first is a subject of ongoing debate. The prevailing approach often depends on the specifics of the injury and the condition of the patient. Hundersmarck et al. outline the argument for both a bone-first (BF) and vessel-first approach (VF) [7]. The VF strategy aims to minimize limb ischemia by addressing the definitive repair of the popliteal artery first, including using a temporary shunt while the venous graft is harvested if an RSVG is used. This approach also minimizes the disturbance of surgical exposure that may be caused by the hardware in an external fixator and allows knee flexion, which may be required by the vascular surgeon for the medial popliteal approach [7]. The BF strategy, on the other hand, aims to protect the upcoming new graft by minimizing the chances of an osseous fragment from a fracture damaging it. This involves the application of an external fixator to provide stability to the knee joint [65]. Grossly unstable knee joints requiring external fixation may be seen in irreducible dislocations. Even if a patient's dislocation is reduced but cannot mobilize with a knee brace or splint, external fixation is also indicated [68]. Proponents of the BF approach believe that subsequent reduction in the VF approach may cause undue traction, putting the vascular graft at risk [7]. Their paper determined that in patients with blunt popliteal artery damage due to knee dislocation, the BF was preferred, assuming the ischemia time was not great enough to threaten limb amputation.

The prolonged use of external fixation carries risks such as pin site infections and joint stiffness. Prolonged usage of an external fixation in an MLKI is associated with arthrofibrosis, though manipulation of the knee under anesthesia is associated with better outcomes [69]. Fulton et al. discuss a case report in which a patient who had initially presented with bilateral knee dislocation underwent vascular repair and external fixation application [70]. The patient underwent manipulation under anesthesia after external fixation removal and promptly developed acute femoropopliteal bypass thrombosis, which needed to be addressed with thrombectomy. Matthewson et al. [65] emphasize that external fixation should be limited to the shortest duration necessary, with conversion to internal fixation or ligament reconstruction as soon as possible. A hinged external fixation construct may prevent the development of arthrofibrosis by allowing an earlier range of motion [65,71]. One of the drawbacks of external fixator application is the possibility of not being able to obtain post-application MRI scans of the ligamentous damage. Although MRI-compatible external hardware is often used, along with recommendations for pin placement to avoid imaging artifacts and disrupting future potential graft tunnel sites [11], there remains to be an FDA-approved MRI-safe external fixation construct [72]. As such, some hospitals may still prohibit MRI scanner usage in these patients, and certain severe soft tissue injuries may present with significant artifacts on imaging, thus disrupting pre-operative planning for ligament repair.

Timing or staging of and whether to repair or reconstruct during surgical interventions are other factors to consider in MLKI patients. Repair is generally reserved for ligaments with sufficient tissue quality and where the torn ligament may be approximated. However, in many cases, particularly with the posterolateral corner cruciate ligaments, reconstruction is favored due to higher success rates and improved return to pre-injury activity levels [48]. As stated by Ng et al. [32], there are three general timing strategies. Acute repair or reconstruction is conducted soon after injury and is arbitrarily deemed to be within 3 weeks. They state that this is the time range within which soft tissue planes may still be defined without scarring, and the ligaments will not be retracted. Staged repair or reconstruction involves the acute surgical intervention on medial and/or lateral structures while delaying cruciate reconstruction until the full range of motion is returned. Finally, delayed reconstruction occurs more than 3 weeks after the initial trauma and imparts the advantage of increased knee range of motion and allows certain structures to potentially reach acceptable healing without surgical intervention [32]. Levy et al. state that while, historically, some studies have shown arthrofibrosis development in patients with acute repair, the patients in their systematic review showed an acceptable range of motion and flexion loss, potentially due to aggressive post-surgical rehabilitation [48]. Ng et al. and Levy et al. discussed opposing approaches, specifically with respect to KD II, III, and IV injuries. While Levy et al. [48] preferred acute repair, Ng et al. [32] preferred staged repair and reconstruction, with medial and lateral extra-articular structures being repaired acutely, followed by delayed cruciate reconstruction. Levy et al., in 2010 [73], also proposed a management algorithm most similar to the delayed reconstruction described by Ng et al. [32]. They proposed that in patients receiving initial external fixator application after the injury, a delayed reconstruction 3 to 6 weeks after injury provided satisfactory outcomes with enough time to provide diminished soft tissue inflammation but still stave off fibrosis development [73]. To allow the healing of capsular structures and minimize fluid extravasation, one study suggests waiting 1 week from injury before acute arthroscopic ACL and PCL repair [33]. The repair of ACL and PCL tibial avulsions is recommended by affixing the osseous fragment to the bone tunnels in the tibia through the passage of large, nonabsorbable sutures [74]. Care must also be taken during the repair of the PCL regarding iatrogenic popliteal neurovascular damage during the creation of the tibial tunnel [74].

6. Conclusions

Injury to the popliteal artery due to knee dislocation is a rare but devastating orthopedic and vascular injury that can result in detrimental effects if not found and treated quickly. Those effects include limb ischemia, necrosis, and even amputation due to loss of blood flow. These injuries present as pain, absent pulse, and potentially numbness below the knee. The current literature recommends the use of arterial duplex ultrasound or CT angiography to confirm injury to the popliteal artery if ABI is found to be less than 0.9. Emergent exploratory vascular surgery is recommended in patients with a lack of pedal pulses. The sources included in our review indicate that a high BMI and a patient age over 30 years are factors that can decrease functional outcomes in long-term follow-ups. At this time, there remains debate over the timing and methodology of surgery and the utility of external fixation. However, recent research indicates that in knee dislocations presenting with MLKI, there is a preference for a staged approach focusing on the repair of medial and lateral structures (acutely) and cruciate structures at a delayed time. Patients may experience the development of arthrofibrosis in the knee and a thrombus at the site of their bypass. However, the sources in our review indicate that ligament reconstruction provides better long-term functional outcomes than non-reconstruction or non-operative approaches. In considering approaches to vascular repair, patients may benefit from the usage of fem-pop bypass utilizing an RSVG if there is no damage to their saphenous vein and tension-free anastomosis cannot be achieved in interpositional grafts. They may also experience better patency rates than with prosthetic grafts. Temporary shunts may also be applied to provide attention to other sites of injuries in polytrauma before definitive vascular repair. Although this review offers insights into the existing data on long-term functional outcomes in this injury, its reliance on retrospective literature poses limitations, including potential biases, small sample sizes, and varied study populations. To enhance the evidence base and guide clinical practice more effectively, future research should prioritize well-designed prospective studies. Addressing these gaps will foster more consistent, high-quality care and improve long-term functional outcomes in the management of knee dislocations with popliteal artery injuries.

Clinical Implications

- ***Early Diagnosis and Intervention:***
    - *Essential for preventing severe complications (e.g., limb ischemia, nerve damage, and potential amputation);*
    - *Prioritize initial diagnostic methods such as ABI measurements and bedside Doppler ultrasound for quick, reliable assessments;*
    - *Utilize CT angiography for detailed imaging when available.*
- ***Orthopedic Management:***
    - *Ensure prompt joint reduction to prevent further vascular or nerve damage;*
    - *Use external fixation to stabilize the knee in cases involving multi-ligamentous knee injuries (MLKIs) before definitive surgical repair;*
    - *Balance between bone-first and vessel-first approaches based on patient-specific factors to protect vascular grafts and minimize ischemic time.*
- ***Vascular Repair Strategy:***
    - *Prefer reversed saphenous vein graft (RSVG) for better long-term patency;*
    - *Consider synthetic grafts when autologous veins are unavailable, with attention to potential complications;*
    - *Employ temporary shunts to maintain limb perfusion during complex, multi-step surgeries.*
- ***Patient-Specific Considerations:***

- ○ *Recognize that higher BMI and age over 30 are linked to poorer outcomes;*
- ○ *Incorporate orthopedic rehabilitation to prevent joint stiffness and arthrofibrosis, emphasizing early mobilization.*

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