

Effectiveness of surgical treatment for popliteal artery injury: A cross-sectional descriptive study

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ABSTRACT

Background: Popliteal artery injuries are among the most severe vascular traumas, often associated with high-energy impacts such as traffic accidents and workplace injuries. Due to the limited collateral circulation in the popliteal region, delays in revascularization can lead to irreversible ischemic damage and limb loss. This study evaluates the surgical treatment outcomes of popliteal artery injuries at Viet Duc Friendship Hospital. **Methods:** A cross-sectional descriptive study was conducted on 120 patients with popliteal artery injuries who underwent emergency surgical revascularization at Viet Duc Friendship Hospital from January 2020 to August 2023. Data were collected retrospectively for cases from January 2020 to December 2022 and prospectively for cases from January to August 2023. Surgical techniques included end-to-end anastomosis, autologous vein grafting, and angioplasty. Limb salvage rates, postoperative complications, and long-term functional outcomes were analyzed. **Results:** The study population had a mean age of 32.4 years, with traffic accidents being the leading cause of injury (85.83%). End-to-end anastomosis (47.5%) and vascular grafting (36.66%) were the most common surgical techniques. The overall limb salvage rate was 95.83%, with five cases (4.16%) requiring secondary amputation due to irreversible ischemic damage. Early postoperative complications included infection (27.5%), anemia (23.33%), and muscle necrosis (15%). Long-term follow-up showed that 96.61% of patients had good limb function, while 2.5% experienced sensory and motor deficits. Timely surgical intervention significantly improved limb salvage in popliteal artery injuries. **Conclusion:** Despite a high success rate, complications remain a challenge, emphasizing the need for early diagnosis, multidisciplinary management, and long-term rehabilitation. Further research is needed to optimize treatment protocols and reduce postoperative complications.

Keywords: Artery injury, Limb salvage, Popliteal vascular trauma, Revascularization surgical treatment.

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INTRODUCTION

Popliteal artery injuries are among the most severe and challenging vascular traumas due to their anatomical location and association with complex orthopedic injuries. These injuries commonly occur in

high-energy trauma cases, such as traffic accidents and workplace injuries, and are often accompanied by fractures and knee dislocations. Due to the limited collateral circulation in the popliteal region, delays in revascularization can result in irreversible ischemic damage and limb loss [1,2].

Despite advancements in vascular surgery, the management of popliteal artery injuries remains complex, requiring a multidisciplinary approach involving vascular and orthopedic specialists. Early recognition, timely surgical intervention, and appropriate postoperative care are crucial in improving outcomes and reducing amputation rates. However, diagnosing these injuries can be challenging due to the presence of concurrent fractures, soft tissue injuries, and variable clinical presentations [3,4].

Traditional diagnostic methods, such as physical examination and ankle-brachial index (ABI) measurements, have limitations in detecting subtle vascular injuries. The integration of imaging modalities such as Doppler ultrasound and CT angiography has significantly improved diagnostic accuracy, allowing for early identification of arterial occlusions, thrombosis, and intimal tears.

Surgical management strategies vary depending on the extent of vascular damage. Direct vessel repair, end-to-end anastomosis, and autologous vein grafting are commonly employed techniques. The choice of surgical approach depends on factors such as the degree of disruption, the presence of associated musculoskeletal injuries, and the time elapsed since injury. Additionally, fasciotomy is often necessary in cases with prolonged ischemia to prevent compartment syndrome and optimize tissue perfusion post-revascularization [5].

The study aimed to assess the surgical treatment outcomes of popliteal artery injuries at Viet Duc Friendship Hospital, with a focus on limb salvage rates, surgical techniques employed, and the factors influencing patient prognosis. The study would contribute to the understanding of practices in managing these complex injuries

and to improve future treatment protocols for vascular trauma cases.

METHOD

Study design and subjects

The research plan and content were approved by the ethics committee, the leadership board of Viet Duc University Hospital, and the leadership council of Hai Phong University of Medicine and Pharmacy.

This was a cross-sectional descriptive study, approved by the ethics committee, the leadership boards Viet Duc University Hospital, and Hai Phong University of Medicine and Pharmacy. Informed consent was obtained from patients and their families for participation. The study consisted of a retrospective analysis of 99 patients from January 2020 to December 2022 and a prospective analysis of 21 patients from January 2023 to August 2023. The study was conducted at Viet Duc Friendship Hospital, Hanoi, Vietnam. Convenience sampling was applied, including all eligible patients within the study period.

Inclusion criteria

Patients were included in the study if they met all of the following conditions:

Had a confirmed diagnosis of popliteal artery injury, either preoperatively or intraoperatively.

Underwent emergency surgical revascularization of the popliteal artery at Viet Duc Friendship Hospital.

Had complete medical records and sufficient clinical information for the study.

Exclusion criteria

Patients who were diagnosed with popliteal artery injury but did not undergo emergency surgical revascularization at Viet Duc Friendship Hospital.

Patients with incomplete medical records.

Data collection method

Data were collected using a standardized medical record form from January 1, 2020, to August 31, 2023, including a retrospective review from January 2020 to December 2022 and a prospective study from January 2023 to August 2023.

Data collection process

Patient identification: A list of patients was compiled based on archived medical records and surgical logs from the Planning and General Affairs Department of Viet Duc Friendship Hospital, ensuring adherence to the inclusion and exclusion criteria.

Data recording: All relevant information was documented using a standardized medical record form. Cases with incomplete data were excluded from the study. The patient list was verified by the Planning and General Affairs Department of Viet Duc Friendship Hospital and the supervising instructor.

Data entry and analysis: The collected data were entered and processed using medical statistical software.

Assessment of clinical characteristics

Key symptoms:

- Swelling and Bruising: Knee swelling, bruising, hematoma formation.
- Reduced or Absent Peripheral Pulses: Assessment of dorsalis pedis and posterior tibial artery pulses, compared to the uninjured limb.

Acute limb ischemia symptoms:

- Severe calf pain and tightness.
- Cold extremity (compared to the unaffected side).
- Pale skin (compared to the unaffected side).
- Numbness or sensory loss in the toes.
- Reduced or absent movement of the foot and toes.

- Delayed capillary refill (>2 seconds; normal is ≤ 2 seconds).

Signs of irreversible limb ischemia:

- Complete loss of movement in the foot and toes.
- Complete loss of sensation in the foot.
- Rigor mortis in the joints.
- Blackened, necrotic tissue in the distal limb.
- Fracture or Dislocation Indicators:
- Severe pain and inability to move the knee.
- Swollen and deformed knee joint.

Compartment syndrome:

- Severe pain, worsening with passive or active movement.
- Swollen, tense, and bruised calf.
- Reduced or absent peripheral pulses.
- Numbness, weakness, or complete loss of limb movement.

Associated systemic injuries:

- Traumatic brain injury, chest trauma, abdominal trauma, spinal injury, or fractures in other areas.
- General Systemic Signs.

Assessment of Paraclinical characteristics

Doppler Ultrasound: Detects intraluminal thrombus, absence or reduction of blood flow signals at and below the arterial injury, and assesses triphasic arterial waveforms. This is a commonly used diagnostic test with a sensitivity and specificity exceeding 90%.

X-ray Imaging of Bones and Joints: Confirms fractures or dislocations around the knee joint. Identifies injury patterns such as knee dislocation, tibial plateau fracture, supracondylar femur fracture, distal third femur fracture, proximal third tibia fracture, and fractures of both tibia and fibula in the proximal third.

Multislice Computed Tomography Angiography (MSCTA): Visualizes arterial

occlusion, thrombus formation, and collateral circulation. Indicated in complex cases where clinical findings and Doppler ultrasound results are inconclusive, in early hospital admissions where conditions allow for further testing, or when Doppler ultrasound is limited due to excessive limb swelling, extensive wounds, or severe soft tissue damage.

Blood tests:

- Complete Blood Count (CBC): Includes red blood cell count, hemoglobin, and hematocrit levels.
- Biochemical Tests: Measures blood urea, creatinine, and creatine kinase (CK) levels.

Assessment of blood loss

- Mild Blood Loss: Heart rate < 90 bpm, systolic blood pressure > 100 mmHg, red blood cell count > 3.5 million/mm³, hemoglobin > 10 g/dL, hematocrit 30–35%.
- Moderate Blood Loss: Heart rate 100–120 bpm, systolic blood pressure 80–100 mmHg, red blood cell count 2.5–3 million/mm³, hemoglobin 9–10 g/dL, hematocrit 25–30%.
- Severe Blood Loss: Heart rate > 120 bpm, systolic blood pressure < 80 mmHg, red blood cell count < 2.5 million/mm³, hemoglobin < 8 g/dL, hematocrit < 25%.

Surgical procedure

The surgical procedure for popliteal artery revascularization involves patient preparation with general or spinal anesthesia, sterilization, and the use of vascular surgical instruments, including Fogarty catheters. The patient is positioned supine with a 30-degree knee flexion, and the surgical approach depends on the injury's location. Bone injuries are managed

with external fixation, Kirschner wires, or screws, while soft tissue injuries require debridement and irrigation. The popliteal artery is exposed using either a low or high approach, depending on the injury site. Arterial injuries are treated by removing thrombi and reconstructing the artery through direct anastomosis (if the segment is <2 cm) or autologous great saphenous vein grafting (if >2 cm). Synthetic grafts are rarely used due to thrombosis and infection risks. If the popliteal vein is injured, it is either repaired or ligated. Fasciotomy is performed when ischemia lasts over six hours or compartment syndrome develops. Postoperative circulation is monitored via clinical examination and Doppler ultrasound, assessing arterial patency, limb color, temperature, pulses, movement, and capillary refill. A minimum follow-up of one month ensures vascular healing and endothelialization.

Surgical management of popliteal artery injuries

Preoperative management

Patients with popliteal artery injuries require careful preoperative stabilization, including fracture and joint dislocation management, administration of isotonic and colloid fluids to maintain hemodynamic stability, and blood transfusion in cases of significant hemorrhage. Medications such as antibiotics, tetanus prophylaxis for open wounds, pain management drugs, and selective anticoagulants are administered as necessary. Soft tissue injuries are classified based on the Tscheme and Gotzen Classification (1984) and the Gustilo Open Fracture Classification (1984), assessing the extent of tissue damage and the risk of complications such as infection and compartment syndrome. Injury severity ranges from minimal soft tissue damage with

simple fractures to extensive tissue destruction involving muscle crushing and vascular injury.

Surgical treatment management

Fracture stabilization around the knee is achieved through external fixation, plating, or Kirschner wires. Popliteal artery injuries are classified based on the pattern of damage, including complete arterial transection, arterial contusion, intimal thrombosis, or arterial spasm, and are further categorized by location (supragenicular, infragenicular, at knee level, or combined). Vascular reconstruction techniques involve angioplasty, primary arterial repair, end-to-end anastomosis, autologous reversed saphenous vein grafting, or synthetic vascular grafting. To prevent compartment syndrome, fasciotomy may be performed. Associated injuries, such as nerve and venous damage, are managed with selective nerve reconstruction, venous repair, or ligation. Intraoperative anticoagulation is sometimes used, and the duration of surgery is monitored to optimize outcomes.

Postoperative management

Postoperative monitoring focuses on circulatory assessment, including peripheral pulses (dorsalis pedis and posterior tibial), limb temperature, skin color, sensory and motor function, and capillary refill. Wounds are managed carefully to prevent infection, while laboratory tests such as Complete Blood Count (CBC), biochemical markers (urea, creatinine, creatine kinase), and Doppler ultrasound are used to detect vascular complications like thrombosis or hemorrhage. Fracture reassessment via X-ray ensures proper alignment. Postoperative care includes fluid resuscitation, blood transfusion if necessary, antibiotic therapy, and anticoagulation, typically starting with heparin infusion for 48–72 hours, followed

by oral anticoagulants (Aspegic) for 30 days. Early rehabilitation is encouraged, with patients gradually resuming sitting and limb mobilization. The length of hospitalization is determined by the patient's progress and complications.

Evaluation of arterial reconstruction outcomes

Postoperative functional assessment includes evaluating limb color (pink, pale, or cyanotic), temperature (warm or cold), peripheral pulses (strong, weakened, or absent), distal motor and sensory function (normal, reduced, or absent), and capillary refill. Doppler ultrasound is used to assess arterial patency, identify complications such as stenosis or occlusion, and analyze blood flow patterns, categorized as triphasic, biphasic, or monophasic.

Complication management

Complications following surgery range from severe anemia, characterized by pallor, tachycardia (>120 bpm), hypotension (systolic BP <90 mmHg), and reduced hematocrit levels, managed with blood transfusion and oxygen therapy, to acute kidney injury, indicated by reduced urine output (<500 ml/24h), elevated creatinine (>130 pmol/l), and serum CK (>1000 U/l), requiring fluid resuscitation and diuretics. Infections are managed based on severity, with early-stage infections treated through wound drainage, necrotic tissue debridement, and high-dose broad-spectrum antibiotics, while vascular occlusion requires surgical ligation and bypass creation. Vascular occlusion may necessitate re-exploration surgery, thrombus removal, and vascular grafting, while compartment syndrome requires immediate fasciotomy. Prolonged limb edema is treated with limb elevation and gentle mobilization, and irreversible limb ischemia may necessitate

amputation. Additional complications include pseudoaneurysms at anastomotic sites, arteriovenous fistulas, and reduced limb function, each managed through endovascular or surgical interventions and rehabilitation therapy. Mortality is documented as an outcome when applicable.

Postoperative sequelae management

Long-term postoperative issues include vascular stenosis, managed with angioplasty, and vascular occlusion, which may require surgical revascularization. Patients experiencing arterial aneurysms or arteriovenous fistulas undergo surgical ligation or excision, while those with

functional and sensory deficits receive structured rehabilitation therapy to restore limb movement and sensation.

Data statistics

Data were entered and analyzed using SPSS 20.0. Qualitative variables were expressed as percentages, while quantitative variables were analyzed using the T-Student test to compare means. Categorical variables were assessed using the Chi-square test (χ^2) to determine associations. Non-parametric variables were presented as absolute values and proportions. A p-value < 0.05 was considered statistically significant.

RESULTS

Demographic and injury characteristics

The participants ranged in age from 11 to over 70 years. The most common age groups were 21-30 years (n = 28, 23.33%) and 11-20 years (n = 27, 22.5%), followed closely by 31-40 years (n = 27, 22.5%). Fewer cases were observed in older age groups, with 41-50 years accounting for 20 individuals (16.67%), 51-60 years for 14 individuals (11.67%), and only 3 individuals (2.5%) in the 61-70 age range. The least represented group was those above 70 years, with just one individual (0.83%).

The predominant cause of injury was traffic accidents, which accounted for 103 cases (85.83%). Work-related accidents were the second most common cause, affecting 11 individuals (9.17%), while domestic accidents were the least frequent, with 6 cases (5%). Pre-hospital treatment primarily involved fracture immobilization, which was administered to 119 individuals (99.17%). Bone fixation was performed in only one case (0.83%).

Surgical and therapeutic approaches in popliteal artery trauma management

Among 120 patients with popliteal artery injuries, end-to-end anastomosis was the most commonly performed procedure, accounting for 47.5% of cases, mainly in patients with contusions (20.83%) and small-segment transections (10.83%). Vascular grafting was performed in 36.66% of cases, predominantly for larger contusions (18.32%) and extensive thrombotic damage (12.5%). Angioplasty was used in 15.84% of cases, specifically for patients with vasospasms. These findings indicate that surgical intervention varies depending on the severity and type of arterial injury. All other vascular injuries associated with popliteal artery trauma undergo surgical repair to maximize blood flow restoration (Table 1).

Among the 119 cases, external fixation was applied in 21 cases (17.65%), while Kirschner wire fixation was used in 98 cases (82.35%). Notably, no cases were treated using plate fixation (0%). Anticoagulant therapy with heparin was administered in 118 cases (98.34%), while only 2 cases (1.66%) did not receive anticoagulation. Heparin was administered in 119 cases

(99.17%), while Aspegic was used in 115 cases (95.84%). Only 1 case (0.83%) did not receive anticoagulant therapy.

Table 1. Morphology and management of popliteal artery injuries (n=120)

Treatment Method	Segmented Transection ≤ 2cm No. (%)	Segmented Transection > 2cm No. (%)	Contusion ≤ 2cm No. (%)	Contusion > 2cm No. (%)	Contusion with Thrombosis ≤ 2cm No. (%)	Contusion with Thrombosis > 2cm No. (%)	Vasospasm No. (%)
End-to-End Anastomosis	13 (10.83%)	0 (0%)	25 (20.83%)	0 (0%)	19 (15.84%)	0 (0%)	0 (0%)
Angioplasty	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	19 (15.84%)
Vascular Grafting	0 (0%)	7 (5.84%)	0 (0%)	22 (18.32%)	0 (0%)	15 (12.5%)	0 (0%)
Total	13 (10.83%)	7 (5.84%)	25 (20.83%)	22 (18.32%)	19 (15.84%)	15 (12.5%)	19 (15.84%)

Complications

Table 2 presents early postoperative complications in 120 cases. The most common complications were infection (27.5%) and postoperative anemia (23.33%), followed by muscle necrosis (15%). Limb necrosis occurred in 4.16% of cases, while vascular occlusion was observed in 2.5%. Osteomyelitis was rare (0.83%), and no cases of postoperative bleeding were reported. All postoperative complications were managed to the fullest extent; however, limb amputation was still required in some cases on the second postoperative day (n = 5, 4.16%).

Table 2. Early postoperative complications (n=120)

Complications	No.	%
Infection	33	27.5%
Vascular occlusion	3	2.5%
Bleeding	0	0%
Postoperative anemia	28	23.33%
Muscle necrosis	18	15%
Limb necrosis	5	4.16%
Osteomyelitis	1	0.83%

Outcomes at discharge

During postoperative treatment, five patients in the study group developed limb necrosis, necessitating secondary amputation due to the inability to preserve the limb. As a result, 115 patients remained eligible for the assessment of limb perfusion status at discharge. The majority of patients had good limb perfusion at discharge, with signs of a pink, warm limb, palpable pulses, and preserved capillary refill (100%). Limb motor function and sensation were well maintained in 98.26% of cases (n = 113), while the rate of motor and sensory impairment was low (n = 2, 1.74%).

All patients who successfully preserved their limbs at discharge had favorable Doppler ultrasound results, showing good vascular patency, no stenosis, and a triphasic flow pattern (100%).

Long-term outcome assessment

The study group conducted follow-up examinations on patients at a minimum of one month and a maximum of four years after surgery. Among the study group, five patients underwent limb amputation due to irreversible limb damage postoperatively. In these cases, inadequate perfusion led to critical limb ischemia and necrosis. The remaining 115 patients were eligible for long-term outcome evaluation. Of these, 80 patients (66.67%) were successfully followed up, with a minimum follow-up period of one month and a maximum of four years post-surgery. However, 35 patients (29.16%) could not be re-evaluated due to loss of contact. Among the followed-up patients, 21 (26.25%) were examined one month after surgery as part of the prospective study group, while 59 patients (73.75%) were evaluated more than one month postoperatively and belonged to the retrospective study group.

All patients who were followed up one month after surgery had well-perfused limbs, with a pink, warm appearance, palpable peripheral pulses, good motor function, intact sensation, and preserved capillary refill (100%).

Among patients followed up more than one month postoperatively, the majority also exhibited well-perfused limbs with a pink, warm appearance, palpable peripheral pulses, and preserved capillary refill (100%). Additionally, 96.61% (n = 57) maintained good motor function and sensation, while 3.32% (n = 2) experienced numbness and reduced mobility.

All 80 patients who underwent follow-up examinations had favorable Doppler ultrasound results, showing good vascular patency, no stenosis, and a triphasic Doppler waveform in 100% of cases.

Postoperative sequelae were observed in two cases (2.5%) where patients experienced limb numbness and reduced mobility, both belonging to the retrospective study group. No cases of vascular occlusion, infection, or limb necrosis were reported after hospital discharge.

DISCUSSION

The findings of this study highlight the complexity of managing popliteal artery injuries and emphasize the importance of timely surgical intervention to optimize patient outcomes. The study demonstrated that traffic accidents were the predominant cause of these injuries, accounting for 85.83% of cases. This finding aligns with previous studies indicating that high-energy trauma is a major risk factor for vascular injuries [6-10]. The high incidence of popliteal artery injuries among young adults (ages 11-40) underscores the significant socioeconomic impact of these injuries, as

they frequently affect the working-age population.

Our study found that end-to-end anastomosis (47.5%) and vascular grafting (36.66%) were the most commonly used surgical techniques. These findings are consistent with global trends in vascular trauma management, where direct anastomosis is preferred for shorter arterial defects, while autologous vein grafting is required for larger segmental losses. The use of angioplasty in 15.84% of cases reflects an effort to restore blood flow in cases of vasospasm or minor arterial injuries.

Despite advancements in surgical techniques, complications remain a concern. Infection

(27.5%) and postoperative anemia (23.33%) were the most common early complications, which may be attributed to the severity of associated soft tissue injuries and blood loss during surgery. The need for secondary amputation in 4.16% of cases indicates that despite surgical efforts, delayed or inadequate revascularization can lead to irreversible ischemic damage. This underscores the necessity for rapid diagnosis and intervention to improve limb salvage rates.

Our findings are comparable to previous studies that reported limb salvage rates between 80-95% following timely surgical intervention for popliteal artery injuries [6-10]. The high percentage of successful limb preservation in our study (95.83%) supports the effectiveness of current surgical protocols at Viet Duc Friendship Hospital. However, the presence of long-term sequelae in a small subset of patients, such as numbness and reduced mobility (2.5%), suggests the need for continued rehabilitation and monitoring to optimize functional recovery.

The study reinforces the critical role of a multidisciplinary approach in managing popliteal artery injuries. Early recognition, immediate vascular imaging, and prompt surgical intervention are crucial in improving outcomes. The use of Doppler ultrasound and CT angiography proved to be essential diagnostic tools, allowing for early detection of arterial occlusions and guiding surgical decision-making.

The findings also highlight the importance of postoperative care, including vigilant monitoring for complications such as vascular occlusion, infection, and compartment syndrome. The implementation of standardized postoperative anticoagulation protocols with heparin and Aspegic was

associated with good vascular patency and reduced rates of thrombosis.

Despite its valuable insights, this study had some limitations. The retrospective design may introduce selection bias, and the relatively small sample size may limit the generalizability of the findings. Additionally, the loss of follow-up in 29.16% of cases restricts the ability to assess long-term functional outcomes comprehensively. Future research should focus on prospective, multicenter studies with larger sample sizes to validate these findings and explore novel techniques for improving limb salvage and functional recovery in popliteal artery injury cases.

CONCLUSIONS

The study underscores the significant challenges in managing popliteal artery injuries and highlights the effectiveness of surgical interventions in limb preservation. While the overall limb salvage rate was high, the occurrence of complications emphasizes the need for continued advancements in surgical techniques, perioperative care, and rehabilitation strategies. Implementing standardized treatment protocols and ensuring timely intervention can further enhance patient outcomes in vascular trauma cases.

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Institutional Review Board Statement: approved by the ethics committees and leadership boards of Viet Duc University Hospital and Hai Phong University of Medicine and Pharmacy

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reasonable request, after the signature of a formal data-sharing agreement in an anonymous form, from the corresponding author because they are protected by privacy.

Conflicts of Interest: The authors declare no conflicts of interest.

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