Five-year outcomes of trauma-specific function in patients after acute blunt popliteal artery injury: a matched cohort analysis

Gang Liu†, Jialei Chen† and Zhou Xiang*

Abstract

Background: Few studies focus on the trauma-specific functional outcomes after surgical revascularization and risk factors contributing to poor outcomes in patients with acute blunt popliteal artery injury (PAI). The objective of this study was to investigate the long-term trauma-specific functional outcomes in patients with acute blunt PAI and identify the associated risk factors.

Methods: There were 36 patients with acute blunt PAI who require surgical revascularization at a national trauma center of West China Hospital of Sichuan University between March 2010 and April 2019. After propensity matching, each patient was matched to one patient who did not have a concomitant vascular injury in control cohort. Functional outcomes were assessed with trauma-specific functional scores, physical examination of range of motion, nerve functional status and knee stability. A logistics regression model was established to determine the independent risk factors.

Results: The 5-year (range 2–10 years) follow-up showed that 22 patients (22/36, 61.1%) had functional deficit due to limited activity or chronic neurological symptoms. Patients in vascular cohort had significantly decreased FIM score and AHFS score compared with matched patients without vascular involvement (P = 0.003 and P < 0.001), whereas there was no statistically significant difference in KSS (P = 0.136). Spearman correlation analysis of functional scores in vascular cohort showed that the FIM score was positively correlated with AHFS score (r = 0.926, P < 0.001), but not correlated with the KSS (r = −0.007, P = 0.967). Additionally, there was significant difference in the range of motion of ankle between two groups (P < 0.001 and P = 0.034). Logistic regression analysis further demonstrated nerve injuries and compartment syndrome were risk factors for poor ankle function after surgery (OR 22.580, P = 0.036 and OR 12.674, P = 0.041).

Conclusion: Most patients who sustained blunt PAI had significant functional deficit associated with limited activity and chronic neurological symptoms of ankle and foot, and poor functional outcomes were related to nerve injury and compartment syndrome. Therefore, early and effective decompression for compartment syndrome remains the only potentially modifiable risk factor for improving functional outcomes following PAI.

Keywords: Popliteal artery injury, Blunt trauma, Function, Risk factor, Long-term follow-up

Background

Acute popliteal artery injury (PAI) is a potentially limb-threatening medical emergency associated with fracture/dislocation of knee [1, 2]. Previous investigations have demonstrated that 56.8%-61% of the injuries were involved in blunt mechanism. Compared with...
penetrating trauma, blunt trauma is thought to yield high amputation rate and poor clinical outcomes because of complicated soft tissue injuries [3, 4]. Non-operative treatment is definitely not recommended if popliteal artery injuries are significant and present with acutely ischemic limbs [5]. Although significantly reduced amputation rates for PAI have been achieved with improved revascularization technology, it is still a challenge for orthopedic surgeons mainly due to the heterogeneous patient populations with moderately to severely blunt PAI [6, 7].

Despite extensive reviews on limb salvage and the difference between blunt and penetrating PAI [3, 4, 8], minimal studies have focused on the functional outcomes after limb salvage in this patient population. Additionally, the major limitations of previous studies which had explored functional outcomes were the focus of self-care disability and activities of daily living instead of trauma-specific function, and the unknown reason for functional loss following treatment of PAI [3, 9]. A detailed description of the long-term functional outcomes from trauma-specific design for patients with acute blunt PAI and risk factors contributing to poor trauma-specific function is lacking. Therefore, the purpose of this study was to evaluate trauma-specific functional outcomes in patients with acute blunt PAI after successful limb salvage. The research also identified risk factors contributing to poor functional outcomes.

Methods
Inclusion and exclusion criteria
Patients were identified through a search of prospectively gathered database of patients with acute blunt PAI who require surgical revascularization at a national trauma center of West China Hospital of Sichuan University between March 2010 and April 2019. Inclusion criterion was patients who had acute blunt PAI requiring surgical revascularization. Patients were excluded if they were followed for <2 years, sustained PAI caused by non-trauma or penetrating injury, or were treated non-operatively. Patients who had undergone primary surgery before being admitted to our hospital were also excluded. Additionally, all patients with limb salvage should receive physiotherapy by a professional specialist and be followed up in our outpatient interviews for a minimum of 2 year after surgery.

A total of 296 patients with acute blunt popliteal artery injury were admitted to the institution. Of these patients, limb salvage was obtained in 36 patients after surgical procedures, and these patients were identified in vascular cohort (Fig. 1). In order to compare limb function during the follow-up, each patient was matched to one patient who did not have a vascular injury in control cohort. The matching was based on age at injury (within 5 years if the age was <50 years and within 10 years if the age was ≥50 years), knee dislocation (KD) grade [10] and knee fracture classification [11]. According to the matching system, 14 patients in each cohort had knee dislocation, including 5 KD-III L, 6 KD-III M, 2 KD-IV and 1 KD-V. A total of 22 patients with knee fracture in each cohort, including 5 patients with extraarticular fracture, 9 with partial articular fracture and 8 with complete articular fracture (Table 1).

Postoperative management
Patients had delayed passive activity of knee joint at least 3 weeks after surgery with the assistance of an external fixator, progressive active and weight-bearing exercise at least 6 weeks and 12 weeks after surgery, respectively. However, if patients had nerve or complicated soft tissue injuries, weight-bearing exercise should be postponed to 6 months after surgery. Early active and passive activity of ankle joint was recommended.

Data collection
A prespecified form was used to general data from patients’ medical records and outpatient interviews, including the Injury Severity Score (ISS) [12], associated injuries, surgical interventions and functional outcomes at the follow-up period. Ischemia time was defined as the time interval from trauma to blood flow restoration. Complicated soft tissue injury was defined as open fracture and/or dislocation around knee. Nerve injury was diagnosed according to clinical symptom and electromyogram. The diagnosis of compartment syndrome was based on clinically apparent compartment hypertension or after intracompartmental pressure measurement.

Functional assessment
Modified Functional Independence Measure (FIM) score was used to evaluate the degree of dysfunction of lower extremity from three aspects, including pain, locomotion and climb stairs. The patient-reported functional score for each aspect ranges from 1 (full dependence on assistance) to 4 (full independence), giving a maximum total score of 12 representing full independence if three aspects are added together (Table 2). Patients were considered to have excellent or good result if FIM score was ≥10, fair 6 to 9 points and poor <6 points. Additionally, Knee Society Score (KSS) and Ankle–Hindfoot Scale from American Orthopaedic Foot and Ankle Society (AHFS, short for AOFAS-AHFS) were assessed, and KSS≥69 points or AHFS score <75 points were defined as poor functional results [13, 14]. The ranges of motion and nerve status were also assessed with physical examination at the end of follow-up visit. If the patient had a
Fig. 1 Flow diagram depicting patients arrived at final vascular cohort

Table 1 Demographic data and injury details in vascular and control cohorts

|                      | Vascular injury (n = 36) | No vascular injury (n = 36) | P value |
|----------------------|--------------------------|----------------------------|---------|
| Age (year)           | 41.5 (16–72)             | 42 (21–74)                 | 0.057   |
| Sex (male/female)    | 31/5                     | 28/11                      | 0.089   |
| Follow-up (year)     | 5 (2–10)                 | 4 (2.5–7)                  | 0.073   |
| Injury Severity Score (points) | 11 (9–22)       | 4 (4–13)                  | <0.001  |
| Mechanism of injury, no. (%) |                  |                            | 0.525   |
| Fall                 | 9 (25%)                  | 13 (36.1%)                 |         |
| Crush                | 10 (27.8%)               | 7 (19.4%)                  |         |
| Traffic accident     | 17 (47.2%)               | 16 (44.4%)                 |         |
| Knee dislocation (KD) grade, no. (%) |              |                            | –       |
| I                    | 0                        | 0                          |         |
| II                   | 0                        | 0                          |         |
| III L                | 5                        | 5                          |         |
| III M                | 6                        | 6                          |         |
| IV                   | 2                        | 2                          |         |
| V                    | 1                        | 1                          |         |
| Knee fracture classification, no. (%) |              |                            | –       |
| Extraarticular       | 5                        | 5                          |         |
| Partial articular    | 9                        | 9                          |         |
| Complete articular   | 8                        | 8                          |         |
| Nerve injuries, no. (%) | 25 (69.4%)            | 6 (16.7%)                  | <0.001  |
| Compartment syndrome, no. (%) | 16 (44.4%)        | 5 (13.9%)                  | 0.004   |

The values are given as the medians with the range or counts with percentages in parentheses.
knee dislocation, with or without knee fracture, physical examination tests of knee stability included the Lachman test, valgus stress test, varus stress test and external rotation drawer test.

Statistical analysis
Continuous variables are expressed as medians and interquartile range (IQR) and analyzed by Mann–Whitney U test because of the nonparametric nature of the data and associated small sample size. Categorical variables were shown as frequencies (percentages), and compared by χ² or the Fisher exact test. Spearman correlation analysis was performed to assess whether FIM score was associated with KSS or AHFS score. A multivariate logistics regression model was established, and an enter method was utilized to determine independent risk factors for poor functional outcomes. Statistical analyses were performed using SPSS 25.0 software (IBM Corp, Armonk, NY). All statistical tests were a two-tailed, and significance was set at P < 0.05.

Results
Patient characteristics
This study consisted of 31 males (86.1%) and 5 females (13.9%). The median age was 41.5 years (range 16–72 years). The median follow-up time was 5 years (range 2–10 years). The average ISS for patients with complicated soft tissue injuries in this study was 13.5 points (range 13–22 points), and none of the patients had an ISS > 25. All surgical procedures were performed with open repair, including Fogarty thrombectomy in 4 patients (11.1%), direct repair in 9 (25.0%) and autogenous vein grafts in 23 (63.9%). Flow-restored arterial repair was obtained ≥ 8 h after injury in all patients with an average of 22.9 h (range 8 to 61 h). Of these patients, delayed repair < 10 h were found in 3 patients, 10–15 h in 6 patients, 16–24 h in 16 patients, >24 h in 11 patients. External fixators were used to stabilize the knee joint before vascular repair in 23 patients (63.9%). Fasciotomy was performed in 19 patients (52.8%) as a prophylactic procedure or due to a clinically apparent compartment syndrome. The technique we used was a two-incision four-compartment fasciotomy.

Functional outcomes
The functional outcomes of lower extremity are presented in Table 3. Using the FIM score to quantify the level of dysfunction of lower extremity of patients with successful limb salvage, we found moderate-to-severe degree of impairment, with an overall outcome score of 9.0 (4–12). The median of KSS score was 83.5 points (range 74 to 100 points), rated as excellent or good in all patients (100%). The median of AHFS score was 68 points (range 24 to 99 points), rated as excellent or good for 16 patients (44.4%) and poor for 20 patients (55.6%). Patients in vascular cohort had significantly decreased FIM score and AHFS score compared with matched patients without vascular involvement (P = 0.003 and P < 0.001), whereas there was no statistically significant difference in KSS (P = 0.136).

On physical examination, there were no significant differences the final ranges of motion of knee between two cohorts (P = 0.865 and P = 0.083). However, there were

| Index | FIM score |
|-------|------------|
| Pain  | Severe     | Moderate  | Slight | Painless      |
| Locomotion | Walking < 15 m requiring help > 1 person | Walking < 45 m requiring standby supervision | Walking > 45 m with brace or crutch | Walking > 45 m without assistance |
| Climb stairs | Cannot climb stairs | Can only climb up stairs with handrails | Can climb stairs with handrails | Unlimited climbing stairs |

Table 2 Modified Functional Independence Measure (FIM) score of lower extremity

| Index | FIM score |
|-------|------------|
| 1 point (dependent, total help required) | 2 points (dependent, partial help required) | 3 points (independent, with device) | 4 points (independent, without assistance) |

| Index | Functional Independence Measure (FIM) score of lower extremity | Vascular injury (n = 36) | No vascular injury (n = 36) | P Value |
|-------|------------------------------------------------------------|--------------------------|-----------------------------|---------|
| FIM   | 9.0 (4–12)                                                 | 10.5 (5–12)              | 0.003                        |
| KSS   | 83.5 (74–100)                                             | 92 (75–100)              | 0.136                        |
| AHFS  | 68 (24–99)                                                | 100 (90–100)             | <0.001                       |
| Range of motion (°) | 3.5 (0–10) | 5 (0–9) | 0.865 |
| Extension of knee | 115 (80–145) | 120 (100–145) | 0.083 |
| Flexion of knee | 45 (35–45) | 45 (35–45) | <0.001 |
| Plantar flexion of ankle | 40 (25–50) | 45 (40–50) | 0.034 |

The values are given as the medians with the range in parentheses
FIM Functional Independence Measure; KSS Knee Society Score; and AHFS Ankle–Hindfoot Scale
significant differences in activity of dorsiflexion and plantar flexion of ankle \((P<0.001\) and \(P=0.034\)) (Table 3).

There were also no significant differences in the results of physical examination tests of knee stability, including the Lachman test, valgus stress test at 0° or 30°, varus stress test at 0° or 30° and external rotation drawer test. Of these 25 patients who had initial nerve injuries, 14 regained normal nerve function and 11 had chronic neurological symptoms at the time of final follow-up. The 5-year clinical follow-up showed that 22 \((22/36, 61.1\%)\) patients with FIM \(\leq 9\) were recorded as having functional deficit after surgery because of limited activity or chronic neurological symptoms.

### Potential risk factors for poor functional outcomes

Spearman correlation analysis of functional scores in vascular cohort showed that the FIM score was positively correlated with AHFS score \((r = 0.926, P<0.001)\), but not correlated with the KSS \((r = -0.007, P = 0.967)\) (Fig. 2). Logistic regression analysis further demonstrated nerve injuries and compartment syndrome were risk factors for poor ankle function after surgery \((OR 22.580, P = 0.036\) and \(OR 12.674, P = 0.041)\) (Table 4).

### Complication after surgical revascularization

Observed complications after surgery included shock in 7 patients, deep infection in 5 patients and gastrocnemius necrosis in 25 patients. Compartment syndrome, which is the most severe potential complication after revascularization, was not observed in this series. Repeated debridement was required in 21 patients due to severe soft tissue damage and infection, with an average hospital stay of 21.7 days \((range 3–47\) days).

### Discussion

To our knowledge, this is the first trauma-specific study investigating the long-term functional outcomes in patients with acute blunt PAI after surgery. The 5-year clinical results of our study suggested that most patients who sustained blunt PAI had significant functional deficit associated with limited activity and chronic neurological symptoms of ankle and foot. Additionally, we also found that long-term outcomes were related to nerve injury and compartment syndrome. Early and effective decompression for compartment syndrome remains the only potential modifiable risk factor for improving functional outcomes following PAI.

Few studies reported trauma-specific functional outcomes for patients with blunt PAI after revascularization. We are aware that only two studies gave a detailed account of self-care disability or daily activity, although they did not include trauma-specific functional outcomes [3, 9]. An analysis of 64 patients with traumatic PAI at 1-year clinical follow-up showed that 30 patients returned to their normal activity level [3]. Similarly, 12 of the 61 survivors with acute blunt PAI had a basic mobility score that fell within the normal range and 15 patients had a normal measure of daily activity at the median follow-up of 11.2 years in another study [9]. Our study confirmed these findings and further explored that the poor subjective function of lower extremity was mainly caused by dysfunction of ankle and foot due to limited activity and residual neurological symptoms. It may be related to complicated soft tissue injuries, prolonged limb ischemia, nerve injuries and compartment syndrome. In addition, nearly two-thirds of the patients had used external fixators for prolonged immobilization because of complicated soft tissue injuries in our series. Despite this, there was no significant difference in postoperative functional scores and range of motion of knee between the two groups.

Compartment syndrome was associated with persistent sequelae after traumatic PAI, particularly presented as long-term sequelae of foot and ankle [15, 16]. A retrospective series of 60 patients who underwent fasciotomy for acute compartment syndrome following limb

---

**Table 4** Potential risk factors for poor functional outcomes

| Variable                   | Odds ratio (95% CI) | \(P\) value |
|----------------------------|---------------------|-------------|
| ISS                        | 0.688 (0.289–1.641) | 0.399       |
| Complicated soft tissue injury | 1.294 (0.047–35.430) | 0.879       |
| Nerve injuries             | 22.580 (1.228–415.024) | 0.036       |
| Compartment syndrome       | 12.674 (1.116–143.936) | 0.041       |
| Duration of ischemia       | 0.955 (0.870–1.048) | 0.331       |

**ISS** Injury Severity Score
trauma reported 42 patients had persistent sequelae including motor weakness, paresthesia and dysesthesia [17]. A similar series demonstrated that deformity and functional impairment in the foot and ankle secondary to ischemia are determined by fibrotic cicatrix [18]. Therefore, persistent sequelae were associated with a higher rate of reoperation, post-fasciotomy complications and neuromuscular dysfunction. It may be mainly related to prolonged ischemia because of delayed diagnosis and treatment [19, 20]. In our series, fasciotomy cannot be performed within ≤6 h since the majority of patients (27/36) were treated after 16 h from initial injury. Nevertheless, prolonged fasciotomy did not increase the risk of amputation, and unsatisfactory functional results were more common, presenting as limited activity and chronic neurological symptoms of ankle and foot. Some authors support the concept of urgent revascularization within 6 h from the time at injury to repair could be predictive of poor functional outcome, particularly in these condition combined with prolonged warm ischemia and compartment syndrome [3, 9]. In fact, it may be related to decreased collateral circulation from superficial femoral artery due to osteofascial compartment hypertension [21]. Therefore, there was no better strategy for dealing with compartment syndrome other than early recognition and prompt decompression, especially in these patients with acute limb ischemia.

The results of the study also showed that the majority of patients with nerve dysfunction had significant lower ankle functional scores, which is in accordance with previous literature [22]. O’Malley et al. [23] found that patients with complete nerve injuries typically had a worse prognosis and appeared more severe ankle dysfunction than those with incomplete palsies. In addition, Woodmass et al. [24] identified vastly different prognosis between patients who suffered an incomplete common peroneal nerve palsy and complete common peroneal nerve palsy after knee dislocation in 13 studies with 214 patients. Eighty-seven percent of patients with an incomplete palsy had achieved a full motor recovery. By contrast, 38% of patients with a complete motor palsy had regained the ability to dorsiflex at the ankle. It is probably because complete common peroneal nerve palsy usually followed more severe soft tissue injuries and had concurrent motor end plate death [25, 26]. It has been reported that chronic pain may still exist for a long time even after corrective arthrodesis, peroneal or tibial nerve transfer, posterior tibial tendon transfer, which had the highest effect on functional outcomes [20, 27].

There is still no consensus regarding whether prolonged ischemia time contributed to amputation or poor function or not [3, 26]. Some authors support the concept of urgent revascularization within 6 h from the time at injury to repair could be predictive of poor functional outcome, particularly when the diagnosis is delayed [26]. The key of this concept is to decrease warm ischemia time. In our series, delayed flow-restored arterial repair was very common in all patients due to long transport or delay diagnosis. Nevertheless, our results showed duration of ischemia was not a risk factor for poor functional outcomes after surgery, which can be explained by compensatory collateral artery circulation from superficial femoral artery. It also needs to be noted collateral circulation blood supply will be affected under certain conditions, including compartment hypertension, complicated soft tissue injuries, occlusion of collateral artery pathways and unstable hemodynamics [19, 21, 28].

Although we improved treatments for concomitant injuries, better surgical techniques and multidisciplinary intervention, patients had a higher rate of surgical complications. In a retrospective study of 2175 patients in nationwide US inpatient database [29], patients with concomitant popliteal injury were also more likely to experience secondary complications, experience longer hospital stays and incur greater healthcare costs. The development of gastrocnemius necrosis after PAI has been described frequently in many studies due to severe trauma of gastrocnemius or no revascularization of the gastrocnemius artery [30, 31]. However, a surprising finding was that gastrocnemius necrosis was not the risk factor for poor ankle function in our series. This can be explained by the compensatory results of soleus and plantar flexor muscles and the patients’ low demand for ankle function [32]. In fact, there is no existing evidence about whether gastrocnemius artery repair contributes to lower functional outcomes in these patients.

This study also has weaknesses. First is the small sample in size and the single-center design of the study. Second, we cannot thoroughly rule out some biases due to unknown and unmeasured confounding factors. Despite these limitations, the strengths of our study included the identification of a matched cohort to compare trauma-specific function of the salvaged limbs in patients after acute blunt popliteal artery injury, minimized confounding factor and long-term follow-up.

**Conclusion**

Five-year trauma-specific outcomes showed that most patients who sustained blunt PAI had significant functional deficit associated with limited activity and chronic neurological symptoms of ankle and foot. Additionally, poor functional outcomes were related to nerve injury and compartment syndrome. Therefore, early and effective decompression for compartment syndrome remains the only potentially modifiable risk factor for improving functional outcomes following PAI.
Abbreviations
PAI: Popliteal artery injury; ISS: Injury Severity Score; FIM: Functional Independence Measure; KSS: Knee Society Score; AHFS: Ankle–HindFoot Scale.

Acknowledgements
Not applicable.

Authors contributions
GL and JC contributed equally to this work. GL and JC participated in data collection, patients’ follow-up and data analysis. GL was a major contributor in writing the draft. ZX designed the research and revised the manuscript. All authors read and approved the final manuscript.

Funding
No funds, grants or other support were received.

Availability of data and materials
All the data will be available upon request to the corresponding author of the present paper.

Declarations

Ethics approval and consent to participate
The study was approved by the Ethics Committee on Biomedical Research, West China Hospital of Sichuan University, and was done in accordance with the Declaration of Helsinki. All patients gave their informed consent prior to their inclusion in the study.

Consent for publication
Written informed consent was obtained from each patient to authorize the publication of their data.

Competing interests
The authors declare that they have no competing interests.

Received: 1 March 2022 Accepted: 26 April 2022
Published online: 07 May 2022

References
1. Hafez HM, Woolgar J, Robbs JV. Lower extremity arterial injury: results of 550 cases and review of risk factors associated with limb loss. J Vasc Surg. 2001;33(6):1212–9.
2. Grigorian A, Wilson SE, Kabutey NK, Fujitani RM, de Virgilia C, Schulb SD, Gabriel V, Chen S, Joe V, Nahmas J. Decreased national rate of below the knee amputation in patients with popliteal artery injury. Ann Vasc Surg. 2019;59:195–201.
3. Lang NW, Joestl JB, Platzer P. Characteristics and clinical outcome in patients after popliteal artery injury. J Vasc Surg. 2015;61(6):1495–500.
4. Mullinen PS, Steele SR, Andersen CA, Starnes BW, Salim A, Martin MU. Limb salvage and outcomes among patients with traumatic popliteal vascular injury: an analysis of the National Trauma Data Bank. J Vasc Surg. 2006;44(1):94–100.
5. Demiraz B, Ozturk C, Bilgen OF, Durak K. Knee dislocations: an evaluation of surgical and conservative treatment. Ulus Travma Acil Cerrahi Derg. 2004;10(4):239–44.
6. Potter HA, Alfson DB, Rowe VL, Wadé NB, Weaver FA, Inaba K, O'Banion LA, Siracuse JJ, Magee GA. Endovascular versus open repair of isolated superficial femoral and popliteal artery injuries. J Vasc Surg. 2021;74(3):814–22. e1.
7. Butler WJ, Calvin RD, Sise MJ, Bowie JM, Wessells LE, Bansal V, Beth SC. Outcomes for popliteal artery injury repair after discharge: a large-scale population-based analysis. J Trauma Acute Care Surg. 2019;86(2):173–80.
8. Ramdass MJ, Muddleen A, Hanarayan P, Spence R, Linde D. Risk factors associated with amputation in civilian popliteal artery trauma. Injury. 2018;49(6):1188–92.
9. Magnotti LJ, Sharpe JP, Tolley B, Thomas F, Lewis RH, Filiberto DM, Evans C, Kokorev L, Fabian TC, Croce MA. Long-term functional outcomes after traumatic popliteal artery injury: a 20-year experience. J Trauma Acute Care Surg. 2020;88(2):197–206.
10. Gooebel CP, Dornes C. Classifications in brief: the Schenck classification of knee dislocations. Clin Orthop Relat Res. 2020;478(6):1368–72.
11. Kellam JF, Meineberg EG, Ageel J, Karam MD, Roberts CS. Fracture and dislocation classification compendium—2018. J Orthop Trauma. 2018;32(1Suppl):S1–T0.
12. Dehoune N. The injury severity score: an operations perspective. BMJ Med Res Methodol. 2022;2(2):1–48.
13. Jacquet C, Piocher C, Khakha R, Steitzelen C, Kley K, Pujol N, Ollivier M. Evaluation of the “Minimal Clinically Important Difference” (MCID) of the KOOS, KSS and SF-12 scores after open-wedge high tibial osteotomy. Knee Surg Sports Traumatol Arthrosoc. 2021;29(3):820–6.
14. Vosoughri AR, Roustaeei NA, Mahdavizad H. American orthopaedic foot and ankle society ankle–hindfoot scale: a cross-cultural adaptation and validation study from Iran. Foot Ankle Surg. 2019:24(3):219–23.
15. MacKenzie SA, Carter TH, MacDonald D, White TD, Duckworth AD. Long-term outcomes of fasciotomy for acute compartment syndrome following a fracture of the tibial diaphysis. J Orthop Trauma. 2020;34(10):S12–7.
16. Rothenberg KA, George EL, Trickey AW, Chandra V, Stern Jr. Delayed fasciotomy is associated with higher risk of major amputation in patients with acute limb ischemia. Ann Vasc Surg. 2019;59:195–201.
17. Dover M, Memon AR, Marafi H, Kelly G, Quinlan JF. Factors associated with persistent sequelae after fasciotomy for acute compartment syndrome. J Orthop Surg (Hong Kong). 2012;20(3):312–5.
18. Santi MD, Botte MJ. Vollmann’s ischemic contracture of the foot and ankle: evaluation and treatment of established deformity. Foot Ankle Int. 1995;16(6):368–77.
19. Lintz F, Collobnier JA, Letenneur J, Gouan F. Management of long-term sequelae of compartment syndrome involving the foot and ankle. Foot Ankle Int. 2009;30(9):847–53.
20. Mortensen SJ, Zhang D, Mohamadi A, Collins J, Weaver MJ, Nazarian A, von Keudell AG. Predicting factors of muscle necrosis in acute compartment syndrome of the lower extremity. Injury. 2020;51(2):S22–6.
21. Kruse RR, Doromnir DE, Malthe KV, Koobos JGM, Koetz SC, Reijnen MMPI. Collateral artery pathways of the femoral and popliteal artery. J Surg Res. 2017;211:45–52.
22. Giuseffi SA, Bishop AT, Shin AY. Surgical treatment of peroneal nerve palsy after knee dislocation. Knee Surg Sports Traumatol Arthrosoc. 2010;18(11):1583–6.
23. O'Malley MP, Pareek A, Readon P, Krych A, Stuart MJ, Levy BA. Treatment of peroneal nerve injuries in the multiligament injured/dislocated knee. J Knee Surg. 2016;29(4):287–92.
24. Woodmass JM, Romatoivski NP, Esposito JG, Mohtadi NG, Longino PD. A systematic review of peroneal nerve palsy and recovery following traumatic knee dislocation. Knee Surg Sports Traumatol Arthrosc. 2015;23(10):2992–3002.
25. Murovic JA. Lower-extremity peripheral nerve injuries: a Louisiana State University Health Sciences Center literature review with comparison of the operative outcomes of 806 Louisiana State University Health Sciences Center sciatic, common peroneal, and tibial nerve lesions. Neurosurgery. 2009;65(4 Suppl):A18–23.
26. Asensio JA, Dabezian PJ, Miljkovic SS, Kotaru TR, Kessler JJ, Kalanchi LD, Wenzl FA, Sanford AP, Rowe VL. Popliteal artery injuries. Less ischemic time may lead to improved outcomes. Injury. 2020;51(11):2524–31.
27. O’Malley MP, Pareek A, Readon P, Krych A, Stuart MJ, Levy BA. Treatment of peroneal nerve injuries in the multiligament injured/dislocated knee. J Knee Surg. 2016;29(4):287–92.
28. Woodmass JM, Romatoivski NP, Esposito JG, Mohtadi NG, Longino PD. A systematic review of peroneal nerve palsy and recovery following traumatic knee dislocation. Knee Surg Sports Traumatol Arthrosc. 2015;23(10):2992–3002.
29. O’Malley MP, Pareek A, Readon P, Krych A, Stuart MJ, Levy BA. Treatment of peroneal nerve injuries in the multiligament injured/dislocated knee. J Knee Surg. 2016;29(4):287–92.
30. Berber R, Lewis CP, Copas D, Forward DP, Moran CG. Postero-medial shearing fracture of the tibia due to a fracture of the tibial diaphysis. International Orthopaedics (SICOT). 2009;33(10):1368–72.
31. Kwon YJ, Kwon TW, Gwon JG, Cho YP, Hwang SJ, Go KY. Anatomical popliteal artery entrapment syndrome. Ann Surg Treat Res. 2018;94(5):262–9.
32. Prathapamchandra V, Prabhu LV, Pai MM, MurliMANju BV, Vadgaonkar R. Arterial supply to the soleus muscle an anatomical study with emphasis on its application in the pedicle flap surgery. Surg Radiol Anat. 2015;37(9):1055–61.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.