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Limb salvage and functional outcomes among patients with traumatic popliteal artery injury: a review of 64 cases

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Summary

Background Traumatic popliteal arterial injury carries the greatest risk of limb loss among all peripheral vascular injuries and is associated with high levels of morbidity and worse functional outcomes. The purpose of this study is to analyse the functional outcome among patients with popliteal artery injury (PAI) due to blunt and penetrating trauma and identify influencing factors.

Methods We critically reviewed 64 cases of PAI due to blunt and penetrating trauma treated at our institution over a 20-year period. We evaluated the influence of parameters, such as patient demographics, injury mechanism, initial ISS and performed interventions, on limb amputation rates and functional outcomes. Functional outcome was examined within the 12-months follow-up using the Functional Independence Measure (FIM) score for feeding, expression and locomotion. FIM scores for each category ranged from 1 (full assistance required) to 4 (fully independent), with a maximum total FIM score of 12 representing full independence.

Results The mechanism of injury was blunt in 55 % and penetrating in 45 % of the patients. The overall amputation rate in our series was 28 %. Out of these, 83.3 % of all performed amputations in our series were due to blunt trauma and 88.6 % of all blunt trauma patients were severely injured (ISS >9) or polytraumatized (ISS >15). Blunt mechanism of injury has also shown a negative effect on the functional outcome. Analysis of the 1-year clinical follow-up showed that 30 patients (65.3 %) returned to their normal activity level within 1 year after trauma. A total of 16 patients (34.7 %) were recorded to have limited activity levels, 76.5 % of them sustained a blunt trauma. Using the FIM score to quantify the level of disability, we detected significantly worse results in both FIM total (8.8 vs. 10.4) and FIM locomotion score (3.1 vs. 2.7) following blunt trauma.

Conclusion The main findings of the present study were that PAI due to blunt trauma is associated with a high percentage of severely injured or even polytraumatized patients. Amputation rates following blunt trauma were significantly higher compared to penetrating trauma. Functional independence measurement, assessed 12 months after injury, also showed significantly worse results in both FIM total and FIM locomotion score after blunt trauma. Other factors that seem to have a negative influence on the outcome in terms of amputation rates after PAI are patient's age, presence of associated injuries and prolonged lower extremity ischemia.

Keywords Polytrauma · Popliteal artery injury (PAI) · Functional outcome

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Introduction

Ischemia of the lower limb as a result of an injured popliteal artery is one of the major causes of lower extremity morbidity and is associated with poor rates of limb salvage [1, 2].

In the setting of traumatic popliteal artery injury (PAI), this is most common in blunt trauma, where severe skeletal and soft tissue injuries are frequently resulted in high rates of limb amputation, while penetrating injuries to the popliteal artery have been reported to have a better outcome with limb salvage rates of up to 84 % [2–5].

While the majority of the published data focuses on amputation rates, functional outcomes among patients with PAI due to blunt or penetrating trauma have not been described well in the current literature.

Therefore, the purpose of this study was to analyse patient-related factors as well as diagnostic and therapeutic variables in the management of patients with PAI due to blunt and penetrating trauma, admitted to our level-I trauma centre over a 20-year period, with the main focus on limb amputation rate and functional outcome.

Patients and methods

Study design and patient recruitment

We performed a retrospective analysis of prospectively collected data for all patients treated with PAI at our level-I trauma centre over a 20-year period. A sample of 89 patients with PAI due to blunt or penetrating trauma, treated between January 1989 and December 2009, was sorted and their dataset was examined for completeness and accuracy. From that initial sample, we excluded those who have undergone previous surgery of the ipsilateral lower limb arteries ($n=2$) or primary surgical treatment before being transferred to our department ($n=11$). In addition, we excluded all patients with an incomplete data set ($n=12$).

A total of 64 patients (20 female and 44 male), 35 cases (54.7 %) due to blunt and 29 (45.3 %) due to penetrating trauma with an average age of 44 years (17–79), was evaluated for clinical characteristics, amputation rates and functional outcome following traumatic PAI due to blunt or penetrating trauma.

Collected data included terms such as age, gender, injury mechanism (blunt or penetrating), associated injuries, Injury Severity Score (ISS), diagnostic tools, surgical interventions, operative techniques, resource utilisation and clinical outcome.

Patients were divided into two groups to compare our analysis according to the mechanism of injury. The first group includes patients who have suffered PAI following blunt trauma, whereas the second group includes patients with penetrating arterial injuries. The causes of injury are summarised in Table 1.

Diagnosis and surgical management

The diagnosis was based on clinical and radiological examination (presence of peripheral pulses, time of revascularisation, colour and temperature) combined with preoperative imaging including standard radiographs of the knee in two planes, the use of a handheld duplex-scanner as well as conventional or CT angiography.

Surgical explorations were performed according to standard arterial exposure and repair procedures:

Table 1 Causes of injury in a sample of 64 patients with traumatic popliteal artery injury (PAI)

Blunt	
Motorcycle	14
Car	7
Fall	10
Other	4
Penetrating	
Stab	11
Cut	14
Firearm	4
Total	*64*

The patients were placed in supine position and the injured artery was exposed through a medial approach. Proximal and distal control of the injured segment was achieved with the use of separate incisions. Low-weight-molecular-heparin was applied for anticoagulation at the beginning of the vascular repair. First, a debridement of devitalised tissue was performed. Fogarty-catheter embolectomy was performed if necessary to ensure physiological inflow and unobstructed distal flow. Arterial repair methods included primary arterial sutures (37 patients, 58.7 %), the use of autogenous vein grafts (contralateral great saphenous vein) (8 patients, 12.9 %) or polytetrafluoroethylene (PTFE) vascular patches (18 patients, (28.6 %).

All vascular procedures performed during the operations were done by vascular surgeons or experienced trauma surgeons supported by vascular surgeons. Angiography was performed intra-operatively in cases of inadequate distal perfusion after vascular repair or subsequent to the operation, to confirm a successful restitution of the arterial flow. Arterial repair was obtained within 3 h from the time of injury in 21 patients, within 6 h in 40 patients and after more than 6 h in 3 patients. Duration of surgery showed an average length of 175 min, within the range of 90 to 270 min.

In 78.6 % of the patients with concomitant fractures, fixation was performed prior to vascular restoration by use of an external fixator. In three cases, revascularisation proceeded fracture management that was performed in the second stage.

Fasciotomy was performed in 54 patients either as a prophylactic procedure or due to a clinically apparent compartment syndrome. We abstained from direct intracompartmental pressure measurement in all of the patients. The technique we used was a 2-incision 4-compartment fasciotomy.

Primary amputation was necessary in one patient as limb salvage was deemed impossible after tissue debridement. Eleven patients underwent one or more surgical procedures due to their associated injuries.

Outcome assessment

To determine the clinical outcome and degree of disability for survivors (amputees excluded), the modified Functional Independence Measure (FIM) score was used. Necessary data therefore were collected in line with the 12-month follow-up. The FIM score was established to evaluate the level of disability along three axes: feeding, expression and locomotion. The score for each axis ranges from 1 (full dependence on assistance) to 4 (full independence), giving a maximum total score of 12 representing fully independence. Patients were considered to have a mild functional disability, if the FIM score was lower than 10 and a severe functional disability, if the score was lower than 6. FIM for locomotion ranged from 1 (full assistance required) to 4 (full independence). Patients were considered to have a severe functional disability related to their extremity of injury if the FIM score for locomotion was lower than 3.

Statistical analysis

Quantitative data were compared between two groups using the student's *t*-test; qualitative data were compared using the χ^2-analysis. Statistical significance was set at $p<0.05$. Multiple regression analysis with a 95 % confidence interval was used to examine the independent associations of various demographic and injury-related factors. Amputation rate was used as dependent variable for regression. The value $p<0.05$ was considered to determine the statistical significance of corresponding variables (age, sex, injury mechanisms, associated injuries, diagnostic tools, performed interventions, time from injury to vascular repair, surgical techniques, resource utilisation and clinical outcome).

Results

Among all 64 patients, 33 (51.6 %) were noted to have severe concomitant injuries (ISS >9) or polytrauma (ISS >15). Within the blunt trauma group ($n=35$), 26 patients (74.3 %) sustained severe concomitant injuries, 5 (14.3 %) were polytraumatized and 4 patients (11.4 %) showed isolated injuries of one limb.

Fractures or knee dislocations of the affected leg were noted in 14 patients (40 %). In the penetrating trauma group ($n=29$), 3 patients (10.3 %) showed isolated injuries of the popliteal artery, whereas 2 patients (6.9 %) sustained severe concomitant injuries. Six (20.7 %) cases involved injuries of the sciatic, femoral, tibial or peroneal nerve; in 16 (55.2 %) cases, combined injuries of the popliteal artery and vein were detected. None of the patients within this group showed any fractures or dislocations. Details on type and frequency of concomitant injuries after both blunt and penetrating trauma are shown in Table 2.

The average ISS for patients with popliteal arterial lesions (PAL) and significant concomitant injuries (ISS >9) in this study was 14.4 points (9–40 points); the average Mangled Extremity Severity Score (MESS) was 6.8 points (6–16). None of the patients had an ISS greater than 40 or an MESS greater than 16.

Statistical analysis revealed that penetrating injuries frequently involved concomitant venous as well as nerval injuries, whereas blunt trauma was more likely to be associated with fractures ($p<0.05$).

Functional outcome

FIM score was analysed in 46 patients (amputees were excluded for functional analysis). Analysis of the 1-year clinical follow-up showed that 30 patients (65.3 %) returned to their normal activity level within 1 year after trauma. Out of these, 16 patients (34.7 %) were recorded to have limited activity as well as occasional and chronic pain symptoms. Using the FIM score to quantify the level of disability for survivors, we had an overall outcome score of 9.6. In the blunt trauma group patients, we have had an average score of 8.8, which was significantly lower ($p<0.05$) than in the penetrating trauma group (average score 10.4). The locomotion component of the FIM (range 1–4) was 2.7 on average in the blunt- and 3.1 on average in the penetrating trauma group.

Amputation rate and complications

The overall amputation rate in our study was 28 % ($n=18$). One amputation was performed primary due to severe soft tissue damage, 17 amputations were performed secondary with an average of 6.5 days (range: 1–27 days) following initial surgery. 2 amputations (11.8 %) were performed following direct suture of the injured popliteal artery, 6 (35.3 %) following bypass-repair and 10 (58.2 %) following PTFE patches. Patients who sustained

Table 2 Type and frequency of concomitant injuries in patients with popliteal artery lesions (PAL)

Mechanism of Injury	Isolated PAL[a]	Venous lesion[a]	Nerval lesion[a]	Severe soft tissue injury[a]	Fractures and/or dislocations[a]	Craniocerebral Injury (CCI)	Thoracic/abdominal/pelvic Injury	Severe Trauma (ISS 9–15)	Polytrauma (ISS >15)
Blunt	4	19	Nil	7	14	2	2	17	5
Penetrating	3	16	6	1	0	0	1	2	0
Total	7	35	6	8	14	2	3	19	5

[a]corresponding to popliteal artery lesion

blunt trauma had significantly higher amputation rates than those with penetrating injuries. More details on amputations are shown in Table 3.

Multiple regression analysis revealed that age, mechanism of injury (blunt or penetrating), presence of associated injuries as well as prolonged ischemia do influence the amputation rate significantly (Table 4).

One patient died postoperatively due to multiple organ failure. General complications and treatment-related complications were noted in 16 (25 %) patients. Postoperative intensive care treatment was required for 47 patients. The average length of stay at ICU was 11.5 days, ranging from 4 to 38 days. Most of the patients with a prolonged ICU stay (>14 days) were severely injured or even polytraumatized and therefore critical care patients.

Discussion

The purpose of this study was to analyse patient-related factors as well as diagnostic and therapeutic variables in the management of patients with traumatic PAI with a main focus on limb amputation rate and functional outcome.

Inadequate initial assessment and subsequent delayed vascular repair lead to amputation rates up to 80 % in patients with traumatic injuries to the popliteal artery [6, 7]. Numerous diagnostic modalities are available to detect vascular injury associated with extremity trauma. Although the role of duplex sonography in clinical practice is evolving, there is unanimous agreement in the literature about the necessity of an (MRI or CT) arteriography to rule out arterial injuries [4, 6–12].

The overall amputation rate in our series was 28 %. This seems to be quite high compared to the results described in other series, for example, in a recent analysis of the US National Trauma Data Bank (NTDB), where an amputation rate of 14.5 % is described in the setting of traumatic popliteal injury [4, 5]. In the blunt trauma group, we observed a significant higher amputation rate than in the penetrating trauma group. These findings seem to be consistent with those described in the current literature [5–7].

Blunt injury to the popliteal vessels is mostly accompanied by severe soft tissue- and bony injuries [1, 2, 5]. In our series, the major part of the patients following blunt trauma sustained severe (ISS >9) trauma or were polytraumatized (ISS >15). In contrast, only 7 % of the patients following penetrating injury to the popliteal artery sustained a severe trauma (ISS 9–15). Additionally, a direct suture of the injured vessel is mostly not possible in cases of blunt trauma due to higher application of force to the lower limb, so autologous bypasses and patches are needed to achieve arterial restoration. In our series, both of these techniques resulted in significant higher amputation rates compared to the direct suture repair.

Table 3 Number of primary and delayed amputations after blunt and penetrating trauma

	Blunt trauma (*n* = 35)	Penetrating trauma (*n* = 29)
Primary amputation	1	0
Delayed amputation	14	3
Total	*15*	*3*

The entirety of all these factors may be an explanation for the higher amputation rates following blunt trauma compared with penetrating injuries.

Blunt mechanism of injury has also shown a negative effect on the functional outcome. Analysis of the 1-year clinical follow-up showed that 65.3 % of the patients returned to their normal activity level within 1 year after trauma. Out of these, 34.7 % were recorded to have limited activity levels; 76.5 % of them sustained a blunt trauma. Using the FIM Score to quantify the level of disability, patients following blunt trauma showed a significantly lower FIM than patients following penetrating trauma.

Other factors that seem to have a negative impact on the functional outcome are delays in vascular repair (<6 h), associated fractures and compartment syndrome [4, 5].

The recent literature reveals controversial opinions about the sequence of surgical repair in cases where both fracture fixation and vascular repair are required [4, 8, 13–17]. Most authors support the concept of urgent revascularization in case of critical perfusion or present severe ischemia of the affected leg. The primary argument of this concept is to decrease warm ischemia time [4, 18]. Otherwise, it seems to be obvious that successful revascularization of the limb in case of artery injury may get affected by an unstable limb. Johansen et al. described the temporary use of an intra-luminal shunt, which does, inserted into the artery to restore perfusion, allow a definite fracture fixation before restoration of the injured artery [19]. Although Gifford et al. reported that temporary vascular shunting did not affect the outcome negatively in their investigated series, the use of this intraluminal temporary shunt is controversial, no larger cohort studies do exist so far [4, 20].

Paris et al. described the use of external fixation system following arterial repair. They have not found any association between method of fracture fixation and outcome in 122 lower limb arterial injuries [13]. In fact, there is no existing high-level evidence about the advantage of external fracture fixation compared with the internal fixation, although recent studies recommended the method of external fracture fixation [4].

In our series, 11 out of 14 patients with bony injuries in terms of compound and complicated fractures or dislocations of the knee have undergone prior fracture fixation by the use of an external fixation system; in three cases, it was necessary to restore arterial continuity prior due to the prolonged ischemia time. However, a recent met analysis by Fowler et al. described no significant

Table 4 Multiple regression analysis for estimating the relationship between the explanatory variables mentioned below and necessity of amputation in patients with traumatic PAI

	Regression coefficient	Standard error	*t*-test	*p*-value[a]	Lower 95 %	Upper 95 %
Calculated intersection	1,33108326	0,48997883	2,71661381	0,00812046	0,35561036	2,30655617
Sex 0 = M 1 = F	−0,05652622	0,11514803	−0,49090044	0,62487519	−0,28576832	0,17271589
Age	0,00916613	0,00621944	−1,47378687	0,01445635	−0,02154809	0,00321583
Injury mechanism 0 = blunt 1 = penetrating	−0,02451666	0,12928709	−0,18962962	0,0350092	−0,28190747	0,23287415
Associated injuries 0 = yes 1 = no	0,26184744	0,12950777	2,02186664	0,04661938	0,00401728	0,51967761
ISS	0,14285502	0,13350759	1,07001425	0,28791291	−0,12293816	0,4086482
FIM	0,02946389	0,04572133	0,64442323	0,21191711	−0,06156028	0,12048805
Time of ischemia	0,00087104	0,00870706	−0,10003844	0,01205705	−0,01820547	0,01646339
Compartment	0,4086482	−0,12293816	0,4086482	0,09234589	−0,05652622	0,11514803

[a]Statistical significant ($p < 0.05$) influencing variables are highlighted in red

influence on the overall amputation rate whether bone- or vascular repair was done first [21].

Although several authors recommend a prophylactic fasciotomy to improve the outcome after PAI, it is not generally agreed in the current literature [2, 22]. Lim et al. have suggested the implementation of fasciotomy prior to arterial repair to allow a restoration of the collateral circulation that contains further ischemia and resultant compartmental hypertension [23]. In our series, fasciotomy was performed in 84.3 % of the patients either as a prophylactic procedure or due to clinical apparent compartment hypertension, without the use of foregoing intracompartmental pressure measurement.

Open surgical management is the standard procedure for peripheral vascular injury. Reports of blunt arterial injuries write on an incidence of graft repair between 67 and 92 % due to extensive arterial disruption or avulsion and resulting from that, the impossibility of arterial repair via direct artery suture [1, 17, 24–26].

The use and durability of vein grafts is well documented and seems to be the best option for below-knee revascularization, whereas the use of PTFE remains controversial [4]. In our series, we registered the highest secondary amputation rates among patients who have undergone arterial repair by PTFE patches, the best outcome could be observed for direct suture repair of the injured artery.

Conclusion

The main findings of the present study were that PAI due to blunt trauma is associated with a high percentage of severely injured or even polytraumatized patients. Amputation rates following blunt trauma were significantly higher compared to penetrating trauma. Additionally, age, the presence of associated injuries and prolonged lower extremity ischemia were detected to have a significantly negative influence on the outcome in terms of amputation rates.

Functional independence measurement (FIM), assessed 12 months after injury, also showed significantly worse results in both FIM total and FIM locomotion score after blunt trauma.

Conflict of interest
The authors declare that they have no conflict of interest.

Ethical standards
All procedures described were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008.

References

1. Hossny A. Blunt popliteal artery injury with complete lower limb ischemia: is routine use of temporary intraluminal arterial shunt justified? J Vasc Surg. 2004;40(1):61.
2. Gupta R, Quinn P, Rao S, Sleunarine K. Popliteal artery trauma. A critical appraisal of an uncommon injury. Injury. 2001;32:357–61.
3. Wagner WH, Calkins ER, Weaver FA, Goodwin JA, Myles RA, Yellin AE. Blunt popliteal lartery trauma: one hundred consecutive injuries. J Vasc Surg. 1988;7:736–43.
4. Halvorson JJ, Anz A, Langfitt M, Deonanan JK, Scott A, Teasdall RD, Carroll EA. Vascular injury associated with extremity trauma: initial diagnosis and management. J Am Acad Orthop Surg. 2011;19:495–504.
5. Mullenix PS, Steele SR, Andersen CA, Starnes BW, Salim A, Martin MJ. Limb salvage and outcomes among patients with traumatic popliteal vascular injury: an analysis of the National TraumaData Bank. J Vasc Surg. 2006;44(1):94–100.
6. Kim JW, Sung CM, Cho SH, Hwang SC. Vascular Injury associated with blunt trauma without dislocation of the knee. Yonsei Med J. 2010;51(5):790–2.

7. Chapman JA. Popliteal artery damage in closed injuries of the knee. J Bone Joint Surg. 1985;67:420–3.
8. Wright LB, Matchett WJ, Cruz CP, James CA, Culp WC, Eidt JF, McCowan TC. Popliteal artery disease: diagnosis and treatment. RadioGraphics. 2004;24:467–79.
9. Drapanas T, Hewitt RL, Weichert RF 3rd, Smith AD. Civilian vascular injuries: a critical appraisal of three decades of management. Ann Surg. 1979;172:351–60.
10. Hollis JD, Daley BJ. 10-year review of knee dislocations: is arteriography always necessary? J Trauma. 2005;59:672–5.
11. Welling RE, Kakkasseril J, Cranley JJ. Complete dislocations of the knee with popliteal vascular injury. J Trauma. 1988;21:450–3.
12. Twaddle BC, Hunter JC, Chapman JR, Simonian PT, Escobedo EM. MRI in acute knee dislocation. A prospective study of clinical, MRI and surgical findings. J Bone Joint Surg Br. 1996;78:573–9.
13. Paris IB, Raptis S, Fitridge R. Arterial injury in the lower limb from blunt trauma. Aust N Z J Surg. 1997;67:25–30.
14. Karavias D, Korovessis P, Filos KS, Siamplis D, Petrocheilos J, Androulakis J. Major vascular lesions associated with orthopaedic injuries. J Orthop Trauma. 1992;6(2):180–5.
15. Huynh TT, Pham M, Griffin LW, et al. Management of distal femoral and popliteal arterial injuries: an update. Am J Surg. 2006;192(6):773–8.
16. Starr AJ, Hunt JL, Reinert CM. Treatment of femur fracture with associated vascular injury. J Trauma. 1996;40(1):17–21.
17. McHenry TP, Holcomb JB, Aoki N, Lindsey RW. Fractures with major vascular injuries from gunshot wounds: implications of surgical sequence. J Trauma. 2004;53(4):717–21.
18. Mohammadzade MA, Akbar MH. Presenting features and surgical outcome of popliteal artery trauma in a civilian set-up. Acta Medica Iranica 2003;41(4):273–6.
19. Johansen K, Bandyk D, Thiele B, Hansen ST. Temporary intra-luminal shunts: resolution of a management dilemma in complex vascular injuries. J Trauma. 1982;22:395–402.
20. Gifford SM, Aidinian G, Clouse WD, et al. Effect of temporary shunting on extremity vascular injury: an outcome analysis from the Global War on Terror vascular injury initiative. J Vasc Surg. 2009;50(3):549–56.
21. Fowler J, Macintyre N, Rehman S, Gaughan JP, Leslie S. The importance of surgical sequence in the treatment of lower extremity injuries with concomitant vascular injury: a metaanalysis. Injury. 2009;40(1):72–6.
22. Downs AR, MacDonald P. Popliteal artery injuries: civilian experience with sixty-three patients during a 24 year period (1960 through 1984). J Vasc Surg. 1986;4:55–62.
23. Lim LT, Michuda MS, Flanigan P, Pankovich A. Popliteal artery trauma: 31 consecutive cases without amputation. Arch Surg. 1980;115:1307–13.
24. Harrell DJ, Spain DA, Bergamini TM, Miller FB, Richardson JD. Blunt popliteal artery trauma: a challenging injury. Am Surg. 1997;63:21–5.
25. Sriussadaporn S, Pak-art R. Temporary intravascular shunt in complex extremity vascular injuries. J Trauma. 2002;52:1129–33.
26. 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;3:1212–9.