



Risk Factors of Amputation in Lower Extremity Trauma with Combined Femoropopliteal Arterial Injury

JeaHwan Kim¹, Yong Sun Jeon², Soon Gu Cho², Kee Chun Hong¹, and Keun-Myoung Park¹

¹Department of Surgery, Inha University Hospital, Incheon, ²Department of Radiology, Inha University Hospital, Incheon, Korea

Purpose: The clinical characteristics and results of femoropopliteal artery injury (FPAI) remain unclear. In this study, we evaluated the outcomes and risk factors of limb loss in patients treated for FPAI.

Materials and Methods: We retrospectively reviewed data from a database of patients who underwent revascularization for an FPAI at a single institution between January 2013 and December 2017. We reviewed and analyzed the characteristics, postoperative results, and factors that influence amputation rates.

Results: Twenty-four femoropopliteal arterial reconstructions in 24 patients were included in this study. Among the patients were 20 (83.3%) male with a first-quartile age of 28 years and a third-quartile age of 45 years (range, 15–68 years). The mean injury severity score (ISS) was 16 (range, 4–55), and 5 patients (20.8%) had ISSs of >20 points. The mean mangled extremity severity score (MESS) was 3.8 (range, 1–11), and 8 patients (33.3%) had MESSs of >5 points. In terms of arterial reconstruction methods, autogenous saphenous vein grafting, vein patching, and primary closure were performed in 9 patients (37.5%), 4 patients (16.7%), and 11 patients (45.8%), respectively. Despite arterial reconstruction, 5 patients (20.8%) underwent above-knee amputation. ISSs of >20, MESSs of >7, and orthopedic fixation were statistically significant factors associated with amputation.

Conclusion: In cases of FPAI with ISSs of >20, MESSs of >7, and orthopedic fixation, amputations should be considered. We were also careful to attempt limb salvage in such cases.

Key Words: Vascular injury, Femoral artery, Popliteal artery, Traumatic amputation

Received August 10, 2018
Revised September 26, 2018
Accepted October 14, 2018

Corresponding author: Keun-Myoung Park
Department of Surgery, Inha University Hospital, 27 Inhang-ro, Jung-gu, Incheon 22332, Korea
Tel: 82-32-890-2738
Fax: 82-32-890-3549
E-mail: redfrag@naver.com
<https://orcid.org/0000-0002-9581-0019>

Copyright © 2019, The Korean Society for Vascular Surgery

This is an Open Access article distributed under the terms of the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/4.0>) which permits unrestricted non-commercial use, distribution, and reproduction in any medium, provided the original work is properly cited.

Vasc Specialist Int 2019;35(1):16-21 • <https://doi.org/10.5758/vsi.2019.35.1.16>

INTRODUCTION

Femoropopliteal artery injury (FPAI) is the most common injury occurring in the arteries of the lower extremity, accounting for approximately one-third of all cases. FPAIs are associated with a mortality rate of approximately 10%, as patients frequently present shock [1].

Over the years, the management of FPAIs has developed with the early diagnostic modalities for arterial injury and

application of an advanced vascular repair technique using a hybrid surgical procedure. An amputation rate of up to 20% has been reported, although the appropriate arterial reconstruction was performed in FPAI cases [1-3]. The high amputation rate in patients with blunt vascular injuries to the extremities can be attributed to the high-energy mechanism of such injuries and the resultant amounts of damage to bone, nerve, and soft tissue, not typically to the vascular injury itself [4,5]. Other tissues are injured with

varying frequencies according to the mechanism of arterial injury. In general, fractures occurred at a high frequency in blunt traumas, with rates as high as 80% to 100% in some reports [6]. In cases of penetrating trauma, fractures occurred in only 15% to 40% of cases [6]. Recently, cases of blunt trauma have increased as compared with cases of penetrating trauma in lower extremity arterial injuries [3]. The presence of a significant tissue injury correlates with amputation in FPAI [1]. In FPAIs with fracture, both vascular reconstruction and orthopedic fixation are essential. The method and priorities of treatment are varied and still controversial [2,7,8]. For improving the survival and limb salvage rates, the current situation in FPAI must be completely understood. However, the number of studies regarding FPAI in Korea is small. To increase our knowledge regarding this topic, we studied the mechanisms, treatments, and results of FPAIs, along with the factors that lead to amputations.

MATERIALS AND METHODS

We evaluated 24 patients who underwent treatment for acute FPAI at a single institution between January 2013 and December 2017. We retrospectively reviewed preoperative (age, sex, mechanism of injury, injury severity score [ISS], mangled extremity severity score [MESS], and time from the accident to the admission to the operating room), operative (time to revascularization, method of vascular repair, and order of vascular repair and orthopedic repair), and postoperative (amputation and fasciotomy, and cause of amputations) clinical data. Total ischemic time was defined as the time from accident to revascularization. ISS was defined on the basis of the accumulation of the three squared abbreviated injury scale (AIS) scores ($ISS=A^2+B^2+C^2$, where A, B, and C are the AIS scores of the three most frequently injured body areas) [9,10]. MESS was defined on the basis of the skeletal/soft tissue injury score, limb ischemia, shock, and age (Table 1) [11].

FPAI was confirmed using preoperative computed tomography (CT) angiography or operative angiography. Surgical intervention was performed as soon as the arterial injury was recognized. In the cases of a combined orthopedic injury, the order of arterial reconstruction or orthopedic fixation was determined by the physician. First, we exposed the injured artery and controlled the proximal and distal vessels. For exposure of the common femoral or proximal superficial artery, we performed a longitudinal incision in the inguinal area. For the mid and distal femoral or popliteal artery, we performed a longitudinal incision medially, near the injured artery. After Fogarty thromboembolectomy was performed, we confirmed the arterial flow. We reconstructed the artery and vein, and administered intravenous

heparin if it was not contraindicated. The method of repair differed among the cases, such as interposition with the saphenous vein, patch angioplasty, primary repair, and ligation. If we suspected compartment syndrome after revascularization, we performed a 2-incision, 4-compartment calf fasciotomy intraoperatively or postoperatively. The indications of fasciotomy were persisting paralysis or paresthesia after vascular reconstructions with severe swelling after revascularization or intramuscular pressure of >20 mmHg. The time and method of fasciotomy were determined by each physician.

We divided the patients into two groups, an amputation and a limb salvage group. The primary end point was a comparison of patient characteristics and operative method between the two groups. The secondary end point was the risk factors that led to amputation. Then, we compared the characteristics and postoperative results between the groups by using the independent t-test and Fisher exact test, and examined the factors that led to amputation by conducting a logistic regression test. This study was a retrospective study that did not cause any harm to the study subjects; therefore, the requirement of informed consent was waived by the institutional review board.

Table 1. Mangle extremity severity score

Skeletal/soft tissue injury	
Low energy (stab, simple fracture, and pistol gunshot wound)	1
Medium energy (open or multiple fractures, and dislocation)	2
High energy (high-speed motor vehicle accident or rifle gunshot wound)	3
Very high energy (high-speed trauma+gross contamination)	4
Limb ischemia	
Pulse reduced or absent but with normal perfusion	1*
Pulseless, paresthesias, and diminished capillary refill	2
Cool, paralyzed, insensation, and numbness	3*
Shock	
Systolic blood pressure always >90 mmHg	0
Hypotensive transiently	1
Persistent hypotension	2
Age (y)	
<30	0
30-50	1
>50	2

*Score doubled for ischemia after >6 h.

Data from the article of Helfet et al. (Clin Orthop Relat Res 1990;(256):80-86) [11].

RESULTS

Twenty-four femoropopliteal arterial reconstructions in 24 patients from January 2013 to December 2017 were included in this study. Of the patients, 20 male (83.3%) and 4 female (16.7%) were included. The first age quartile was 28

years, and the third age quartile was 45 years (range, 15-68 years). The mechanisms of injury were blunt trauma (21/24, 87.5%) and penetrating trauma (3 of 24, 12.5%). The mean ISS was 16 (range, 4-55), and 5 patients (20.8%) had ISSs of >20 points. The mean MESS was 3.8 (range, 1-11), and 8 patients (33.3%) had MESSs of >5 points. The mean total

Table 2. Comparison of the patients' characteristics and operative method between the limb salvage and amputation groups

Variable	Value (n=24)	Limb salvage (n=19)	Amputation (n=5)	P-value
Age (y)	36 (15-68)	34 (15-68)	45 (33-58)	0.564
Male	20 (83.3)	16 (84.2)	4 (80.0)	0.822
Comorbidity				
Hypertension	8 (33.3)	6 (31.6)	2 (40.0)	0.722
Diabetes	4 (16.7)	3 (15.8)	1 (20.0)	0.723
Cardiovascular disease	3 (12.5)	3 (15.8)	0 (0.0)	N/A
COPD	2 (8.3)	2 (10.5)	0 (0.0)	N/A
Chronic renal failure	3 (12.5)	2 (10.5)	1 (20.0)	0.569
Smoking	14 (58.3)	11 (57.9)	3 (60.0)	0.932
Mechanism of injury				0.569
Blunt	21 (87.5)	17 (89.5)	4 (80.0)	
Penetrating	3 (12.5)	2 (10.5)	1 (20.0)	
ISS	16 (4-55)	12 (4-38)	33 (22-55)	<0.001
>20	5 (20.8)	1 (5.3)	4 (80.0)	
MESS	3.8 (1-11)	3.1 (1-9)	8.2 (7-11)	<0.001
>7	8 (33.3)	3 (15.8)	5 (100.0)	
Total ischemic time	10.5 (5-16)	9.2 (5-15)	11.6 (5-16)	0.722
>8 h	16	13	3	
Location				0.155
Common femoral artery	4 (16.7)	3 (15.8)	1 (20.0)	
Superficial femoral artery	16 (66.7)	14 (73.7)	2 (40.0)	
Popliteal artery	4 (16.7)	2 (10.5)	2 (40.0)	
Simultaneous venous injury and management				0.722
Yes	16 (66.7)	13 (68.4)	3 (60.0)	
Ligation	12 (50.0)	10 (52.6)	2 (40.0)	
Reconstruction	4 (16.7)	3 (15.8)	1 (20.0)	
No	8 (33.3)	6 (31.6)	2 (40.0)	
Simultaneous orthopedic injury				0.177
Yes	17	12	5	
Vascular repair first	9	7	2	
Orthopedic fixation first	8	5	3	
No	7	7	0	
Method of repair				
Primary closure	11 (45.8)	10 (52.6)	1 (20.0)	
Patch angioplasty	4 (16.7)	3 (15.8)	1 (20.0)	
Bypass or interposition with vein graft	9 (37.5)	6 (31.6)	3 (60.0)	

Values are presented as mean (range), number (%), or number only.

COPD, chronic obstructive pulmonary disease; ISS, injury severity score; MESS, mangled extremity severity score; N/A, not available.

ischemic time was 10.5 hours (range, 5–16 hours).

In terms of arterial injury location, the common femoral, superficial femoral, and popliteal arteries were injured in 4 patients (16.7%), 16 patients (66.6%), and 4 patients (16.7%), respectively. Sixteen cases of simultaneous venous injuries (66.7%) and 4 cases of venous reconstructions were found. Seventeen patients (70.8%) underwent an associated orthopedic fixation, of whom 8 patients (47.1%) underwent orthopedic fixation first and 9 patients (52.9%) underwent arterial revascularization first. Seven patients (21.9%) underwent only vascular repair without orthopedic fixation. The method of vascular repair was primary closure (45.8%), patch angioplasty (16.7%), and bypass or interposition with a vein graft (37.5%; Table 2).

Five patients (20.8%) required fasciotomy in the intraoperative (n=2) and postoperative periods (n=3). Despite arterial reconstruction, 5 patients underwent above-knee amputation. The causes of amputation were failed revascularization (2 patients), soft tissue injury (1 patient), and osteomyelitis (2 patients). One case of mortality occurred owing to postoperative pulmonary complications occurred.

Statistically significant differences in ISS, MESS, and orthopedic injury were found between the amputation group and limb salvage group (Table 2). ISSs of >20, MESSs of >7, and orthopedic fixation were the statistically significant factors associated with amputation (Table 3).

DISCUSSION

FPAI is the most common injury in the arteries of the lower extremity, accounting for approximately one-third of all cases. As is typical for the general population with FPAI, patients tend to be young, aged 30–39 years and predominantly male (70%–90%) [2,4].

Over the years, the management of FPAI has developed, with early diagnostic modalities for arterial injuries, such

as CT angiography, and application of advanced vascular repair techniques, such as endovascular repair. Despite appropriate arterial reconstruction, an amputation rate of up to 20% has been reported [1,2,12,13].

In this study, the amputation rate was 20.8% (5/24 patients) in all FPAI cases. Other studies showed that the amputation rate reported in FPAI ranged from 10% to 40% [14–17]. Despite the improvements in diagnostic tools, surgical techniques, and postoperative management, the limb salvage rate in FPAI is difficult to increase. The high amputation rate in patients with blunt vascular injuries to the extremities can be attributed to the high-energy mechanism of such injuries and the resultant amounts of damage to bone, nerve, and soft tissue, not typically to the vascular injury itself [4,5]. The causes of amputation in our study varied, such as failed revascularization, soft tissue injury, and osteomyelitis.

In our study, the risk factors that led to amputation were MESSs of >7, ISSs of >20, and orthopedic fixation. The ischemic time and order of vascular reconstruction did not affect the amputation outcome. In other studies, blunt trauma [17–20], femoral arterial injury [7,20–22] involving the popliteal artery, major soft tissue injury, compartment syndrome, age of >55 years, and ischemia for >6 hours [3] were risk factors of FPAI. In another study, ISS, MESS, or other factors did not accurately predict the functional outcomes in FPAI [18]. Ischemia duration was not an influencing factor of the amputation rate because of the small number of cases in our study. Although ischemic time can reflect the degree of cell death, time tolerance varies according to ischemic severity or collateral flow development [2]. The overriding principle in treating acute arterial injury, including FPAI, is to avoid prolonged warm ischemia, as seen in almost all previous studies. Reduction of ischemic time is important to avoid amputation, although our study shows that an ischemic time of >8 hours did not affect the

Table 3. Univariate and multivariate analyses of risk factors that lead to amputation

Variable	Univariate analysis ^a		Multivariate analysis ^b	
	OR (95% CI)	P-value	OR (95% CI)	P-value
Blunt injury	0.975 (0.615–1.459)	0.64	0.898 (0.735–1.421)	0.980
ISS >20	2.624 (1.178–4.389)	0.03	2.804 (1.261–5.427)	0.020
MESS >7	3.468 (2.128–7.269)	<0.01	4.565 (1.923–8.254)	0.010
Fasciotomy	1.251 (0.615–2.273)	0.64	1.034 (0.488–1.932)	0.450
Ischemia >8 h	1.524 (0.192–1.846)	0.35	1.667 (0.192–2.243)	0.250
Preceding vascular repair	1.122 (0.853–1.425)	0.76	1.089 (0.894–1.234)	0.820
Venous injury	1.365 (0.156–4.235)	0.56	1.8.27 (0.565–5.456)	0.560
Orthopedic fixation	1.801 (1.215–3.475)	0.03	1.610 (1.228–3.774)	<0.010

OR, odds ratio; CI, confidence interval; ISS, injury severity score; MESS, mangled extremity severity score.

^aUnivariate analysis using the Fisher exact test. ^bMultivariate analysis using the logistic regression test.

amputation rate.

FPAI affected severe reperfusion syndrome and compartment syndrome despite successful revascularization [1,16,17]. We performed 5 fasciotomies (20.8%) after successful revascularization for compartment syndrome. The overall fasciotomy rate in this study is similar to that in previously reported series [2]. All fasciotomy wounds in our series were successfully closed using with primary closure or skin graft. Liberal fasciotomy saves limbs, but the fasciotomy wounds themselves are a source of morbidity [2].

This study has several limitations, including its retrospective design, single-center site, and limited number of patients. Therefore, we did not recommend any specific treatment method and indication of surgery. Owing to the small number of patients, a between-group comparison should be performed with caution.

In conclusion, in our study, the limb salvage rate after FPAI was similar to that in previous reports. In particular, MESSs of >7, ISSs of >20, and orthopedic fixation affected the amputation rate. In cases of FPAI with a MESS of >7, systemic injury, ISS of >20, and orthopedic fixation, amputations would be considered. In such cases, we were also careful to make maximum efforts for limb salvage.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

FUNDING

This work was supported by INHA University Research Grant.

ORCID

JeaHwan Kim

<https://orcid.org/0000-0003-2804-4980>

Yong Sun Jeon

<https://orcid.org/0000-0001-5148-260X>

Soon Gu Cho

<https://orcid.org/0000-0002-6635-4595>

Kee Chun Hong

<https://orcid.org/0000-0002-8383-8794>

Keun-Myoung Park

<https://orcid.org/0000-0002-9581-0019>

REFERENCES

- Asensio JA, Kuncir EJ, García-Núñez LM, Petrone P. Femoral vessel injuries: analysis of factors predictive of outcomes. *J Am Coll Surg* 2006;203:512-520.
- Huynh TT, Pham M, Griffin LW, Villa MA, Przybyla JA, Torres RH, et al. Management of distal femoral and popliteal arterial injuries: an update. *Am J Surg* 2006;192:773-778.
- Perkins ZB, Yet B, Glasgow S, Cole E, Marsh W, Brohi K, et al. Meta-analysis of prognostic factors for amputation following surgical repair of lower extremity vascular trauma. *Br J Surg* 2015;102:436-450.
- Kauvar DS, Sarfati MR, Kraiss LW. National trauma databank analysis of mortality and limb loss in isolated lower extremity vascular trauma. *J Vasc Surg* 2011;53:1598-1603.
- Rozycki GS, Tremblay LN, Feliciano DV, McClelland WB. Blunt vascular trauma in the extremity: diagnosis, management, and outcome. *J Trauma* 2003;55:814-824.
- 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 Trauma Data Bank. *J Vasc Surg* 2006;44:94-100.
- Cargile JS 3rd, Hunt JL, Purdue GF. Acute trauma of the femoral artery and vein. *J Trauma* 1992;32:364-370; discussion 370-371.
- Razmadze A. Vascular injuries of the limbs: a fifteen-year Georgian experience. *Eur J Vasc Endovasc Surg* 1999;18:235-239.
- Copes WS, Champion HR, Sacco WJ, Lawnick MM, Keast SL, Bain LW. The Injury Severity Score revisited. *J Trauma* 1988;28:69-77.
- Gennarelli A, Wodzin E; Association for the Advancement of Automotive Medicine. Abbreviated injury scale 2005: update 2008. Barrington, Ill.: Association for the Advancement of Automotive Medicine; 2008.
- Helfet DL, Howey T, Sanders R, Johansen K. Limb salvage versus amputation. Preliminary results of the Mangled Extremity Severity Score. *Clin Orthop Relat Res* 1990;(256):80-86.
- McNamara JJ, Brief DK, Stremple JF, Wright JK. Management of fractures with associated arterial injury in combat casualties. *J Trauma* 1973;13:17-19.
- Hughes CW. Arterial repair during the Korean war. *Ann Surg* 1958;147:555-561.
- Sagraves SG, Conquest AM, Albrecht RJ, Toschlog EA, Schenarts PJ, Bard MR, et al. Popliteal artery trauma in a rural level I trauma center. *Am Surg*

- 2003;69:485-489; discussion 490.
- 15) Nair R, Abdool-Carrim AT, Robbs JV. Gunshot injuries of the popliteal artery. *Br J Surg* 2000;87:602-607.
- 16) 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;33:1212-1219.
- 17) Moniz MP, Ombrellaro MP, Stevens SL, Freeman MB, Diamond DL, Goldman MH. Concomitant orthopedic and vascular injuries as predictors for limb loss in blunt lower extremity trauma. *Am Surg* 1997;63:24-28.
- 18) Busse JW, Jacobs CL, Swiontkowski MF, Bosse MJ, Bhandari M. Complex limb salvage or early amputation for severe lower-limb injury: a meta-analysis of observational studies. *J Orthop Trauma* 2007;21:70-76.
- 19) Frykberg ER. Popliteal vascular injuries. *Surg Clin North Am* 2002;82:67-89.
- 20) Feliciano DV, Herskowitz K, O'Gorman RB, Cruse PA, Brandt ML, Burch JM, et al. Management of vascular injuries in the lower extremities. *J Trauma* 1988;28:319-328.
- 21) Degiannis E, Levy RD, Velmahos GC, Potokar T, Saadia R. Penetrating injuries of the femoral artery. *Br J Surg* 1995;82:492-495.
- 22) Carrillo EH, Spain DA, Miller FB, Richardson JD. Femoral vessel injuries. *Surg Clin North Am* 2002;82:49-65.