SAJS
General Surgery

Civilian popliteal artery injuries

M A Banderker, P H Navsaria, S Edu, W Bekker, A J Nicol, N Naidoo

Trauma Centre, Groote Schuur Hospital and University of Cape Town
M A Banderker, FCS (SA), MMed
P H Navsaria, FCS (SA), MMed
S Edu, FCS (SA)
W Bekker, FCS (SA)
A J Nicol, FCS (SA), PhD

Vascular Surgery, Groote Schuur Hospital and University of Cape Town
N Naidoo, FCS (SA)

Corresponding author: *P H Navsaria (pradeep.navsaria@uct.ac.za)*

Background. Civilian popliteal artery injuries are associated with significant amputation rates.
Aim. The aim of this study was to identify factors associated with limb loss in patients with popliteal artery injuries.
Patients and methods. We performed a retrospective chart review of prospectively collected data on patients with popliteal artery injuries presenting to the Trauma Centre at Groote Schuur Hospital, Cape Town, from 1 January 1999 to 31 December 2008. Demographic data, mechanism of injury, haemodynamic status, limb viability, special investigations, associated injuries, ischaemic time, surgical treatment and amputation rates were analysed.
Results. One hundred and thirty-six patients with popliteal artery injuries were identified. Penetrating and blunt trauma accounted for 81 (59.6%) and 55 (40.4%) injuries, respectively. Associated injuries included fractures in 66 patients (48.6%), knee dislocations in 29 (21.3%) and popliteal vein injuries in 59 (43.4%). Fifty-seven patients (41.9%) presented with a compartment syndrome. Arterial injuries were treated with reversed vein grafting in 68 patients, primary anastomosis in 33, prosthetic graft insertion in 11, and primary amputation in 7. Thirty-two patients underwent delayed amputation, giving an overall amputation rate of 37.5%. A delay of more than 7 hours of ischaemic time between injury and definitive repair (p=0.0236) and the presence of a compartment syndrome (p=0.003) were significantly associated with an increased amputation rate.
Conclusion. The most significant factors associated with the high amputation rate of 37.5% were an ischaemic time longer than 7 hours, and the presence of a compartment syndrome.

S Afr J Surg 2012;50(4):119-124. DOI:10.7196/SAJS.1257

Factors known to affect amputation rates after popliteal vascular trauma include time interval between injury and treatment, mechanism of injury, associated injuries, chronic vascular disease and ischaemia.[1-5] Knowledge of these prognostic factors is vital if limb salvage is to be optimised. The aim of this study was to analyse the outcomes of patients presenting to an urban trauma centre with popliteal artery injuries, the key objectives being to define the amputation rate and factors contributing to limb loss.

Patients and methods

All patients presenting to the Trauma Centre at Groote Schuur Hospital, Cape Town, with a popliteal artery injury over the 10-year period from 1 January 1999 to 31 December 2008 were retrospectively reviewed. The Trauma Centre's operative database was used to identify patients with popliteal artery injuries. Approval for the study was obtained from the Faculty of Health Sciences Human Research Ethics Committee. Standard demographic data, mechanism of injury, degrees of ischaemia and vascular investigations were recorded. Operation notes documented the location of the popliteal artery injury, method of repair and local associated injuries. Complications and mortality were noted. Initial management and resuscitation were conducted along standard Advanced Trauma and Life Support™ (ATLS) guidelines. Patients presenting in shock with active bleeding, compartment syndrome or acute limb ischaemia were resuscitated and taken to the operating room for emergency exploration. Haemodynamically stable patients and those who stabilised after simple resuscitation underwent further evaluation. Limb viability on presentation was graded according to Rutherford's classification for limb ischaemia: grade I – viable: not immediately threatened, no sensory or motor loss; grade IIa – marginally threatened: minimal sensory loss, no motor loss; grade IIb – immediately threatened: sensory and motor loss; and grade III – unsalvageable: irreversible tissue and nerve damage. Indications for emergency room single-shot angiography (ERA) included a haemodynamically stable patient with hard signs of a vascular injury (pulseless limb, bruit or pulsatile haematoma) and the clinical assessment of a threatened limb (grade IIa/b). Pulseless

limbs were identified with the use of both digital palpation and hand-held portable Doppler ultrasound. Patients with diminished pulses or shotgun injuries and a viable limb underwent formal angiography in the vascular radiology suite. Indications for formal angiography were ipsilateral distal pulse discrepancy; absent pulse in the presence of a viable limb; a moderate to large haematoma; a palpable thrill and/or audible bruit; and all knee disclocations without any signs of ischaemia. The lengths of time from injury to arrival at the hospital, from presentation to definitive repair, and from injury to definitive repair were determined. Statistical analysis was conducted with the use of an online biostatistics package, Epicalc 2000 (version 1.02) by Brixton Health (http://www.brixtonhealth.com/epicalc.html).

Proportional comparisons between groups were conducted using Fisher's exact test. Normally distributed variables were compared between groups within each category using Student's *t*-test. For non-parametric data or data that were not normally distributed, the Mann-Whitney U-test was used for between-group comparisons. A *p*-value of 0.05 was defined as the level of significance.

Results

One hundred and thirty-six patients with popliteal artery injuries were evaluated. There were 106 men (77.9%) and 30 women (22.1%), with a mean age of 29.7 years (range 13 - 84 years). The mechanism of injury was penetrating in 81 cases (59.6%) and blunt in 55 (40.4%). Gunshot wounds (72, 88.9%) accounted for most of the injuries in the penetrating group, while only 9 patients (11.1%) had sustained stab wounds. Blunt popliteal artery trauma was caused by road traffic accidents in 33 patients (60.0%) and by falls in 22 (40.0%). More than half of the blunt injuries (*n*=29, 52.7%) were associated with knee dislocations.

Eighty-five patients (62.5%) presented with an acutely ischaemic limb, and all proceeded to undergo emergency surgery. Before surgery, 42 patients (49.4%) had emergency room angiography and 12 (14.1%) on-table angiography. Eighteen patients proceeded to surgery without any vascular imaging. Forty patients (29.4%) presented with a viable limb. These patients had formal angiography in the radiology suite and all subsequently proceeded to undergo urgent popliteal artery repair. Seven patients presented with unsalvageable limbs, and all underwent primary amputation. Four patients had no record of limb viability on presentation. Nineteen patients (13.9%) with a history of knee dislocation and a viable limb were investigated with formal angiography. Ten patients (7.4%) with knee dislocation presented with an acutely ischaemic limb, and of these 5 had on-table angiography and 3 emergency room angiography; 2 proceeded to exploration without any imaging.

Thirty-nine popliteal arterial injuries (32.5%) were above the knee joint, 47 (39.1%) at the level of the knee joint and 34 (28.3%) below the level of the knee joint. In 16 cases (11.7%) the level of injury was not recorded. Of the popliteal artery injuries that were explored with intent to revascularise, the majority were repaired with reverse saphenous vein grafts (*n*=68, 53.9%), 33 (26.2%) were repaired primarily, 11 (8.7%) were repaired with polytetrafluoroethylene (PTFE) grafts, and 2 (1.5%) were temporarily shunted. Twelve patients (9.5%) went on to have a primary amputation. No data were available for 3 patients. After repair, only 12 patients had completion angiography studies. Ninety-one fasciotomies were performed, of which 57 (62.6%) were recorded as therapeutic and 34 (37.4%) as prophylactic. Concomitant venous injuries were present in 59 patients (43.4%). The majority of these were ligated (*n*=36, 61%), 19 patients (32.2%) underwent primary repair, 2 (3.3%) had vein grafts, and PTFE grafts were used in 2 cases (3.3%).

There were 66 popliteal artery injuries associated with a fracture. Twenty-five patients (37.8%) underwent open reduction and internal fixation, and 41 (62.2%) were managed with external fixation.

Thirty-two patients (23.5%) required a secondary amputation. Twenty-eight (20.6%) of these patients had an acutely ischaemic limb on presentation, and 4 had a viable limb on presentation. Nineteen patients (13.9%) underwent primary amputation. Seven of these patients presented with unsalvageable limbs and 12 patients presented with ischaemic limbs. The total number of amputations was 51, giving an amputation rate of 37.5%.

Previously documented prognostic factors associated with limb loss were analysed to determine their significance in our series. These factors included mechanism of injury, viability status of the limb on presentation, level of injury, type of repair, concomitant venous injuries and fractures, presence of compartment syndrome and the ischaemic time.[6-9] As shown in Table 1, mechanism of injury (blunt v. penetrating), penetrating injury (gunshot v. stab wounds), knee dislocation, associated fracture, popliteal vein injury, level of arterial injury and type of repair had no significant influence on the amputation rate. Degree of limb viability (assessed as being viable (Rutherford I), ischaemic (Rutherford IIa or IIb) or unsalvageable (Rutherford III)), presence of compartment syndrome and ischaemic time of more than 7.68 hours were associated with significantly increased amputation rates. There were 40 patients who presented with viable limbs. Of these, 4 required amputations, giving an amputation rate of 10.0%. All these amputations were secondary. The causes of these amputations included missed compartment syndrome in 2 patients, graft occlusion, and diseased crural vessels with poor run-off. Eighty-five patients (62.5%) presented with ischaemic limbs. There were 40 amputations in this group, giving an amputation rate of 47.1%. Of these amputations, 12 were primary (30.0%) and 28 were secondary (70.0%). Seven patients presented with an unsalvageable limb, resulting in 7 primary amputations (100%). There were 4 cases in which viability was not recorded; however these did not result in significant morbidity.

In 57 cases (41.9%) compartment syndrome was diagnosed on presentation. These cases were associated with 30 amputations, giving an amputation rate of 52.6 %. Seventy-nine cases were not associated with compartment syndrome. There were 21 amputations in this group, giving an amputation rate of 26.5%. A total of 91 fasciotomies were performed, giving a fasciotomy rate of 66.9%.

The ischaemic time of a peripheral vascular injury is a significant variable. These data were captured in hours, as the length of time from injury to definitive vascular repair. The length of time from making the diagnosis to definitive repair was also calculated. Data with regard to ischaemic times were only available in 109 cases. The mean ischaemic time in hours, i.e. length of time from injury to definitive repair, for the whole group of patients was 18 hours (range 3.5 - 164 hours). The ischaemic times for patients who had amputations were compared with the presenting status of the lower limbs, i.e. viable, ischaemic and unsalvageable. Thirty-four patients presented with viable limbs, and there were 3

Table 1. Prognostic factors and amputation rates

Prognostic factor	*n*	Amputation *n* (%)	*p*-value
Mechanism of injury			
Penetrating	81	32 (39.5)	0.68
Blunt	55	19 (34.5)	
Penetrating injury			
Gunshot	72	28 (38.8)	0.90
Stab	9	4 (4.4)	
Knee dislocation			
Present	29	11 (37.9)	0.78
Absent	26	8 (30.8)	
Fracture			
Present	66	29 (43.9)	0.18
Absent	70	22 (31.5)	
Level of injury			
Above knee	37	14 (35.9)	0.39
Knee	47	15 (31.9)	
Below knee	34	13 (38.2)	
Vein injury			
Present	69	18 (30.5)	0.7
Absent	68	24 (35.2)	
Type of repair			
Primary	33	7 (21.2)	0.086
RSVG	68	19 (27.9)	
PTFE	11	2 (18.2)	
Compartment syndrome			
Present	57	30 (52.6)	0.003538
Absent	79	21 (26.5)	
Limb viability			
Viable	40	4 (10.0)	0.00002
Ischaemic	85	40 (47.1)	
Non-viable	7	7 (100)	
Ischaemic time			
<7.68 hours	33	11 (33.3)	0.002369
>7.68 hours	39	22 (56.4)	

RSVG = reverse saphenous vein graft; PTFE = polytetrafluoroethylene.

amputations in this group (8.8%). The mean length of time from the injury to definitive repair in this group of amputees was 28.05 hours compared with 39.55 hours in the non-amputee group. The mean length of time from making the diagnosis to definitive repair was 15.97 hours. Seventy-two patients presented with ischaemic limbs. There were 33 amputations in this group (45.8%). The mean length of time from the injury to definitive repair in this group of amputees was 15.69 hours as opposed to 7.66 hours in the non-amputee group. The mean length of time from making the diagnosis to definitive repair was 3.43 hours. Three patients presented with unsalvageable limbs, with a 100% amputation rate. The mean length of time of the injury to the definitive procedure was 7.97 hours, and the mean length of time from making the diagnosis to the definitive procedure 2.77 hours. There was a total of 39 amputations in the group of 109 patients who had ischaemic times recorded. In this group, the mean length of time from the injury to the definitive surgical procedure was 15.46 hours. The mean length of time from making the diagnosis to the definitive procedure was 4.55 hours (Table 2). Patients who presented with an ischaemic limb were further analysed as a subgroup. There were a total of 72 patients (52.9%) (as noted above, for whom data were available) in the ischaemic limb group. The mean length of time from the injury to definitive repair was 11.51 hours. Among these patients who presented with ischaemic limbs, there were 33 amputations (45.8%). The mean length of time from the injury to definitive repair was 15.69 hours (Table 3).

The remaining 39 patients in the ischaemic limb group (54.1%) did not have amputations. The mean length of time from injury to definitive repair for these patients was 7.68 hours (Table 3).

The amputation rate in the group of patients presenting with ischaemic limbs (n=72) was examined above and below the mean time of 7.68 hours. When the length of time from the injury to definitive repair was less than 7.68 hours, there were 11 amputations, giving an amputation rate of 15.2% (confidence interval (CI) 8.23 - 26.12), i.e. 11 amputations in the ischaemic limb group of 72 patients. When the length of time from the injury

Table 2. Mean ischaemic time* for threatened limbs with popliteal artery injuries

	Amputation	No amputation	Overall
Number, *N*	33	39	72
Mean ischaemic time (hours)	15.69	7.68	11.51

*Mean length of time from injury to definitive repair for ischaemic limbs.

Table 3. Correlation of overall amputation rate and cut-off ischaemic time of 7.68 hours

Length of time to definitive repair for threatened limbs (hours)	Overall amputations *n* (%)	Non-amputations *n*	Total *N*
<7.68	11 (15.2)	22	33
>7.68	22 (30.5)	17	39
Total	33 (45.8)	39	72

to definitive repair was more than 7.68 hours, the amputation rate was 30.5% (CI 20.53 - 42.67), i.e. 22 amputations in the ischaemic limb group of 72 patients (p=0.0236) (Table 4).

The mortality rate was 4.4%, i.e. 6 of the 136 patients in this series died. All these deaths were related to associated injuries and not directly to the popliteal artery injury. Three deaths were caused by associated head injuries, 1 by an associated pelvic fracture, 1 by an associated penetrating chest injury, and 1 by renal failure and sepsis. Complications and outcome with regard to the limbs that were salvaged were not assessed as the recorded data were insufficient.

Discussion

Popliteal artery injuries have always been associated with high amputation rates. Improved treatments for shock, antibiotic use, better surgical techniques, and rapid transport have all been proposed as reasons for the decreased amputation rates when compared with wartime experiences.[7,8]

Amputation rates after civilian injuries, although lower than wartime reports, remain fairly high for a number of reasons. The quoted amputation rates vary between 0% and 71%.[9-11] In this series the overall amputation rate was 37.5%, with the most statistically significant prognostic variables being the ischaemic time before presentation and the presence of compartment syndrome. During the study, no patients with confirmed angiographic popliteal artery injuries were managed non-operatively, as per our institutional protocol.

Mechanism of injury has been shown to be a significant risk factor for limb loss in popliteal artery injuries. Blunt injuries have been shown to have poor outcomes when compared with penetrating injuries.[7,10,12,13] In this series, however, 60% of the popliteal artery injuries were associated with penetrating mechanisms of injury. The amputation rate in this group was 39.5%. Eighty-nine per cent of the penetrating injuries were due to gunshot wounds, and the rest were due to stab wounds. There was no statistical significant difference in limb loss between gunshot and stab wounds. The blunt injuries were mostly secondary to falls and motor vehicle accidents. The amputation rate for the blunt injuries was 34.5%. When comparing the blunt injuries with the penetrating injuries in this series, there was no statistically significant difference in the limb loss rate.

Posterior knee dislocations are associated with a substantial incidence of popliteal artery injuries.[14,15] In this series there were 29 cases of posterior knee dislocation, with an amputation rate of 38% in this group. This was, however, not statistically significant when compared with the rest of patients in the blunt group of injuries. Popliteal vascular injuries associated with skeletal injuries of the same limb pose a substantially higher risk for limb loss and morbidity than either injury alone.[6,10,16,17]

In our series there were 66 cases of popliteal artery injuries associated with fractures. These injuries were collectively from blunt and penetrating mechanisms. The amputation rate in this group of patients with associated fractures was 44%. However, this did not carry statistical significance when compared with patients who did not have fractures (p=0.183). Concomitant popliteal venous injury ranks as one of the injuries most commonly associated with popliteal artery trauma, and has been reported as increasing morbidity.[5,18,19]

Table 4. Mean ischaemic time for all grades of popliteal artery injuries

Limb viability	Number recorded *n*	Amputations *n* (%)	Mean length of time from injury to definitive repair (hours)	Mean length of time from diagnosis to definitive repair (hours)
Viable	34	3 (8.8)	28.05	15.97
Threatened	72	33 (45.8)	15.69	3.43
Unsalvageable	3	3 (100)	7.97	2.77
Total	109	39 (35.8)	15.46	4.55

We have not been able to show any statistical significance with regard to limb loss when a concomitant venous injury was present. In our series we looked at the level of popliteal artery injury, i.e. whether it was above the level of the knee, at the level of the knee or below the knee. The amputation rate in this series was similar with respect to level of injury (p=0.393).

We also found that the type of repair did not statistically affect the amputation rate (p=0.0865). In this series we compared primary repair of the artery, shunts and interposition vein or PTFE grafts.

Popliteal vascular injuries always pose a high risk for lower leg compartment syndrome. This is usually associated with a significant increase in morbidity.[20,21] In our series 57 patients (42%) presented with full-blown compartment syndrome. The amputation rate in this group was 53%, which is statistically significant when compared with patients in whom compartment syndrome was not present (p=0.003538).

Experimental and clinical evidence has repeatedly confirmed the direct correlation between a delay in treatment of more than 8 hours and limb loss. Most series have documented that the most common cause of limb loss after popliteal vascular injury is delay in diagnosis and treatment.[7,12,13,15,16,22,23] In our series we analysed the patients who presented with ischaemic limbs with regard to the ischaemic time, i.e. length of time from the injury to definitive repair. We found that patients who had an ischaemic time of less than 7.68 hours had a significantly lower amputation rate (15.1%) when compared with patients with ischaemic times of over 7.68 hours (30.5%) (p=0.02369).

In the group of patients who presented with ischaemic limbs, the mean length of time from the injury to the definitive repair was 15.69 hours. The mean length of time from diagnosis to definitive repair was 3.43 hours. These figures reflect a significant delay before definitive treatment, particularly in the pre-hospital aspect of management, although there is potential room for improvement of in-hospital management. The prolonged ischaemic time directly impacted on the overall amputation rate of 37.5%. Efforts to improve limb salvage should include awareness and early diagnosis of popliteal artery injuries at all levels of care, as well as improved transfer time from injury to definitive care, both pre-hospital and in-hospital.

With regard to angiography, completion arteriography was only done in 12 cases. There are data available suggesting that completion arteriography should be done routinely.[24-29] A change in practice in support of routine completion arteriography may result in an improved limb salvage rate. This will, however, depend on available resources.

Pitfalls during analysis of patients with popliteal artery injuries included poor documentation of complications from all disciplines, and also poor follow-up data. The follow-up visits documented were short term, with no record of long-term outcomes or morbidity.

Conclusion

Popliteal vascular injury remains one of the most difficult diagnostic and therapeutic challenges for trauma surgeons. Only with strict attention to rapid diagnosis, early surgical treatment with meticulous technical skill, and aggressive use of adjunctive measures such as completion angiography, anticoagulation, fasciotomy and proper prioritisation of management of multiple injuries can limb salvage be optimised.

Our findings are very similar to past internationally published local South African series.[3,4,26,27,30] They support our findings that both compartment syndrome and prolonged periods of ischaemia (varying between 5 and 7 hours) are the most significant factors associated with an increase in limb loss. We strongly recommend implementing measures at all levels of care to diminish the ischaemic time associated with popliteal artery injuries and to recognise and treat compartment syndrome promptly. The need for early diagnosis and early referral to definitive care must be emphasised.

REFERENCES

1. 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.
2. Fox CJ, Perkins JG, Kragh JF Jr, Singh NN, Patel B, Ficke JR. Popliteal artery repair in massively transfused military trauma casualties: a pursuit to save life and limb. J Trauma 2010;69:S123-134.
3. Nair R, Abdool-Carrim ATO, Robbs JV. Gunshot injuries of the popliteal artery. Br J Surg 2000;87:602-607.
4. Degiannis E, Velmahos GC, Florizoone MGC, Levy RD, Ross J, Saadia R. Penetrating injuries of the popliteal artery: the Baragwanath experience. Ann R Coll Surg Engl 1994;76:307-310.
5. Pourzand A, Fakhri BA, Azhough R, Hassanzadeh MA, Hashemzadeh S, Bayat AM. Management of high-risk popliteal vascular blunt trauma: clinical experience with 62 cases. Vasc Health Risk Manag 2010;9;613-618.
6. Applebaum R, Yellin AE, Weaver FA, et al. Role of routine arteriography in blunt lower extremity trauma. Am J Surg 1990;160:221-225.
7. Armstrong K, Sfeir R, Rice J, et al. Popliteal vascular injuries and war: Are Beirut and New Orleans similar? J Trauma 1988;28:836-839.
8. Daugherty ME, Sachatello CR, Ernst CB. Improved treatment of popliteal arterial injuries. Arch Surg 1978;113:1317-1321.
9. Frykberg ER. Vascular trauma: History, general principles and extremity injuries. In: Callow AD, Ernst CB, eds. Vascular Surgery: Theory and Practice. Stanford, CT: Appleton & Lange, 1995:985-1037.
10. Melton SM, Croce MA, Patton JH, et al. Popliteal artery trauma: Systemic anticoagulation and intraoperative thrombolysis improves limb salvage. Ann Surg 1997;225:518-529.
11. Frykberg ER. Popliteal vascular injuries. Surg Clin North Am 2002;82:67-89.
12. Pretre R, Bruschweiler I, Rossier J, et al. Lower limb trauma with injury to the popliteal vessels. J Trauma 1996;40:595-601.
13. Razuk AF, Nunes H, Coimbra R, et al. Popliteal artery injuries: Risk factors for limb loss. PanAmerican Journal of Trauma 1998;7:93-97.
14. Krige JEJ, Spence RAJ: Popliteal artery trauma: A high risk injury. Br J Surg 1987;74:91-94.
15. Fabian TC, Turkleson ML, Connelly TL, et al. Injury to the popliteal artery. Am J Surg 1982;143:225-228.
16. DeBakey ME, Simeone FA. Battle injuries of the arteries in World War II: An analysis of 2,471 cases. Ann Surg 1946;123:534-579.
17. McCabe CJ, Ferguson CM, Ottinger LW. Improved limb salvage in popliteal artery injuries. J Trauma 1983;23:982-985.
18. Edwards JM, Moneta GL: Peripheral venous injury. Adv Trauma Critical Care 1993;8:217-228.
19. Feliciano DV, Herskowitz K, O'Gorman RB, et al. Management of vascular injuries in the lower extremities. J Trauma 1988;28:319-328.
20. Mubarak SJ, Hargens AR. Acute compartment syndromes. Surg Clin North Am 1983;63:539-565.
21. Hardy JD, Raju S, Neely WA, et al. Aortic and other arterial injuries. Ann Surg 1975;181:640-653.
22. Thomas DD, Wilson RF, Wiencek RG. Vascular injury about the knee: Improved outcome. Am Surg 1989;55:370-377.
23. Yeager RA, Hobson RW, Lynch TG, et al. Popliteal and infrapopliteal arterial injuries: Differential management and amputation rates. Am Surg 1984;50:155-158.
24. Lim LT, Michuda MS, Flanigan P, et al. Popliteal artery trauma: 31 consecutive cases without amputation. Arch Surg 1980;115:1307-1313.
25. Pasch AR, Bishara RA, Lim LT, et al. Optimal limb salvage in penetrating civilian vascular trauma. J Vasc Surg 1986;3:189-195.
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;33:1212-1219.
27. Degiannis E, Bowley DM, Bode F, et al. Ballistic arterial trauma to the lower extremity: recent South African experience. Am Surg 2007;73:1136-1139.
28. Gray JL, Cindric M. Management of arterial and venous injuries in the dislocated knee. Sports Med Arthrosc 2011;19:131-138.
29. Callcut RA, Acher CW, Hoch J, Tefera G, Turnipseed W, Mell MW. Impact of intraoperative arteriography on limb salvage for traumatic popliteal artery injury. J Trauma 2009;67:252-257.
30. Woolgar JD, Reddy DS, Robbs JV. Delayed presentation of traumatic popliteal artery pseudoaneurysms: a review of seven cases. Eur J Vasc Endovasc Surg 2002;23:255-259.