Amputation rate following tibia fractures with associated popliteal artery injuries

A dissertation prepared by Dr Mark Roussot (*RSSMAR024)* in partial fulfillment of the requirements for the Master of Medicine degree in Orthopaedic Surgery from the University of Cape Town

Supervised by Dr Sithombo Maqungo and Dr Steve Roche

February 2015

Conflicts of Interest and Source of Funding: None
Ethics approval was obtained through the University of Cape Town Human Research Ethics Committee (HREC Ref: 413/2013)

Dissertation submitted in the prescribed format for submission to the Journal of Orthopaedic Trauma

Address for correspondence:
Dr Mark Roussot
Division of Orthopaedic Surgery
H49 Old Main Building
Groote Schuur Hospital
South Africa

Tel: 021 404 5108 Fax: 021 447 2709 Email: markroussot@gmail.com

Declaration

I, Mark Roussot, hereby declare that the work on which this dissertation is based is my original work (except where acknowledgements indicate otherwise) and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

……

(Signature)

28 Feb 2015

……

(Date)

Abstract

Objectives: 1. Determine the amputation rate; and 2. identify risk factors in patients with tibia fractures and associated popliteal artery injuries.

Intervention: Amputation or limb salvage.

Design: Retrospective case-control study.

Setting: Level 1 trauma center.

Patients: Thirty popliteal artery injuries with ipsilateral tibial fractures.

Outcome measures: Primary and delayed amputation rates were determined. Risk factors tested for significance (Fischer's Exact) included: mechanism of injury, signs of threatened viability, compartment syndrome, fracture pattern, surgical sequence, and time delay from injury or presentation to revascularization.

Results: The study group consisted of 22 males and 8 females, with a mean age of 31 years. Motor vehicle accidents and gunshot wounds constituted the mechanism in 17 and 11 patients respectively. Twenty-one were polytrauma victims. Intra/extra-articular metaphyseal fractures (OTA 41 A-C) were recorded in 19 and diaphyseal (OTA 42 A-C) in 7 patients. Primary amputation was performed in 7 and delayed in 10 patients (overall rate 57%). No individual risk factors were predictive of amputation; however, the "miserable triad" of a proximal tibia fracture (OTA 41) with signs of threatened viability, and delay to revascularization ≥ 6 hours from injury or ≥ 2 hours from presentation was predictive of amputation (p = 0,036 and p = 0,018 respectively).

Conclusions: We should aim to intervene within 6 hours following injury or 2 hours following presentation to reduce the risk of amputation. This provides a target for trauma teams even with uncertain time of injury.

Level of Evidence: III.

Key Words: Popliteal artery injury, tibia fracture, amputation.

Introduction

Vascular injury following extremity trauma is uncommon with a reported incidence of <1%[1,2,3,4,5]; however, patients with fractures and dislocations about the knee represent a subgroup of individuals that are at increased risk.[1,6] Popliteal vascular trauma carries the highest risk of limb loss of any peripheral vascular injury[7,8,9] with amputation rates reported around 11% and 28% for penetrating and blunt trauma respectively.[6]

Although a variety of scoring systems have been developed and evaluated to assist in the decision of limb salvage versus amputation for major extremity trauma, shortcomings with respect to sensitivity, specificity, subjectivity and failure to predict functional outcome have repeatedly been demonstrated.[10,11,12,13] Delay to revascularization, however, has frequently been associated with poor outcome.[4,14,15,16]

Our primary objective was to evaluate amputation rates in patients with tibial fractures and associated popliteal artery injuries presenting to a level 1 trauma unit draining a large geographical region. Our secondary objective was to evaluate risk factors for amputation.

Patients and Methods

A retrospective analysis was performed on 31 consecutive patients with tibia fractures and confirmed popliteal artery injuries admitted through a level 1 trauma unit from 1 January 1999 to 31 December 2010. Vascular injury was confirmed by angiography or intra-operatively.

The medical records and radiological investigations were analyzed in terms of:

1. Patient demographics (age, gender),
2. Date and time of injury, presentation to the trauma unit and surgical intervention,

3. Injury data - mechanism of injury, classification of skeletal and vascular injury,
4. Surgical sequence of revascularization and external fixation,
5. Limb viability on presentation,
6. Associated injuries, and
7. Amputation or limb salvage.

Tibia fractures were described in accordance with the Orthopaedic Trauma Association (OTA) Classification.[17] Limb viability was graded according to the Rutherford classification.[18] Primary amputation was defined as ablation of the limb at the time of the first operative procedure without an attempt at limb salvage. Delayed amputation was defined as ablation of the limb following an initial attempt at limb salvage. Risk factors analyzed and tested for significance with the Fischer's Exact Test were mechanism of injury, clinical signs of threatened viability (Rutherford grading), compartment syndrome, fracture pattern, surgical sequence (external fixation prior to revascularization or *vice versa*), delay from injury to operating room (OR) of $\geq$ 6 hours, and delay from admission to OR of $\geq$ 2 hours.

Exclusion criteria:

1. Mangled limbs and traumatic amputation,
2. Knee dislocations and fracture-dislocations, and
3. Vascular injury proximal to adductor hiatus or distal to the trifurcation of the popliteal artery.

Results

Thirty-one patients with tibia fractures and popliteal artery injuries were seen at our Trauma Unit from 1 January 1999 to 31 December 2010. One patient was excluded because of missing medical records, leaving 30 patients for analysis: 22 males with a median age of 29 years (range 15 – 63 years), and 8 females with a median age of 28 years (range 17 – 48 years). The average length of stay for the study group was 23 days (5 – 65 days) and the mean duration of follow up after discharge from hospital was 8,8 months (1 – 36,5 months). Three patients were transferred to peripheral hospitals, 1 patient died in the intensive care unit with multi-organ failure and 3 patients were lost to follow up resulting in a follow up rate of 89% (23 patients, N = 26). The data extracted from clinical and radiological records is summarized in **Table I**.

The mechanisms of injury (**Figure 1**) included 17 motor vehicle accidents (MVAs), 11 gunshot wounds (GSWs), a train accident, and a fall from a height. Associated injuries occurred in 21 patients, and included pelvic fractures in 5 patients, other long bone fractures in 5 patients, blunt chest trauma in 4 patients, head injury in 4 patients, and blunt abdominal trauma in 3 patients.

The initial assessment in casualty revealed non-viability (Rutherford III) of the limb in 3 patients, with a further 21 patients having threatened viability (Rutherford IIa or IIb). Compartment syndrome was diagnosed clinically in 10 patients. Angiogram was performed on 26 patients, 10 were in the emergency room, 10 were in the radiology suite, and 6 were performed on the operating table. The 4 patients in whom angiogram was not performed underwent immediate surgical exploration upon which the clinical diagnosis was confirmed.

97 **Table I: Summary of study patients**

Patient Number	Age (Years)	Sex	Mechanism of injury	OTA Fracture Classification	Viability at presentation (Rutherford)	Other injuries	Time from Injury to Hospital (min)	Time from Hospital to OR (min)	Time from Injury to OR (min)	Angio	Diagnostic Modality	Exploration prior to ExFix	Arterial injury	Arterial repair	Amputation	
															Y/N	When
1	47	F	MVA	41-A3	IIa	Y	210	150	360	Y	OT angio	Y	Transection	RSVG	N	
2	17	M	MVA	42-B3	IIa	Y	180	90	270	Y	FR angio	N	NR	RSVG	N	
3	30	F	MVA	42-C2	IIa	Y	60	995	1055	Y	RS angio	N	Laceration	PTFE	N	
4	63	M	MVA	41-C3	III	Y	400	300	700	N	CInical	NA	NR	Nil	Y	Primary
5	32	M	MVA	42-B3	IIb	Y	440	150	590	Y	FR angio	NA	Transection	Nil	Y	Primary
6	23	F	GSW	41-C3	III	N	360	2800	3160	Y	RS angio	NA	Thrombosis	Nil	Y	Primary
7	23	M	GSW	41-C3	I	Y	405	435	840	Y	RS CT angio	N	Thrombosis	RSVG	Y	Delayed
8	32	F	MVA	41-C1	IIb	Y	240	240	480	Y	FR angio	N	Transection	RSVG	Y	Delayed
9	22	M	MVA	42-C2	IIb	Y	210	510	720	Y	RS angio	N	Intimal flap	Primary	Y	Delayed
10	26	F	Fall	41-C1	I	N	660	2160	2820	Y	RS CT angio	N	Transection	RSVG	N	
11	24	M	GSW	41-C3	IIa	N	375	95	470	Y	OT angio	Y	NR	RSVG	N	
12	25	M	GSW	41-B3	I	Y	180	795	975	Y	RS CT angio	N	Thrombosis	RSVG	N	
13	31	M	Train	41-A3	III	Y	NR	415	NR	Y	RS CT angio	NA	Transection	Nil	Y	Primary
14	20	M	GSW	41-C3	IIb	N	195	60	255	N	Clinical	Y	Transection	RSVG	Y	Delayed
15	35	M	GSW	41-C2	IIb	Y	200	70	270	N	Clinical	Y	Transection	RSVG	N	
16	30	M	GSW	42-B1	IIb	Y	300	120	420	Y	FR angio	Y	Transection	Primary	N	
17	48	F	MVA	41-A2	IIb	N	150	190	340	Y	FR angio	Y	Transection	RSVG	N	
18	32	M	MVA	42-C2	IIb	Y	300	100	400	Y	OT angio	Y	Transection	RSVG	N	
19	36	M	MVA	41-B3	I	Y	240	960	1200	Y	RS CT angio	N	Intimal flap	Primary	N	
20	39	M	MVA	41-A3	IIb	Y	360	560	920	N	Clinical	NA	Intimal flap	Nil	Y	Primary
21	22	M	GSW	41-A3	IIb	N	240	240	480	Y	OT angio	Y	Transection	shunt	Y	Delayed
22	17	F	MVA	41-A3	IIb	Y	180	210	390	Y	FR angio	Y	Intimal flap	RSVG	Y	Delayed
23	28	M	MVA	NR	IIb	Y	400	150	550	Y	OT angio	Y	Transection	RSVG	Y	Delayed
24	21	F	MVA	NR	IIb	Y	480	120	600	Y	FR angio	Y	Transection	RSVG	Y	Delayed
25	56	M	MVA	41-C2	I	N	840	2160	3000	Y	RS angio	N	Intimal flap	NR	Y	Delayed
26	20	M	GSW	41-A3	IIa	N	435	270	705	Y	FR angio	N	Transection	RSVG	N	
27	29	M	MVA	NR	IIa	Y	NR	750	NR	Y	OT angio	Y	Thrombosis	RSVG	N	
28	19	M	GSW	41-A2	IIb	N	8640	355	8995	Y	RS CT angio	NA	Transection	Nil	Y	Primary
29	15	M	GSW	NR	IIb	Y	NR	65	NR	Y	FR angio	NA	NR	Nil	Y	Primary
30	53	M	MVA	42-C3	IIb	Y	175	200	375	Y	FR angio	Y	Transection	RSVG	Y	Delayed

ExFix, external fixation; F, female; FR, front room; GSW, gunshot wound; M, male; MVA, motorvehicle accident; N, no; N/A, not applicable; OR, operating room; OT, on-table; PVA, pedestrian vehicle accident; PTFE, polytetrafluoroethylene graft; RS, radiology suite; RSVG, reverse saphenous vein graft; Y, yes.

Nineteen patients presented with OTA type 41 fractures (41a = 8, 41b = 2, 41C = 9) and 7 patients presented with OTA type 42 fractures (42b = 3, 42c = 4). Images were missing for 4 patients.

Popliteal artery transection was found in 16 patients, intimal tear in 5 patients, thrombosis in 4 patients, partial laceration in 1 patient, and not recorded in 4 patients (**Figure 1**). No significant difference was found in terms of the type of arterial injury (i.e. transection, thrombosis, intimal tear or laceration) relative to the mechanism of injury (p = 0,577). The arterial injury was repaired with reverse saphenous vein graft in 17 patients, primary repair in 4 patients, and polytetrafluoroethylene (PTFE) in 2 patients. Fasciotomy was performed in 26 patients, 22 therapeutically and 4 prophylactically.

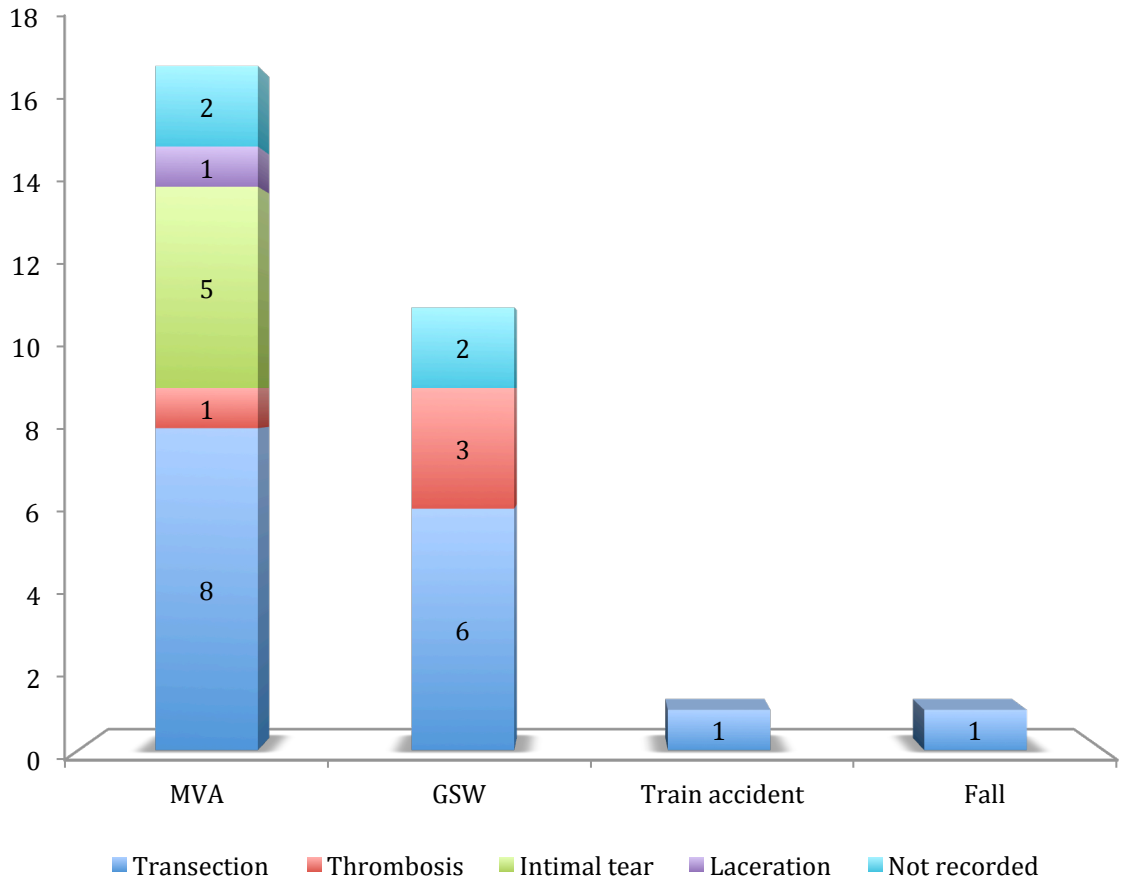

Figure 1 Mechanism of injury and type of arterial injury.
GSW, gunshot wound; MVA, motor vehicle accident.

Primary amputation was performed in 7 patients (Table II). Delayed amputation was performed in 10 patients after a mean of 8 days, resulting in a total amputation rate of 57% (17 patients, $N = 30$). Reported reasons for secondary amputation included graft failure in 4 patients, the development of compartment syndrome in 2 patients for whom prophylactic fasciotomy was not performed, and massive soft tissue injury in 2 patients.

The surgical sequence for the 23 patients in whom limb salvage was attempted included 10 patients who underwent exploration prior to external fixation, and 13 patients who underwent external fixation prior to exploration. Delayed amputation in these two subgroups was performed in 6 and 4 patients respectively, with no statistically significant difference noted ($p = 1,00$).

Table II Amputation rate

	Number of patients	% of study group (N = 30)
Primary amputation	7	23%
Delayed amputation	10	33%
Total amputation	17	57%

The average delay from injury to presentation (Table III) was 10,4 hours (median 5,0 hours, range 1 – 144 hours, $N = 27$); average delay from presentation to OR was 8,7 hours (median 4,0 hours, range 1 – 47 hours, $N = 30$); and average delay from injury to OR was 19,3 hours (median 9,8 hours, range 4 – 150 hours, $N = 27$).

Table III Delay to revascularization.

	Time from injury to presentation (hours)	Time from presentation to OR (hours)	Time from injury to OR (hours)
Mean	**10,4**	**8,7**	**19,3**
Median	**5,0**	**4,0**	**10,0**
Range	**1 - 144**	**1 - 47**	**4 - 150**
N	**27**	**30**	**27**

Analysis of the risk factors revealed that each variable was associated with higher amputation rates, but none were individually predictive of amputation with statistical significance (Table IV). However, the combination of a proximal tibia fracture (OTA 41) with clinical signs of threatened viability, and a delay from injury to the OR of ≥ 6 hours showed a significantly higher amputation rate of 67% versus 18% (p = 0,036). Similarly the combination of a proximal tibia fracture (OTA 41) with clinical signs of threatened viability and a delay from presentation to the OR of ≥ 2 hours showed a significantly higher amputation rate of 69% versus 18% (p = 0,018).

142 **Table IV Analysis of risk factors**

		Amputation	
	N	***n***	***p*-value**
Mechanism of injury			
MVA	17	11	**0,264**
GSW	11	6	
Other	2		
Initial assessment of limb viability			
Viable	6	2	**0,179**
Threatened	21	12	
Non-viable	3	3	
Compartment Syndrome			
Present	10	6	**0,705**
Absent	20	11	
Fracture pattern (AO)			
41	19	12	**0,190**
A	8	5	
B	2	0	
C	9	7	
42	7	2	
A	0	0	
B	3	1	
C	4	1	
Timing of stabilization			**1,000**
Exploration first	13	7	
Exploration after ExFix	10	6	
Delay from injury to OR			
≥ 6 hours	23	14	**0,294**
< 6 hours	4	1	
Delay from admission to OR			
≥ 2 hours	24	15	**0,360**
< 2 hours	6	2	
AO 41 + Threatened + delay from injury to OR ≥ 6 hours			
Yes	12	8	**0,036**
No	11	2	
AO 41 + Threatened + delay from admission to OR ≥ 2 hours			
Yes	13	9	**0,018**
No	11	2	

143

Discussion

More than half of the patients presenting with proximal tibia fractures with associated popliteal artery injuries underwent amputation despite attempts at limb salvage. Notably, the "miserable triad" of a proximal tibia fracture with clinical signs of threatened viability and a delay to OR of ≥ 6 hours from injury or ≥ 2 hours from presentation resulted in a statistically significant increased risk of limb loss, suggesting that every attempt should be made to intervene with this subgroup of patients within 6 hours of injury or 2 hours of presentation to hospital in order to improve outcome. This finding provides trauma teams with a target even if the exact time of injury is uncertain.

The reported amputation rate in patients with popliteal artery injuries varies greatly among authors, averaging 28% for blunt and 11% for penetrating trauma, but has been reported as high as 71%.[6,19] The amputation rate in the present study was 57%, which included 7 primary and 10 delayed amputations. This is greater than that reported in a series of 136 popliteal artery injuries conducted at the same institution, which demonstrated an overall amputation rate of 37,5%.[14] The higher risk of amputation in patients with complex extremity trauma involving popliteal vascular injury combined with skeletal trauma, in comparison to either injury in isolation, is well documented[6,7,8,15,20,21]; however the reasons for this are not clear. Delay in recognition due to the presence of multiple injuries, inadequate soft tissue coverage, and the high incidence of compartment syndrome are factors that may contribute to higher amputation rates in this setting.[6,7,8] The rarity of major vascular injuries in orthopaedic trauma and subsequent lack of experience in managing them has also been postulated to impact on outcome. [3] In this study only 31 patients with tibial

fractures and popliteal artery injuries were seen at our level 1 trauma unit over an 11-year period.

The temporal relationship between ischaemic time and amputation rate is supported by clinical and experimental studies[6,22,23] and generally accepted as one of the most important factors in determining the ultimate fate of a limb with vascular injury,[4,6,8,15] hence early intervention is associated with improved prognosis.[3,8,15] However, the definition of "early" differs among authors, some of whom have challenged the traditionally recommended goal of injury to OR time of less than 6 hours and have even demonstrated the benefit of vascular reconstruction in patients with a delay of more than 12 hours.[3] In the present study the majority of patients reached OR 6 hours or more following injury. This may be explained in part by delays to presentation at the trauma unit, but also due to delays to the OR once in the trauma unit. The reasons for delay need to be evaluated in this setting and cannot be entirely attributed to the inclusion of rural drainage areas alone. The initial clinical assessment of threatened viability was associated with increased risk of limb loss in this study group and has been highlighted as an independent predictor of outcome in previous studies.[6,8]

The finding that the majority of patients in this study group (70%) were polytrauma victims emphasizes the need for a multidisciplinary team approach, prioritizing diagnostic and therapeutic procedures. Identifying vascular injury in this context requires extra clinical vigilance, a high index of suspicion, liberal use of Doppler ultrasound and appropriate use of angiography.[6] On-table angiogram has been shown to prevent delays associated with formal angiography,[3,9] which should be reserved for patients with reasonable distal perfusion in whom the diagnosis of arterial injury is in doubt.[24]

The sequence of revascularization and external fixation in this study group appeared to have no association with limb loss. While the timing of stabilization of fractures in the context of vascular injury is contentious,[1,2,6] a meta-analysis has demonstrated no difference in the amputations rates in patients undergoing vascular repair prior to stabilization versus those undergoing stabilization prior to vascular repair.[2] At our institution it is recommend that the fracture is stabilized with external fixation prior to vascular repair unless the surgical team assesses that the limb is in need of immediate revascularization. In this case, a shunt may be introduced, then manipulation and external fixation performed, followed by definitive vascular repair. This approach is regarded as safe and is common practice.[6,8,9,24] Owing to the difficulty in accurate post-operative clinical assessment of compartment pressures and the high incidence of compartment syndrome following revascularization, it is recommend that prophylactic fasciotomy is performed following revascularization in these patients.[3,6,14,22,25]

Despite advances in trauma care the outcome of lower limb trauma in the presence of popliteal arterial injury still tends to be poor.[3,6,7,9] Resource utilization is high owing to prolonged hospital stays and numerous visits to the OR,[12,13] and the choice between primary amputation and limb salvage remains challenging. This should provide the impetus to intervene timeously.

To our knowledge, this is the largest series of proximal tibia fractures with associated popliteal artery injuries in a resource-limited level 1 trauma center. Follow up was performed to obtain enough information for the primary outcome (amputation or limb salvage); however, the assessment of functional outcome and patient satisfaction through long term follow up was not conducted. Popliteal artery injuries that were not diagnosed but led to subsequent limb ischaemia and amputation were

not included in the analysis as they would not have been distinguishable from end stage compartment syndrome.

Conclusions

Tibial fractures with associated popliteal artery injuries have an amputation rate of 57%. The subset of patients with the "miserable triad" of a proximal tibia fracture, clinical signs of threatened viability and a delay to OR of ≥ 6 hours from injury or ≥ 2 hours from admission have a significantly increased risk of amputation, suggesting that intervention with 6 hours of injury or 2 hours of presentation will reduce the risk of limb loss. This provides a target for trauma teams to intervene even when the time of injury is not certain.

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

References

1. Halvorson JJ, Anz A, Langfitt M, *et al*. Vascular injury associated with extremity trauma: initial diagnosis and management. J Am Acad Orthop Surg 2011 Aug;19(8):495-504.
2. Fowler J, Macintyre N, Rehman S, *et al*. The importance of surgical sequence in the treatment of lower extremity injuries with concomitant vascular injury: A meta-analysis. Injury. 2009 Jan;40(1):72-6.
3. Allen MJ, Nash JR, Ioannidies TT, Bell PRF. Major vascular injuries associated with orthopaedic injuries to the lower limb. Ann R Coll Surg Eng 1984;66:101-104.

4. Howard PW, Makin GS. Lower limb fractures with associated vascular injury. J Bone Joint Surg Br. 1990 Jan;72(1):116-20.

5. Porter MF. Arterial injuries in an accident unit. Br J Surg. 1967 Feb;54(2):100-5.

6. Frykberg ER. Popliteal vascular injuries. Surg Clin North Am 2002;82:67-89.

7. 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 Jul;44(1):94-100.

8. 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 Aug 9;6:613-8.

9. Subasi M, Cakir O, Kesemenli C, Arslan H, Necmioglu S, Eren N. Popliteal artery injuries associated with fractures and dislocations about the knee. Acta Orthop Belg 2001 Jun;67(3):259-66.

10. Dirshl DR, Dahners LE. The mangled extremity: when should it be amputated? J Am Acad Orthop Surg 1996;4:182-190.

11. Ly TV, Travison TG, Castillo RC, Bosse MJ, MacKenzie EJ, LEAP Study Group. Ability of lower-extremity injury severity scores to predict functional outcome after limb salvage. J Bone Joint Surg Am 2008;90:1738-43.

12. Simmons JD, Gunter JW 3rd, Schmieg RE Jr, Manley JD, Rushton FW Jr, Porter JM, Mitchell ME. Popliteal artery injuries in an urban trauma center with a rural catchment area: do delays in definitive treatment affect amputation? Am Surg 2011 Nov;77(11):1521-5.

13. Bosse MJ, MacKenzie EJ, Kellam JF, Burgess AR, Webb LX, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM, McCarthy ML, Cyril JK. A prospective evaluation of the clinical utility of the lower-extremity injury-severity scores. J Bone Joint Surg Am. 2001 Jan;83-A(1):3-14.

14. Banderker MA, Navsaria PH, Edu S, Bekker W, Nicol AJ, Naidoo N. Civilian popliteal artery injuries. S Afr J Surg. 2012 Nov 12;50(4):119-23.

15. McCabe CJ, Ferguson CM, Ottinger LW. Improved limb salvage in popliteal artery injuries. J Trauma. 1983 Nov;23(11):982-5.

16. Pretre R, Bruschweiler I, Rossier J, et al. Lower limb trauma with injury to the popliteal vessels. J Trauma 1996;40:595-601.

17. Marsh JL, Slongo TF, Agel J, *et al*. Fracture and Dislocation Classification Compendium - 2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. J Orthop Trauma. 2007;21 Supplement 10 pp: S1-S163.

18. Rutherford RB, Baker JD, Ernst C, *et al*. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg. 1997 Sep;26(3):517-38.

19. Conkle DM, Richie RE, Sawyers JL, *et al*. Surgical treatment of popliteal artery injuries. Arch Surg 1975;110:1351–1354.

20. Applebaum R, Yellin AE, Weaver FA, *et al*. Role of routine arteriography in blunt lower extremity trauma. Am J Surg 160:221–225, 1990.

21. Downs AR, MacDonald P. Popliteal artery injuries: civilian experience with sixty-three patients during a twenty-four year period (1960 through 1984). J Vasc Surg. 1986 Jul;4(1):55-62.

22. DeBakey ME, Simeone FA. Battle injuries of the arteries in World War II; an analysis of 2,471 cases. Ann Surg. 1946 Apr;123:534-79.

23. Miller HH, Welch CS. Quantitative studies on the time factor in arterial injuries. Ann Surg. 1949 Sep;130(3):428-38.

24. Yahya MM, Mwipatayi BP, Abbas M, Rao S. Popliteal artery injury: Royal Perth experience and literature review. ANZ J Surg 2005;75:882-886.

25. 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 Jun;33(6):1212-9.