

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

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Abstract

1

2

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

5 **Intervention:** Amputation or limb salvage.

6 **Design:** Retrospective case-control study.

7 **Setting:** Level 1 trauma center.

8 **Patients:** Thirty popliteal artery injuries with ipsilateral tibial fractures.

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

13 **Results:** The study group consisted of 22 males and 8 females, with a mean age of 31
14 years. Motor vehicle accidents and gunshot wounds constituted the mechanism in 17
15 and 11 patients respectively. Twenty-one were polytrauma victims. Intra/extra-
16 articular metaphyseal fractures (OTA 41 A-C) were recorded in 19 and diaphyseal
17 (OTA 42 A-C) in 7 patients. Primary amputation was performed in 7 and delayed in
18 10 patients (overall rate 57%). No individual risk factors were predictive of
19 amputation; however, the "miserable triad" of a proximal tibia fracture (OTA 41) with
20 signs of threatened viability, and delay to revascularization ≥ 6 hours from injury or \geq
21 2 hours from presentation was predictive of amputation ($p = 0,036$ and $p = 0,018$
22 respectively).

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

26 **Level of Evidence:** III.

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

28 **Introduction**

29 Vascular injury following extremity trauma is uncommon with a reported incidence of
30 <1%^{1,2,3,4,5}; however, patients with fractures and dislocations about the knee represent
31 a subgroup of individuals that are at increased risk.^{1,6} Popliteal vascular trauma carries
32 the highest risk of limb loss of any peripheral vascular injury^{7,8,9} with amputation
33 rates reported around 11% and 28% for penetrating and blunt trauma respectively.⁶

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

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

43 **Patients and Methods**

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

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

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

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

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

68 Exclusion criteria:

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

73 **Results**

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

85 The mechanisms of injury (**Figure 1**) included 17 motor vehicle accidents
86 (MVAs), 11 gunshot wounds (GSWs), a train accident, and a fall from a height.
87 Associated injuries occurred in 21 patients, and included pelvic fractures in 5 patients,
88 other long bone fractures in 5 patients, blunt chest trauma in 4 patients, head injury in
89 4 patients, and blunt abdominal trauma in 3 patients.

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

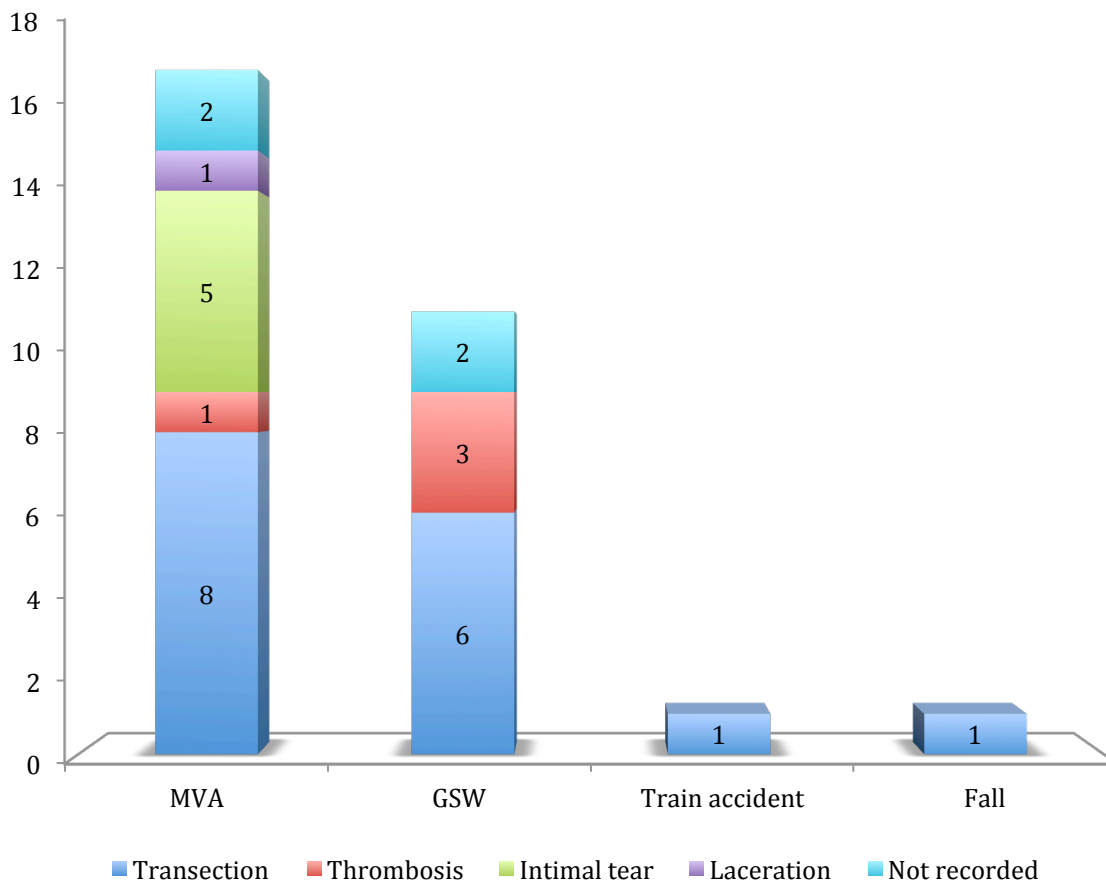
97 Table I: Summary of study patients

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	Clinical	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.

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

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



110 **Figure 1 Mechanism of injury and type of arterial injury.**

111 GSW, gunshot wound; MVA, motor vehicle accident.

112

113 Primary amputation was performed in 7 patients (Table II). Delayed amputation was
114 performed in 10 patients after a mean of 8 days, resulting in a total amputation rate of
115 57% (17 patients, $N = 30$). Reported reasons for secondary amputation included graft
116 failure in 4 patients, the development of compartment syndrome in 2 patients for
117 whom prophylactic fasciotomy was not performed, and massive soft tissue injury in 2
118 patients.

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

124

125 **Table II Amputation rate**

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

126

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

131

132 **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
<i>N</i>	27	30	27

133

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

142 **Table IV Analysis of risk factors**

	Amputation		<i>p</i> -value
	<i>N</i>	<i>n</i>	
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			
Exploration first	13	7	1,000
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

144 **Discussion**

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

154 The reported amputation rate in patients with popliteal artery injuries varies
155 greatly among authors, averaging 28% for blunt and 11% for penetrating trauma, but
156 has been reported as high as 71%.^{6,19} The amputation rate in the present study was
157 57%, which included 7 primary and 10 delayed amputations. This is greater than that
158 reported in a series of 136 popliteal artery injuries conducted at the same institution,
159 which demonstrated an overall amputation rate of 37,5%.¹⁴ The higher risk of
160 amputation in patients with complex extremity trauma involving popliteal vascular
161 injury combined with skeletal trauma, in comparison to either injury in isolation, is
162 well documented^{6,7,8,15,20,21}; however the reasons for this are not clear. Delay in
163 recognition due to the presence of multiple injuries, inadequate soft tissue coverage,
164 and the high incidence of compartment syndrome are factors that may contribute to
165 higher amputation rates in this setting.^{6,7,8} The rarity of major vascular injuries in
166 orthopaedic trauma and subsequent lack of experience in managing them has also
167 been postulated to impact on outcome.³ In this study only 31 patients with tibial

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

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

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

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

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

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

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

220 **Conclusions**

221 Tibial fractures with associated popliteal artery injuries have an amputation rate of
222 57%. The subset of patients with the “miserable triad” of a proximal tibia fracture,
223 clinical signs of threatened viability and a delay to OR of ≥ 6 hours from injury or ≥ 2
224 hours from admission have a significantly increased risk of amputation, suggesting
225 that intervention with 6 hours of injury or 2 hours of presentation will reduce the risk
226 of limb loss. This provides a target for trauma teams to intervene even when the time
227 of injury is not certain.

228

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

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