ORIGINAL RESEARCH

Blunt Vascular Trauma in the Lower Extremity at a Major Trauma Centre: Salvage Rate and Complications

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Abstract

Introduction: Blunt trauma of the lower limb with vascular injury can cause devastating outcomes, including loss of limb and even loss of life. The primary aim of this study was to determine the limb salvage rate of patients sustaining such injuries when treated at Leeds General Infirmary (LGI) since becoming a Major Trauma Centre (MTC). The secondary aim was to establish patient complications.

Methods: A retrospective analysis found that from 2013 to 2018, 30 patients, comprising of 32 injured limbs, were treated for blunt trauma to the lower limb associated with vascular injury.

Results: Twenty-four patients were male and six were female. Their mean ages were 32 and 49, respectively. Three limbs were deemed unsalvageable and underwent primary amputation; of the remaining 29 potentially salvageable limbs, 27 (93%) were saved. Median ischaemic times for both amputees and salvaged limbs were under 6 hours. Of the 32 limbs, 27 (84%) were salvaged. All amputees had a MESS score ≥ 7, although not all patients with MESS ≥ 7 required amputation. Eleven limbs had prophylactic fasciotomies, three limbs developed compartment syndrome – all successfully treated and three contracted deep infections – one of which necessitated amputation. All but one patient survived their injuries and were discharged from the hospital.

Conclusion: Attempted salvage of 27/29 (93%) limbs was successful and all but one patient survived these injuries when treated at an MTC. MESS scoring and ischaemic time are useful but not sole predictors of limb salvage. Complication rates are low but may be significant for their future implications.

Keywords: Amputation, Blunt trauma, Lower limb, Limb salvage, Vascular injury.

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Introduction

Lower limb trauma associated with vascular injury is a relatively rare occurrence but can be associated with devastating outcomes, principally loss of limb and even loss of life.[1,2]

In April 2013, the West Yorkshire Regional Trauma Network (RTN) was established, which comprised Leeds General Infirmary (LGI) as the Major Trauma Centre (MTC) with five trauma units (TUs) and its pre-hospital services. This is one of twenty-six RTNs established nationwide since April 2012, with the purpose being to provide streamlined, on-site multidisciplinary care for trauma patients and ultimately improve their outcomes. Before this time, patients were more likely to be taken to their local hospital and have initial treatment before consideration of tertiary transfer.

Two well-documented factors crucial to the salvaging of a limb are early recognition of vascular injury and prompt surgical treatment.[3,4] The ischaemic time – the time from vascular injury to repair – should, according to traditional guidelines, last no longer than 6 hours before the limb's viability is compromised.[5] In those with ischaemic times exceeding 8 hours, the rate of lower limb amputation has been found to surpass 80%.[6] Conversely, when ischaemic time is less than 6 hours, amputation rates have been found to be below 10%.[4,7]

Patients with vascular injury are present with either hard or soft signs.[6] Those with hard signs are more likely to warrant immediate surgical intervention,[8] whilst patients with soft signs should have either surgical exploration or further investigations to assess for the presence and degree of vascular injury.[6,9] It has been reported that up to 25% of patients with soft signs have a vascular injury, therefore justifying the need for further investigation.[3]

The primary aim of the study was to determine the limb salvage rate of adult patients, admitted to LGI between April 2013 and December 2018, who have sustained a blunt trauma to their lower limb(s) with vascular injury. The secondary aim was to determine patient complications. The timeframe provides a period spanning 5 years, importantly since LGI became an MTC, to assess the aims.

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Methods

The inclusion criteria consisted of all patients, aged 18 or over, treated at LGI for blunt trauma associated with vascular injury of the lower limb(s). Data were collected from April 2013 to December 2018. Patients first seen at the neighbouring TUs who were transferred to LGI for definitive treatment were also included. Excluded from the study were paediatric patients, as a study of this cohort at LGI has been recently published as a cohort of 3B and 3C open fractures with a 100% union rate in 32 lower limb injuries.[10]

All patients were treated in accordance with the advanced trauma life support (ATLS) guidelines.[11] Patients were then taken to the theatre under a multi-disciplinary team of orthopaedic, vascular and, if required, plastic surgeons. The treatment of the traumatic, arterial injuries was in keeping with the BOAST guidelines.[12]

Patients were identified using relevant International Statistical Classification of Diseases (ICD)-10 codes on local databases. Data were assimilated from both paper and local electronic records (PPM+). The injury severity was graded using MESS and ISS scoring systems, which, in some instances, were calculated retrospectively.[13,14] Only complications correlating to the lower limb injuries were recorded. Ischaemic times were determined from the time of injury to the time of initial surgery. Amputees were divided into those necessitating primary or secondary amputations.

Any statistical significance between amputees and non-amputees was verified using a one-tailed *t*-test ($p \leq 0.05$).

Results

A total of 30 patients met the study's inclusion criteria, and a summary of all 30 patients can be seen in Table 1. Two patients sustained bilateral blunt vascular injuries resulting in 32 lower limb arterial injuries. The cohort compromised of 24 (80%) males and 6 (20%) females, their mean ages were 32 and 49, respectively.

The most common mechanism of injury was those involving motorcycle vs vehicle collisions ($n = 12$). Others included falls ($n = 7$), pedestrian vs vehicle ($n = 5$), motor vehicle accident ($n = 2$), bicycle vs vehicle ($n = 2$), crush injuries ($n = 1$) and injury from industrial machinery ($n = 1$).

Table 2 shows all orthopaedic and vascular injury sites. A fracture was the most frequent cause of lower limb injury – of which the tibia ($n = 16$, 47%) was the most frequently observed site and most often resulted in popliteal arterial injury ($n = 7$, 44%). Dislocation occurred in six limbs, five at the knee, and all resulted in popliteal arterial injury, which, overall, was the most common site of vascular injury ($n = 12$). Of the 32 injured vessels, only four occurred solely above the knee.

All patients were documented as primarily having undergone clinical examination to assess their limb's neurovascular status. Twenty five had vascular signs of injury – 20 had hard signs, 2 soft and 3 mixed, with often more than one sign being present (Table 1). By far, the most often reported sign of limb ischaemia was an absent pulse ($n = 19$) and secondly, paraesthesia ($n = 7$).

The severity of injuries is displayed in Table 3. The mean ISS was over double for those requiring an amputation, but was not shown to be significantly different in comparison to non-amputees ($p = 0.08$). Between primary and secondary amputees, the ISS was found to be greater in those with secondary amputations. Likewise, MESS scores were found to be significantly higher in all amputees ($p = 0.03$), and the mean MESS higher in those with primary amputation than those with secondary amputation.

Twenty nine of the 30 patients had ischaemic times available (Table 4). Nineteen patients had ischaemic times under 6 hours, whilst 10 were over. The median was judged to be more reflective of the average ischaemic time, as the mean for all limbs injured was grossly inflated by one outlier whose time was 23040 minutes due to a missed diagnosis in the emergency department (Table 4).

The patients' orthopaedic and vascular treatments are outlined in Table 1. The most common definitive orthopaedic management was the application of an Ilizarov frame ($n = 12$) – principally for the treatment of tibial fractures. Vascular treatment was required in just twenty-two limbs, the GSV graft being the most frequently utilised intervention.

Of the 32 limbs in the study, 27 (84%) were salvaged and 5 were amputated (Table 5). Three of the limbs were deemed non-salvageable and underwent primary amputation. Of the remaining 29 limbs, 27 were successfully salvaged (93%). One of the secondary amputations occurred due to deep infection, while the other owing to the limb being deemed non-salvageable despite initial surgical interventions. All but one patient survived.

Post-injury complications are outlined in Table 6. Fourteen limbs required fasciotomies, 11 prophylactically and 3 following a clinical diagnosis of compartment syndrome prior to their initial operation. None of the limbs later developed secondary compartment syndrome. Three patients contracted deep infections.

Discussion

Ischaemic time has been repeatedly shown to be a crucial factor in determining limb viability, with times under 6 hours correlating with significantly lower rates of amputation.[4–7] This paper's findings advocate, however, that it should not be used as a sole indicator of limb viability. Clearly, there are many factors implicating a patient's need for limb amputation, for example, patient comorbidity, resource availability and severity of injury.[15] Nevertheless, the authors advocate prompt stabilising and revascularisation of the patient, including within 6 hours, as prolonged times are associated with a worse prognosis. Notably, the time for those with primary amputations may, therefore, be under 6 hours as it was apparent that the limb was non-viable due to factors other than the ischaemic time, and restoration of arterial supply would not result in a viable limb.

An absent pulse was the most observed hard vascular sign ($n = 19$), which reflects findings in previous research (Table 1).[16] Other studies have shown, however, that the presence or absence of vascular signs does not confirm or exclude vascular injury.[17] As shown by patient 7 in Table 1 who suffered a knee dislocation and initially attended to the LGI emergency department intoxicated following a fall. He did not display any signs of neurovascular injury and was discharged the following day, only to represent 8 days later with an absent popliteal pulse and footdrop. Barnes et al.'s meta-analyses showed for patients with knee dislocations an abnormal pedal pulse was only 79% sensitive and 91% specific in identifying arterial injury requiring surgical intervention.[18] The reasons for the inaccuracy include inconspicuous intimal damage, decreasing sensitivity and hypotension secondary to trauma-reducing specificity – reinforcing the need for a high degree of clinical suspicion of arterial injury.[19]

ISS and MESS scores were greater in amputees than non-amputees, even significantly greater comparing MESS scores. However, 10 patients with salvaged limbs had a MESS score ≥7. Under current MESS guidance, these limbs should be subject to amputation. In 1997, Lin et al. showed that owing to advances

Table 1: Summary of patients within the study

No.	Age, Gender	Orthopaedic injury	Vascular injury site	Initial hospital visited	Uni/bilateral injury	Open/ closed #	Ischaemic time*	Hard signs	Soft signs	ISS	MESS	CTA	Amputation	Orthopaedic treatment	Vascular treatment	Complications
1	73, F	Multiple site #	Multiple sites	LGI	Bi	Open	175	N	N	20	9, 9	Y	Primary	N/A	N/A	DVT
2	29, M	Femur #	SFA	BRI	Uni	Closed	390	Ischaemia	Non-expansive haematoma	N/A	7	Y	N	Ex-Fix, IMN	Shunt & GSV graft	N
3	33, M	Femur #	SFA	LGI	Uni	Open	114	Absent pulse	N	10	5	Y	N	Ex-Fix, IMN	GSV graft	N
4	24, M	Femur #	SFA	LGI	Uni	Open	210	Absent pulse	N	10	5	Y	N	IMN	Shunt & GSV graft	N
5	27, M	Femur #	DFA	LGI	Uni	Closed	917	N	N	N/A	4	Y	N	IMN	Conservative	N
6	18, F	Knee dislocation	PA	LGI	Uni	N/A	125	Absent pulse and pallor	N	45	7	Y	Secondary	Ex-Fix	Shunt & GSV graft	N
7	19, M	Knee dislocation	PA	LGI	Uni	N/A	23040	Absent pulse	Foot drop	N/A	6	N	N	KLR, Brace	GSV graft	Neuropathy
8	37, F	Knee dislocation	PA	LGI	Uni	N/A	180	Absent pulse	N	9	5	N	N	Ex-Fix, Brace	Shunt & GSV graft	Neuropathy
9	40, M	Knee dislocation and tibial #	PA	HRI	Uni	Closed	332	Cold, active bleeding, paraesthesia & absent pulse	N	25	7	N	Secondary	Ex-Fix	GSV graft	Deep infection and phantom limb pain
10	41, F	Knee dislocation and fibula head #	PA	LGI	Uni	Open	31	Absent pulse, paraesthesia, active bleeding and cold	N	N/A	6	Y	N	Ex-Fix, ORIF	GSV graft	N
11	69, F	Knee dislocation with femoral condyle and fibula #	PA	LGI	Uni	Closed	492	N	Diminished pulse	N/A	5	N	N	Ex-Fix, Jigsaw cast	Vein patch	N
12	24, M	Tibial #	PA	LGI	Uni	Open	230	Absent pulse and cold	N	9	8	Y	N	Wound and knee washout	GSV graft	Deep infection
13	55, F	Tibial #	PA	LGI	Uni	Closed	130	Absent pulse	N	N/A	3	Y	N	Ex-Fix, ORIF	GSV graft	N
14	25, M	Tibial #	PA	LGI	Uni	Open	307	Pallor and absent pulse	N	N/A	7	Y	N	Ex- Fix, Frame	GSV graft	Compartment syndrome
15	27, M	Tibial #	PTA	LGI	Uni	Open	827	Absent pulse	N	9	7	N	N	Ex-Fix, Frame	GSV graft	N
16	31, M	Tibial #	PTA	LGI	Uni	Open	90	Absent pulse, paraesthesia and pallor	N	18	8	Y	N	Ex-Fix, Frame	Conservative	N

(Contd...)

Table 1: *(Contd...)*

No.	*Age, Gender*	*Orthopaedic injury*	*Vascular injury site*	*Initial hospital visited*	*Uni/bilateral injury*	*Open/ closed #*	*Ischaemic time**	*Hard signs*	*Soft signs*	*ISS*	*MESS*	*CTA*	*Amputation*	*Orthopaedic treatment*	*Vascular treatment*	*Complications*
17	22, M	Tibial #	PTA	HRI	Uni	Closed	453	Paraesthesia	Diminished pulse	19	9	Y	N	Ex-Fix, Frame	Bovine patch	Compartment syndrome and haemorrhage
18	20, M	Tibial #	ATA and PTA	LGI	Uni	Open	247	Absent pulse and cold	N	9	6	Y	N	Ex-Fix, IMN	Conservative	N
19	59, M	Tibial #	ATA	LGI	Uni	Open	450	Absent pulse	N	13	10	Y	N	Ex-Fix, Frame	Conservative	N
20	59, M	Tibial #	PA	LGI	Uni	Closed	238	Absent pulse	N	9	7	Y	N	Ex-Fix, Frame	GSV graft	Neuropathy
21	20, M	Bilateral tibial #	Right PA and left ATA	LGI	Bi	Open	156	Absent pulse, paraesthesia	N	9	6, 6	N	N	Bi Ex-Fix, Bi Frame	Right GSV graft, Left conservative treatment	N
22	47, M	Tibial #	PA	BRI	Uni	Open	120	Absent pulse and paraesthesia	N	9	9	Y	N	Ex-Fix, Frame	GSV graft	Neuropathy, compartment syndrome
23	67, M	Tibial #	ATA	LGI	Uni	Open	395	Pallor and cold	N	18	9	Y	N	Ex-Fix, Frame	Conservative	Deep infection
24	27, M	Tibial #	PTA	HRI	Uni	Open	573	Notes not present	Notes not present	9	N/A	N	N	ORIF, Ex-Fix, Frame	GSV graft	N
25	21, M	Tibial #	ATA and PRA	LGI	Uni	Open	226	N	N	9	N/A	Y	N	Ex-Fix, Frame	Conservative	N
26	55, M	Ankle dislocation	PTA	PGH	Uni	N/A	N/A	N	N	13	N/A	N	N	Ex-Fix, walker boot	Vein patch	N
27	40, M	Ankle #	PTA	LGI	Uni	Open	175	Absent pulse and cold	N	13	8	Y	N	Ex-Fix, ORIF	Conservative	N
28	23, M	Ankle #	PTA	LGI	Uni	Open	245	Absent pulse, paraesthesia	N	13	5	Y	N	ORIF	Vein patch	N
29	65, M	Ankle #	ATA and PTA	LGI	Uni	Open	300	N	Proximity-related injury	10	8	Y	Primary	N/A	N/A	N
30	27, M	Crush injury no #	PTA	LGI	Uni	Closed	459	Expanding haematoma	N	4	5	Y	N	N/A	Balloon control	N

ATA, anterior tibial artery; BRI, Bradford Royal Infirmary; CTA, computed tomography angiography; DFA, deep femoral artery, Ex-Fix, external fixation; F, female; Frame = Ilizarov frame; GSV, great saphenous vein; HRI, Huddersfield Royal Infirmary; IMN, intermedullary nail; KLR, knee ligament reconstruction; LGI, Leeds General Infirmary; M, male; N, no; N/A, not applicable; ORIF, open reduction internal fixation; PA, popliteal artery; PGH, Pinderfields General Hospital; PRA, peroneal artery; PTA, posterior tibial artery; SFA, superficial femoral artery; Uni, unilateral; Y, yes; #, fracture
* In minutes; ** In days

Table 2: Lower limb injury vs site of vascular injury

	Vascular site of injury								
Lower limb injury	*PA*	*PTA*	*SFA*	*ATA*	*ATA and PTA*	*Multiple sites*	*ATA and PRA*	*DFA*	*Total*
Tibial #	6	4		3	1		1		15
Femur #			3					1	4
Ankle #		2			1				3
Knee dislocation	3								3
Multiple site crush injury						2			2
Femoral condyle and fibula #	1								1
Knee dislocation, femoral condyle and fibula #	1								1
Knee dislocation & tibia #	1								1
Ankle dislocation		1							1
Crush injury no #		1							1
Total	12	8	3	3	2	2	1	1	32

ATA, anterior tibial artery; DFA, deep femoral artery; PA, popliteal artery; PRA, peroneal artery; PTA, posterior tibial artery; SFA, superficial femoral artery; #, fracture

Table 3: Mean MESS and ISS available of those with amputations and those with salvaged limbs

	1° amputation	*2° amputation*	*All amputees*	*Salvaged*	*Total cohort*
Number of limbs	3	2	5	27	32
MESS	9	7	8	$6^{(1)}$	$7^{(2)}$
ISS	15	35	25	$11^{(3)}$	$14^{(4)}$

Key: 1, MESS of 24 salvaged limbs; 2, MESS of 28 limbs; 3, ISS of 19 salvaged patients; 4, ISS of 23 patients

Table 4: Median ischaemic times

	Ischaemic time
$\text{Overall}^{(1)}$	4 hours 5 minutes
$\text{Salvaged}^{(2)}$	4 hours 5 minutes
$\text{Amputees}^{(3)}$	3 hours 57 minutes

Key: 1 = ischaemic time of 29 patients, 2 = ischaemic time of 25 patients with salvaged limbs and 3 = ischaemic time of all 4 amputees

in surgical technique, MESS scores of the lower limb ≥9 could be salvaged and, therefore, caution should be applied when using MESS to predict limb outcome.[20] Of note, all of those with amputations had MESS scores ≥7.

The limb salvage rate was comparable with those described in the literature.[19,21] In fact, it may underplay the performance of the MTC as majority of the amputations were primary ($n = 3$). One patient who underwent bilateral primary amputation – which did not lead to any complications – died 29 days post-admission from multi-organ failure.

Table 5: Amputee patients' profiles

Patient	*No. 1*	*No. 2*	*No. 3*	*No. 4*
Age	73	40	18	65
Sex	Female	Male	Female	Male
Unilateral/bilateral amputation	Bilateral	Unilateral	Unilateral	Unilateral
Primary/secondary	Primary	Secondary	Secondary	Primary
Mechanism of injury	Pedestrian vs vehicle	Motorcycle incident	Pedestrian vs vehicle	Pedestrian vs vehicle
Orthopaedic injury	Multiple open # sites	Knee dislocation and tibial #	Knee dislocation	Ankle #
Site of vascular injury	PA	PA	PA	ATA and PTA
Cause of amputation	Unsalvageable	Deep tissue infection	Unsalvageable	Unsalvageable
MESS	9	7	7	8
ISS	20	25	45	10
Ischaemic time (minutes)	175	332	125	300

ATA, anterior tibial artery; PA, popliteal artery; PTA, posterior tibial artery; #, fracture

Table 6: Type and frequency of complications observed in patients' post-surgical treatment

Post-injury complication	*Number of limbs affected*
Neuropathy	4
Deep tissue infection	3
Compartment syndrome	3
Deep vein thrombosis	1
Haemorrhage	1
Phantom pain	1

Whilst there is no prescriptive orthopaedic repair for lower limb injuries, Ilizarov frames were used to repair all but three tibial fractures with soft tissue and vascular injury following external fixation. A two-staged repair was typically required for limbs requiring a circular frame, in accordance with BOAST guidelines. In the initial operation, vascular repair was undertaken followed by insertion of a simple monolateral external fixation device to the fracture site. Provided this was satisfactory, a period of 7–10 days was given to allow for soft tissue swelling to subside, as well as confirming successful revascularisation before replacing the external fixation device with a circular frame.

For circular frames on the tibia, extra care and planning were given to wire and half-pin placement. In particular, the orthopaedic surgeon must be aware of the position of the anastomosis as well as any anatomical displacement of the major vessels. In some cases, a 3D CT angiogram was undertaken after the revascularisation to help with this planning, for instance, in one-vessel legs. The construct would then be adapted, for instance, using more anteromedial half-pins rather than standard transverse olive wires in the midshaft, for example. Extra care would also be given not to significantly displace the initial fracture in case this would stretch or distort the anastomosis.

This is the common practice when utilising the Ilizarov frame at LGI following their published successes over the past 18 years.[22–24] This is possible owing to the infrastructure available at the trust, including surgeons who are comfortable with this technique and a multidisciplinary team who can manage the frame in an outpatient setting.

In total, four vascular shunts were used. Three were used in limbs that were ultimately salvaged. One patient, however, who did receive a shunt and subsequent GSV grafting, necessitated a secondary below-knee amputation (patient 6, Table 1). This patient's CT angiogram displayed total transaction of all vessels at the trifurcation, had an unreconstructable leg from a soft tissue perspective and was quite unstable from a severe head injury perspective, culminating in a decision for early secondary amputation.

The most frequent definitive method of arterial repair was the use of great saphenous vein graft (50%). This is also similar to other studies and can be explained due to their ease of harvest and use.[15,25] Finally, despite the liberal use of prophylactic fasciotomies to mitigate its development, it still occurred in three patients. The fasciotomy rates for this series were lower than that of comparable studies – Hafez et al. 47% and Huynh et al. 60%.[2,21]

Pin site infections have been described as not a 'true' complication, as the majority can be treated successfully with a course of oral antibiotics,[26] but the potential for morbidity associated with deep infection is great. One patient, patient 9, who contracted an infection – the source never identified – required secondary amputation. The result of the infection included a protracted length of hospital stay and multiple revisits to the operating theatre. This reiterates the need for comprehensive wound debridement, adequate soft tissue and early involvement of a specialist lower limb plastic surgeon in order to cover the vascular graft.[19,27] After their amputation, this patient also suffered from phantom limb pain, which, to this day, is poorly controlled.

Limitations

This study is subject to the inherent bias of any retrospective research, having had to use incomplete datasets and no uniform process being in place to retrieve data. Furthermore, the small patient cohort restricted comparison between the two groups, although this is difficult to mitigate given the rarity of these injuries.

Conclusion

The cohort's overall limb salvage rate was 84%, however, this includes three patients needing primary amputations. Attempted salvage of 27/29 (93%) limbs was successful, which may better reflect the MTC's performance. This is encouraging evidence in support of the recently established regional trauma network.

Whilst ischaemic time is a well-documented important aspect in determining limb viability, times over 6 hours were not found to be a sole indicator for limb amputation, and it should be used in conjunction with other factors.

The findings support the revision of the MESS criteria to better reflect contemporary surgical capabilities and state that whilst the complication rate observed was low, their implications can have a crucial impact on the short-term outcome of patients' management.

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