

➤ **Original Article** ➤

# Evaluation, Surgical Management and Outcome of Traumatic Extremity Vascular Injuries: A 5-year Level-1 Trauma Centres Experience

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**Objective:** We aim to share our experience regarding the surgical management and outcome of extremity vascular trauma in level-1 trauma centres in Pakistan.

**Patients and methods:** All consecutive patients with traumatic extremity vascular injury (TEVI) fulfilling the inclusion criteria; between June 2012 and June 2017 were included. The demographics, clinical presentation, management, and outcome measures were recorded.

**Results:** The study included 81 patients. The mean age±standard deviation was 28.6±14.5 years and 81.5% (n=66) of the patients were males. Blunt TEVI was found in 65.4% (n=53) of the cases. Partial laceration was the most common type of arterial injury (64.2%, n=52) and autologous interposition venous grafting was the most common repair performed (60.5%, n=49). Fasciotomy was performed in 67.9% (n=55) of the patients. The limb salvage rate was 82.7%. The amputation rate was higher in the blunt trauma group when compared with that of the penetrating trauma group. The length of the intensive care unit stay and the use of polytetrafluoroethylene as interposition graft were two independent predictors of limb loss. The mortality rate in this series was 8.6%.

**Conclusion:** Blunt TEVI is associated with higher morbidity and limb loss. The use of synthetic graft should be discouraged. The liberal use of autologous interposition venous graft and the judicious use of fasciotomies are helpful to achieve favorable outcomes.

**Keywords:** vascular injury, trauma, limb injury, extremity, arterial

## Introduction

Vascular trauma constitutes 3% of all traumatic injuries.<sup>1</sup> Unfortunately, traumatic extremity vascular injury (TEVI) associated with concomitant fractures and major soft tissue loss results in a relatively high morbidity in terms of prolonged hospital stays and high amputation rates.<sup>2–4</sup>

The surgical management of extremity vascular injuries has evolved over time. In the civilian population, blunt trauma in road side accidents is more prevalent when compared with penetrating trauma, which is mostly related to warfare injuries.<sup>5</sup> However, recently, due to an increase in the urban violence, the patterns of vascular injuries are changing.<sup>2,6</sup> To date, there are no well-defined guidelines for the management of extremity vascular trauma and optimal strategies are variable depending upon the local setup and expertise available.<sup>6</sup>

In this multicentre prospective cross-sectional study, we aim to describe our experience in dealing with TEVI in level-1 military centres in Pakistan. We focused on the patterns of vascular injuries, initial presentation, surgical treatment, complications, and outcome.

## Patients and Methods

All patients with TEVI presenting to urban level-1 trauma centres, namely the Combined Military Hospitals Lahore, Peshawar and Quetta, between June 2012 and June 2017 were included in the study. Patients who had non-salvageable traumatic limb loss at the time of injury and

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those who had amputations performed in periphery as lifesaving treatment were excluded from the study. The demographics, initial management in the field ambulance or emergency room of the trauma centre, patterns of TEVI, concomitant injuries, surgical management, and complications were reviewed. Apart from the clinical and laboratory data, the severity of the injury was quantified using two trauma scores, namely the Revised Trauma Score and the Injury Severity Score.

TEVI was diagnosed clinically and augmented by colour Doppler scan. Associated bony injuries, if any, were assessed with relevant X-rays where indicated. Patients with definitive hard signs of vascular trauma were immediately shifted to the operating theater for exploration of the vascular injury. Definitive repair to restore circulation to the traumatic limb was performed. All patients were clinically assessed for compartment syndrome and relevant fasciotomies were performed where indicated. Patients with soft signs of vascular trauma were further assessed by computerized tomographic angiography (CTA) where indicated before planning for definitive vascular repair.

The primary end points of this study were mortality and limb salvage rate. The secondary end points included vascular complications, re-explorations, and fasciotomy rate. The statistical analysis was performed with the Statistical Package for Social Sciences Version 17.0 software (SPSS Inc., Chicago, IL, USA). The numerical variables were expressed as means and standard deviations and categorical data was expressed as frequency and percentage. Continuous variables were compared using the Student's t-test. P-values of less than or equal to 0.05 were considered statistically significant. When assessing the limb loss, patients were divided into two groups, namely the amputation and the salvage groups. Odd Ratio (OR) and 95% Confidence Interval (CI) were calculated. An univariate logistic regression was performed to assess the impact of demographic, laboratory- and injury-related variables in the two groups. A multivariate logistic regression was performed only for those variables where the P-value for such a variable in the univariate regression was less than or equal to 0.2.

## Results

In a period of 5 years, a total of 81 patients with TEVI fulfilling the inclusion criteria presented to us. The mean age at the time of presentation was  $28.6 \pm 14.5$  (range, 19.5–58) years. There were 81.5% ( $n = 66$ ) males and the male-to-female ratio was 4.4:1. The mechanisms of injury are shown in **Table 1**.

All patients presenting with hard signs of vascular trauma (22.2%,  $n = 18$ ) were immediately shifted to the OR while those with soft signs (77.8%,  $n = 63$ ) were further investigated using colour Doppler (100%,  $n = 63$ ) and

**Table 1** Baseline characteristics of the patients ( $n = 81$ )

Age in years (Mean $\pm$ SD)	28.6 $\pm$ 14.5
Male gender [n, (%)]	66 (81.5)
Female gender [n, (%)]	15 (18.5)
GCS at presentation [Mean $\pm$ SD]	13 $\pm$ 3
Trauma score at presentation [Mean $\pm$ SD]:	
Injury Severity Score	15 $\pm$ 10 (5–55)
Revised Trauma Score	8 $\pm$ 3 (4–12)
Mechanism of injury [n, (%)]:	
Penetrating:	28 (34.6)
Gunshot	26 (32.1)
Stab	2 (2.5)
Blunt:	53 (65.4)
Accidental fall	5 (6.2)
Crush injury	6 (7.4)
Motor vehicle accident	14 (17.3)
Motor cycle accident	17 (21.0)
Pedestrian accident	11 (13.6)
Hospital stay [Mean $\pm$ SD]	16 $\pm$ 7 (4–38)
ICU stay [Mean $\pm$ SD]	13 $\pm$ 7 (1–30)
Concomitant procedures [n, (%)]:	
Laparotomy	22 (27.2)
Thoracotomy	3 (3.7)
Craniotomy/burr hole	4 (4.9)
Fasciotomy	55 (67.9)

SD: standard deviation; GCS: Glasgow Coma Scale; ICU: intensive care unit

CTA (28.5%,  $n = 18$ ).

All patients underwent operative intervention for their vascular injuries. On exploration, partial laceration was the most common type of arterial injury (64.2%,  $n = 52$ ) and reverse interposition venous grafting (60.5%,  $n = 49$ ) using autologous vein was the most common repair performed (**Table 2**). Three patients received polytetrafluoroethylene (PTFE) graft for their femoral artery injuries since their own saphenous veins were inadequate/unavailable. In 9.9% ( $n = 8$ ) of the patients, the injured artery was in the distal part of the forearm or calf and hence ligated. Temporary intravascular arterial shunt (TIVAS) was used as damage control in 3.7% ( $n = 3$ ) of the patients where major non-vascular chest/abdominal injuries warranted emergency treatment first. The mean time while TIVAS was in place was  $75 \pm 20$  min. There were 22.2% ( $n = 18$ ) patients with concomitant venous injuries. Femoral vein with partial laceration was primarily repaired in four cases while it was ligated in two patients who had complete transection. Popliteal vein was ligated in two and repaired in other two cases. The remaining eight cases included injuries to the venae comitantes of smaller arteries distal of the elbow or knee and they were all ligated.

Fasciotomy was performed in 67.9% ( $n = 55$ ) of the patients. Of these, 81.8% ( $n = 45$ ) had standard two incision four compartment below-knee fasciotomy, 12.7%

(n=7) had below-knee fasciotomy with extension into the thigh and 5.4% (n=3) received forearm fasciotomy. There were 32.7% (n=18) patients who needed partial thickness skin grafting later on for closure of their fasciotomy wounds. The limb salvage rate was 82.7%. There were 14 amputations in total, all in the lower extremity (10 below-knee and four foot amputations). The amputation rate was higher in the blunt trauma group compared with the penetrating trauma group (22.6% [n=12] vs. 7.1% [n=2] respectively;  $P<0.001$ ) (Table 3). Concomitant bone fractures were found in 81.5% (n=66) of the

patients, with 33.3% (n=22) needing external fixation. There were 11.1% (n=9) patients with extensive tissue loss needing complex myocutaneous flap reconstructions. Other complications included wound hematoma (21%, n=17), seroma (4.9%, n=4), superficial surgical site wound infection (23.5%, n=19), deep vein thrombosis (14.8%, n=12), and pulmonary embolism (2.5%, n=2).

There were 74.1% (n=60) patients who were admitted to the intensive care unit (ICU) after surgery. Of these, 68.3% (n=41) had blunt trauma while 31.7% (n=19) had penetrating injuries. The mean ICU stay was  $13\pm 7$  (range, 1–30) days. The total length of the hospital stay was  $16\pm 7$  (range, 4–38) days. Comparison of various variables between the blunt and penetrating trauma groups is shown in Table 3. The mortality rate in this series stands at 8.6%, with no difference between the blunt and penetrating trauma groups. All patients had colour Doppler scan prior to discharge, which confirmed the patent vascular repairs.

Univariate analysis identified six variables ( $P<0.05$  each) independently associated with limb loss (Table 4). The multivariate analysis for these variables showed that the length of the ICU stay (OR 1.08 [95% CI 1.02–1.29];  $P=0.002$ ) and the use of PTFE graft (OR 5.11 [95% CI 1.01–47.32];  $P=0.039$ ) are two independent predictors of limb loss (Table 5).

## Discussion

Extremity vascular trauma is a challenging entity on its own. Extremity vascular injuries make up only 3% of all traumatic injuries, but they are associated with potentially fearful complications such as limb loss and even death.<sup>5,7)</sup> The incidence of TEVI is even higher (10%) in patients with poly-trauma.<sup>5)</sup> In the civilian population, blunt trauma as a result of road side accidents is the major cause, but increasing violence is resulting in more penetrating

**Table 2** Vascular injuries and their surgical repair (n=81)

Site of arterial injury:	
Popliteal	31 (38.3)
Femoral	20 (24.7)
Tibial	7 (8.7)
Subclavian	2 (2.5)
Axillary	3 (3.7)
Brachial	9 (11.1)
Radial/ulnar	9 (11.1)
Concomitant injuries:	
Vein	18 (22.2)
Nerve	11 (13.6)
Bone fractures	66 (81.5)
Type of arterial vascular injury:	
Contusion with thrombosis	19 (23.4)
Partial laceration	52 (64.2)
Complete transection	8 (9.9)
Arteriovenous fistula	2 (2.5)
Arterial vascular repair:	
Vein interposition graft	49 (60.5)
Primary repair	11 (13.6)
Synthetic graft (PTFE)	4 (4.9)
Ligation of artery	8 (9.9)
Temporary intravascular shunt	3 (3.7)
Catheter embolectomy	6 (7.4)

PTFE: polytetrafluoroethylene

**Table 3** Comparison of variables by mechanism of vascular injury

Variable	Blunt trauma (n=53)	Penetrating trauma (n=28)	P-value
Age in years (Mean±SD)	25.4±12.6	32.2±9.1	<0.001
Male gender [n, (%)]	38 (71.7)	28 (100)	
Concomitant fracture [n, (%)]	46 (86.8)	20 (71.4)	<0.001
Concomitant major soft tissue loss [n, (%)]	8 (15.1)	1 (3.5)	<0.05
Injury severity score [Mean±SD]	19±3	11±2	<0.001
Revised trauma score [Mean±SD]	6.44±1.1	5.22±2.12	<0.001
Hospital stay [Days±SD]	22±6	10±4	<0.001
ICU stay [Days±SD]	11±3	3±2	<0.001
Fasciotomy [n, (%)]	35 (66.0)	20 (71.4)	
Amputation [n, (%)]	12 (22.6)	2 (7.1)	<0.001
Mortality [n, (%)]	4 (7.5)	3 (10.7)	

SD: standard deviation; ICU: intensive care unit

**Table 4** Univariate regression analysis of the patient variables associated with limb loss

Patient variable	Salvage group	Amputation group	Univariate analysis ORs (95% CI)	P-value
Total patients (n)	67	14		
Age in years (Mean±SD)	23.4±10.4	30.1±8.2	1.01 (0.89–1.21)	0.198
Male gender [n, (%)]	55 (82.1)	11 (78.6)	1.56 (0.56–10.91)	0.481
Female gender [n, (%)]	12 (17.9)	3 (21.4)	1.69 (0.59–2.92)	
Mechanism of injury:			0.20 (0.01–1.64)	0.126
Blunt [n, (%)]	42 (62.7)	11 (78.5)		
Penetrating [n, (%)]	25 (37.3)	3 (21.5)		
Vital signs at presentation:				
Pulse rate per minute (Mean±SD)	90±25	95±20	1.20 (1.00–1.66)	0.495
Systolic blood pressure (mmHg±SD)	139±12	141±10	1.21 (1.01–1.59)	0.573
Diastolic blood pressure (mmHg±SD)	73±9	78±11	1.24 (0.99–1.74)	0.431
Respiratory rate per minute (Mean±SD)	16±4	19±3	0.99 (0.97–1.11)	0.492
Oxygen saturation (% ± SD)	94±4	93±2	1.11 (0.99–1.32)	0.594
Laboratory indices at presentation:				
Hematocrit at presentation (% ± SD)	35.4±6	33.6±3	0.99 (0.92–1.22)	0.339
Initial pH at presentation (Mean±SD)	7.34±0.2	7.35±0.1	1.99 (0.18–3.77)	0.499
pO <sub>2</sub> at presentation (mmHg±SD)	90±3	91±4	1.09 (0.97–1.21)	0.512
pCO <sub>2</sub> at presentation (mmHg±SD)	43±10	41±11	0.98 (0.91–1.02)	0.668
Base deficit at presentation (in negative)	4.9±2.1	3.84±2.9	1.11 (0.91–1.23)	0.483
Operative variables:				
Complete arterial transection [n, (%)]	6 (8.9)	2 (14.3)	1.99 (0.51–19.23)	0.429
Concurrent vein ligation [n, (%)]	14 (20.9)	4 (28.6)	0.82 (0.19–2.19)	0.599
Temporary intravascular shunt [n, (%)]	3 (4.5)	0	1.04 (5.94–)	1.000
Venous interposition graft [n, (%)]	40 (59.7)	9 (64.3)	1.92 (0.81–2.99)	0.571
PTFE interposition graft [n, (%)]	3 (4.5)	1 (7.1)	0.31 (0.02–1.83)	0.111
Concurrent bony injury [n, (%)]	53 (79.1)	13 (92.8)	5.21 (0.72–19.8)	0.115
Concurrent laparotomy [n, (%)]	20 (29.8)	2 (14.3)	1.15 (0.43–3.95)	0.958
Concomitant thoracotomy [n, (%)]	3 (4.5)	0	1.04 (5.94–)	1.000
Fasciotomy [n, (%)]	45 (66.2)	10 (71.4)	0.69 (0.54–2.11)	0.421
External fixation [n, (%)]	19 (28.3)	3 (21.4)	0.81 (0.44–2.22)	0.471
Other variables:				
Injury Severity Score (Mean±SD)	16.4±11.3	18.6±9.3	1.04 (0.88–1.34)	0.594
Revised Trauma Score (Mean±SD)	5.9±0.98	5.1±0.77	0.96 (0.88–1.04)	0.391
Packed red cells units (Mean±SD)	8.4±9.2	11.5±4.6	1.09 (0.91–1.18)	0.185
Total hospital stay in days (Mean±SD)	14.4±9.4	19.6±12.8	0.79 (0.15–1.99)	0.521
Total ICU stay in days (Mean±SD)	6.5±10.2	16.4±11.4	1.06 (1.01–1.11)	0.043

SD: standard deviation; PTFE: polytetrafluoroethylene; ICU: intensive care unit; OR: Odd Ratio; CI: Confidence Interval

**Table 5** Multivariate regression analysis of patient variables associated with limb loss

Patient variable	Univariate analysis ORs (95% CI)	P-value	Multivariate analysis ORs (95% CI)	P-value
Age in years (Mean±SD)	1.01 (0.89–1.21)	0.198	0.99 (0.91–1.17)	0.599
Mechanism of injury	0.20 (0.01–1.64)	0.126	1.21 (0.44–8.31)	0.611
PTFE interposition grafting	0.31 (0.02–1.83)	0.111	5.11 (1.01–47.32)	0.039
Concurrent bony injury	5.21 (0.72–19.8)	0.115	1.44 (0.89–2.14)	0.483
Packed red cells units	1.09 (0.91–1.18)	0.185	1.01 (0.91–1.11)	0.729
Total ICU stay in days	1.06 (1.01–1.11)	0.043	1.08 (1.02–1.29)	0.002

SD: standard deviation; PTFE: polytetrafluoroethylene; ICU: intensive care unit; OR: Odd Ratio; CI: Confidence Interval

vascular traumas.<sup>7)</sup> In this study, 65.4% of the patients suffered blunt traumas, with the majority of them resulting from road side accidents. Penetrating traumas were seen in 34.6% cases; however, civilian cases accounted for only 21.4% (n=6) of the cases, whereas the remaining were related to the battlefield.

The majority of the vascular injuries can be easily diagnosed clinically. Presence of “hard signs” of vascular trauma should warrant immediate exploration.<sup>8)</sup> In our study, 47% (n=38) of the patients with hard signs were immediately explored in the OR. Patients with “soft signs” of vascular trauma warrant additional adjuncts to diagnose extremity vascular injury.<sup>8)</sup> Although CTA is the gold standard in diagnosing TEVI,<sup>9)</sup> the non-invasive investigation colour Doppler is widely available and a very reliable method with a high specificity (98%), sensitivity (96%) and accuracy (98%).<sup>10,11)</sup> In our study, 53% of the patients with either soft signs or no signs at all underwent colour Doppler and were positively identified as having TEVI.

Blunt trauma results in high transmission of physical force to the extremity, which can result in fractures and major soft tissue loss. Such associated injuries often result in increased morbidity and higher rates of limb loss.<sup>2)</sup> In our study, we compared blunt trauma to penetrating trauma. There was a clear difference in terms of morbidity, with increased hospital and ICU stays associated with blunt trauma and also higher incidence of concomitant fractures and soft tissue loss. Although the morbidity was higher in the blunt trauma group, there was no statistically significant difference for mortality between the two groups. The mortality in our series was 8.6%, which was similar to that observed in other studies such as those of Hafez et al. and Kauvar et al. (range, 4%–9%).<sup>3,4)</sup>

The most common type of arterial repair performed in our series was interposition venous grafting (60.9%). Prosthetic graft was only used in 4.9% of the patients. Our multivariate analysis showed that prosthetic graft was an independent variable for limb loss. Similar to our study, Hafez et al. used interposition venous graft in 49.1% and prosthetic graft in 9% of the cases.<sup>3)</sup> The authors have also reported artificial graft as a risk factor for amputation. The use of prosthetic graft is also discouraged by other studies due to low long-term patency and higher amputation rates.<sup>12,13)</sup>

The treatment of concomitant venous injuries is controversial. Those in favor advocate that increased venous drainage results in less edema and the chances of developing compartment syndrome eventually leading to limb loss are low.<sup>14)</sup> Others advocate that venous repair is time-consuming and that there is no long-term added advantage over venous ligation. Kurtoglu et al. performing venous ligation in 63 cases concluded that there was no

sequel of chronic venous insufficiency and there was no detrimental effect of venous ligation on the concomitant arterial repairs.<sup>15)</sup> In our series, we repaired only veins that needed simple running stitches. Keeping in view the principles of damage control surgery, the veins were ligated if they needed complex repair such as interposition grafting.

TIVAS can be used to perfuse the limb when other life-threatening injuries need to be addressed first. Some authors believe that the regular use of TIVAS is associated with reduced intra-operative limb ischemia time, hence reducing the overall morbidity in terms of re-explorations, post-operative complications, amputation rates (limb salvage 76.5%), and hospital stay.<sup>16)</sup> On the contrary, others oppose the use of TIVAS and advocate that definitive arterial repair should take priority over skeletal and associated soft tissue injuries.<sup>17)</sup> Huynh et al. performed arterial repairs before addressing concomitant skeletal injuries, without the use of TIVAS, and had a limb salvage rate of 92%.<sup>17)</sup> A recent multicentre review advised the use of shunt in patients with open long bone fractures or as a damage control measure in patients with physiological near-exsanguination.<sup>18)</sup> We preferred arterial repairs first before addressing other concomitant non-vascular injuries. We advocate the use of TIVAS in cases where there are life-threatening major injuries to the chest and abdomen that need to be addressed with priority.

Compartment syndrome is a fearful complication of TEVI which can result in limb loss if not treated early. Common risk factors for development of compartment syndrome are prolonged ischemia time of more than 6 h and concurrent bony and venous injuries.<sup>8,19)</sup> Farber et al. reported a fasciotomy rate of 41.7% when he analyzed the National Trauma Data Bank.<sup>20)</sup> In our study, the fasciotomy rate of 67.9% was comparable to that of previous studies.<sup>2,17,21)</sup> We performed fasciotomy in all of those patients with clinical evidence of compartment syndrome, prolonged ischemia time (more than 6 h), associated skeletal injuries, and major venous injuries requiring ligation. In our study, we believe that the lower amputation rate of 17.3% (22.6% in the blunt trauma group vs. 7.1% in the penetrating trauma group; P<0.001) was attributed to the liberal use of fasciotomies. Similar low amputation rates of 17% (27% in the blunt trauma group vs. 5% in the penetrating trauma group) attributed to the liberal use of fasciotomy (74.4%) was also reported by Sciarretta et al.<sup>2)</sup>

There were several limitations to our study. Since extremity vascular trauma is a vast subject, it was not possible to assess and standardise all aspects such as the vascular suturing techniques, etc. Furthermore, we did not perform any endovascular intervention in this series. Also the use of anticoagulation during and after surgery was not standardised and the decision was left with the

attending surgeon. Such factors may have confounding effects and must be kept in mind when interpreting the end results.

## Conclusion

Management of TEVI is complex and requires a multi-disciplinary approach. Blunt trauma is associated with increased morbidity in terms of higher risk of concomitant fractures and major soft tissue loss. There is also prolonged hospital and ICU stays in blunt TEVI when compared with penetrating vascular trauma. The use of synthetic graft and prolonged ICU stay are independent risk factors for amputations. To reduce the morbidity and limb loss, we recommend early intervention, frequent use of autologous interposition venous grafts, TIVAS as a damage control measure and liberal use of fasciotomies.

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All authors have no conflict of interest.

## Author Contributions

Study conception: RU

Data collection: RU, MJ

Analysis: MFA

Investigation: MJ

Writing: RU, MJ

Critical review and revision: all authors

Final approval of the article: all authors

Accountability for all aspects of the work: all authors

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