Peripheral Vascular Injuries in Extremity Trauma, Single-center Experience

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ABSTRACT

Background

Peripheral vascular injuries are relatively uncommon and constitute 2-4% of cases presenting in the Orthopaedic Department. Managing vascular injuries in the Provincial hospital of Nepal is very challenging when they occur in combination with nerve injuries, fractures, and extensive soft tissue injury. It becomes more challenging when peripheral vascular injuries have to be managed by orthopedic surgeons in absence of Vascular Surgeons. Ligation and amputation are routine in the Provincial hospital setup.

Method

A total of 118 cases of all age and sex groups were included in the study. Only those patients were included who had extremity trauma with vascular injury which can be penetrating and blunt.

Result

Peripheral vascular injuries after extremity trauma were more common in 21-40 (52.5%) age group and predominantly in Males (77.9%). Road traffic accidents were the most common cause accounting for 22.4% followed by physical assault by sharp weapon (20.5%). Isolated Ulnar artery was most commonly injured (25.2%) followed by Radial artery (16.8%). Popliteal artery injuries were seen in (8.41%). The commonest type of injury was Transection (65.4%) followed by Intimal injury/Contusion (13%). End-to-end anastomosis (54.2%) was the most common type of repair, followed by ligation (30.8%) and interposition vein graft in (10.2%). Complications were seen in 43.2%. Primary amputation was required in 16.1% of cases.

Conclusion

Penetrating injuries were the most common injuries seen in our study with blunt injuries being common in lower extremity. Transection of vessel wall being common and end-to-end repair done by orthopedic surgeons was sufficient for the salvage of limbs irrespective of functional outcome. Early diagnosis, prompt resuscitation, and timely treatment given by primary surgeon irrespective of subspecialty training can save life and limb.

KEY WORDS

Amputation, Extremity, Peripheral vascular injury, Trauma

INTRODUCTION

Peripheral vascular injury after extremity trauma is relatively rare. Incidence accounts for less than 1% in patients with long bone fractures, which can be as high as 16% with Knee dislocation.[1,2] Whereas upper extremity vascular injury constitutes up to 50%, in which penetrating injury is the most common mechanism of injury with 80-98% of incidence in the upper extremity.[3,4] Any vascular injuries should be managed promptly. Delay can lead to complications like hemorrhage and irreversible ischemia of the injured limb which can result in increased mortality and morbidity.[1,2]

Managing Peripheral vascular injuries in association with fractures, extensive soft tissue injuries and Nerve injuries are challenging for orthopaedic surgeons in limited facility centers. Managing vascular injuries in Provincial hospitals of Nepal poses a great challenge. Lack of subspecialty expertise, infrastructure, equipment, and trained staffs are major issues in the optimal management of these injuries.

The Center, where this study was performed, is in Eastern Nepal, which is almost 441 kilometers away from Capital city with all the facilities to manage such injuries. Referring patients for subspecialty treatment to the capital city took extra 9-12 hours on a tortuous hilly road and resulted in a high rate of amputation. All patients were operated at our center by orthopaedic surgeons having experience in vascular surgery. Extremity vascular injury treatment by an orthopedic surgeon is intimately related to experience gained during the residential period or during the fellowship. Ligation and amputation are common in Provincial hospitals of Nepal. Amputation rates vary from 0% to 5.7% in upper extremity vascular injury in different literature and can reach up 9% with open tibia fracture and 16% with Knee dislocation.[5,6]

METHODS

In this retrospective study, we report etiology of injury, type of vascular injury, type of repair, and possible complications presenting to B & C Teaching Hospital and Research center (Proposed), Birtamod, Jhapa, Nepal. After approval from Institutional Review Board, data were retrieved from Emergency notes, operating notes and patients' charts.

One hundred and eighteen patients presenting with peripheral vascular injury were included in this retrospective study from April 2016 till April 2020. All patients were evaluated and resuscitated according to ATLS (Advance Trauma Life Support) protocols. Vascular injuries were evaluated clinically and by the use of Duplex Sonography. Clinical examinations were based on ''Hard signs'' or ''Soft signs''. Massive bleeding from the wound was the most common presentation, apart from clinical signs of vascular injury. Vessel ligation was commonly seen in those patients who attended other centers before presenting to our center. Hard signs such as Pulselessness, Pallor, Paraesthesia, and massive bleeding from the wound were immediately taken for surgical intervention. Detail distal pulse and neurosensory examination was done to rule out arterial and nerve injuries. All patients were evaluated by Duplex Ultrasonography for identification of vascular injury. CT Angiography or Arteriography was not done in any cases as those diagnostic procedures will delay in management and Duplex Ultrasonography was accurate in diagnosing vascular injury.

All vascular injuries were operatively explored and repaired. To minimize blood loss proximal and distal control was achieved with a proximal pneumatic tourniquet, direct temporary occlusion using non-traumatic clamps like Bulldog clamps or Acland clamps, and digital pressure. Fogarty embolectomy catheter of appropriate size was passed in the proximal and distal segments to perform thrombectomy. Routinely both the segments were flushed with heparinized solution before repair. An autogenous reversed saphenous vein graft from uninjured lower extremity or ipsilateral extremity was used whenever end to end anastomosis was not possible due to Intimal damage or segmental loss of more than three centimeter. End-to-end anastomosis was achieved using interrupted suturing technique. Polypropylene suture of 6-0 or 7-0 was used for anastomosis of Radial, Ulnar, and Tibial arteries. Brachial, Femoral, and Popliteal arteries were sutured with 6-0 polypropylene sutures in interrupted fashion. For suturing venous graft to recipient vessel 7-0 and 6-0 sutures were used. To facilitate approximation of vessel ends Aclands vascular clamps were used (Fig. 1c). An isolated Radial or Ulnar artery injury in upper extremity and isolated Posterior tibial and anterior tibial artery injury doesn't result in limb-threatening ischemia, given the rich vascular anastomosis found in the hand and foot. If one remaining artery was present ligation of the injured artery was done. If both were injured then ulnar artery or posterior tibial artery repair was preferred as these arteries are dominant and has large diameter. In all cases, loupe magnification was used, and whenever indicated microscope was used. Partial lacerations were directly repaired after exploration of vessel. Vessel compressions were released after meticulous dissection of vessel away from bony fragments. After release fractures or dislocations were reduced and fixed with appropriate implants. After addressing arterial injury additionally needed procedures were performed in the following order; venous repair or ligation, fasciotomy, tendon repair, and nerve repair. Nerve repair was done primarily. If a nerve graft was needed repair was usually delayed by six to eight weeks. Bony stabilization preceded vascular repair in all cases. Quick external fixator application or intramedullary titanium elastic nailing for forearm fracture was done. In case of wrist or hand bony injuries, Kirschners wire fixation was the method of choice.

In cases where clinical signs of compartment syndrome had already been established at presentation fasciotomy

preceded vascular repair and in cases that presented late prophylactic fasciotomy was done following vascular repair. In upper extremity; patients who had near total amputation and limb with critical vascularity were also attempted for salvage. Primary amputation decision was made for those extremities with mangled extremity severity score (MESS) of more than seven in lower limbs, patients with severely crushed extremity, established limb-threatening ischemia or compartment syndrome with nonviable muscle in the leg during surgery, and absent ankle or toe movement with absent pulse clinically. Venous injury was usually ligated. In some cases with near-total amputation of upper extremity primary repair was done. All repairs were evaluated for patency by use of Ultrasonography in the intraoperative period by operating surgeons and within 24 hours using Duplex Sonography. Systemic anticoagulation with unfractionated heparin (50-100 IU/Kg) was used to prevent thrombosis at the repair site. In isolated arterial repair low molecular weight heparin (Enoxaparin 60 mg subcutaneous twice daily or 1 mg/kg twice daily) and Aspirin (Tablet Aspirin 150 mg once daily) were used for Anticoagulation. A successful repair was defined as a patent vessel on Duplex scan and viable extremity at the time of discharge and during follow up at six weeks. All patients with extremity trauma with vascular injuries were included in this retrospective study. Patients with hand injuries distal to wrist and foot injuries distal to ankle were excluded in this study. Similarly, injuries proximal to Axilla and proximal to groin were also excluded from this study

RESULTS

One hundred and eighteen patients with vascular injuries were studied. Most of the patients were from local district 55 (46.6%), and 92 (77.9%) were males and 26 (22%) were females. Peak incidence was seen in 21-40 years age group with a mean age of 30.47 years (Table 1). Penetrating trauma was the commonest mechanism of injury with 61.8% of cases and was common in the upper extremity whereas blunt trauma was seen in 38.1% cases (Table 2).

Blunt trauma was common in Road traffic accident group (25.4%) followed by Injuries by fall in 10.1%. Commonest side involved was left side (50%). Isolated Ulnar artery injury was commonest and seen in 23.9% (Table 5). In lower extremity Popliteal artery injury was seen in 12 (10.1%) cases; out of which eight were due to Knee dislocation (Table 5).

Injury to both Anterior and Posterior Tibial artery were seen in 8.4% of cases. Most common type of vascular injury in our study was Transection (64.4%), followed by Contusion/ Intimal injury (12.7%), Partial Laceration (11%), segmental loss (7.6%), and Compression/Entrapment by bone ends (4.2%) (Table 3). End-to-end anastomosis was achieved in 50% of vessels and primary ligation was done in 36.4%. Autogenous reverse saphenous vein graft was used in 4.3% of arterial repair in lower extremity and cephalic and Basilic or forearm vein grafts were used in 5% of arterial reconstruction. Compression release was achieved in 4.2% of cases and direct repair of arterial wall was done in 11.1% of cases (Table: 4).

Table 1. Age Distribution

Age	n(%)
< 20 years	27 (22.8)
21-40 years	62 (52.5)
41-60 years	21 (17.7)
> 60 years	8 (6.7)
Total	118 (100)

Table 2. Mechanism of injury

Penetrating	n (%)
Physical Assault by sharp weapon	22(18.6)
Machinery	22(18.6)
Glass Cut	12 (10.1)
Sickle cut injury	9 (7.6)
Manual grass cutter	5 (4.2)
Suicidal cut injury	2 (1.6)
Axe injury	1 (0.84)
Total	73 (61.8)
Blunt Injury	
RTA	30(25.4)
Fall injury	12 (10.1)
Crushed by Stone	2 (1.6)
Blast	1 (0.84)
Total	45 (38.1)
Grand Total	118 (100%)

RTA= Road Traffic Accident

Table 3.

Type of injury	n (%)
Transection	76 (64.4)
Intimal injury	15 (12.7)
Partial Laceration	13 (11)
Segmental Loss	9 (7.62)
Compression	5 (4.23)
Total	118 (100)

Table 4.

Type of repair	n (%)
End to end anastomosis	59 (50)
Ligation	43 (36.4)
Compression release	5 (4.2)
Forearm Vein graft	6 (5)
Saphenous vein graft	5 (4.2)
Total	118 (100)

Table 5. **Artery, Nerve, and Bony Injury Distribution according to Extremity Involvement**

Artery Injury	n (%)	Nerve Injury	n (%)	Bony Injury	n (%)
Upper extremity					
Isolated Ulnar	28 (23.9%)	Isolated Ulnar	26 (22%)	Radius+ulna Fx	15 (12.7%)
Isolated Radial	18 (15.2%)	Isolated Median	19 (16.1%)	S/C Humerus Fx	12 (10.1%)
Radial + Ulnar both	19 (16.1%)	Ulnar + Median both	20 (16.9%)	Wrist Injuries	4 (3.3%)
Brachial	17 (14.4%)	Radial + Ulnar + Median	4 ((3.3%)		
Lower Extremity					
Popliteal	12 (10.1%)	Tibial + Peroneal both	14 (11.8%)	Tibia+Fibula Fx	14 (11.8%)
Anterior + Posterior Tibial both	10 (8.4%)	Tibial	2 (1.6%)	Knee Dislocation	8 (6.7%)
Isolated Anterior Tibial	6 (5%)	Peroneal	1 (0.84%)	Femur Fx	3 (2.5%)
Isolated Posterior Tibial	4 (3.3%)	Sciatic	1 (0.84%)		
Femoral	4 (3.3%)				
Total	118 (100%)		87 (73.7%)		56 (47.4%)
n= Number of cases, (%)= Percentage, S/C =Supracondylar , Fx= Fracture					

Associated injuries like bony injuries were seen in 47.4%, out of which Radius and Ulna fractures were common in upper extremity and Tibia Fibula fractures were common in lower extremity (Table 5). Associated nerve injuries were seen in 73.7% out of which Isolated Ulnar nerve injury (24.5%) was most common (Table 5). Tendon injuries were seen in 75 (63.5%) cases. Complications were seen in 43.2% and commonest was superficial infection seen in 17.7% (Table 6). In three (2.5%) patients where leg revascularization was achieved in more than 12 hours, sensory function recovered and motor function did not recover till the last follow up at nine months time. Primary amputation was done in 16.1% (Table 7). Dialysis was required in two patients with crush injuries and mortality was observed in a four-year-old child with accidental brachial artery injury with reperfusion injury.

Table 6. **Complications**

Superficial Infection	21(17.7%)
Haemorrhage	17(14.4%)
Deep infection	9 (7.6%)
Arterial thrombosis	4 (3.3%)
Total	51(43.2%)

Table 7. **Amputations**

Primary Amputations	**N (%)**
Unsalvageable (MESS >7)	9 (7.6)
Established Ischemia/	
Late presentation	6 (5)
Near total amputation	4 (3.3)
Total	19 (16.1)
Secondary Amputations	**N (%)**
Arterial Thrombosis	4 (3.3)
Deep infection	3 (2.5)
Total	7 (5.9)
MESS- Mangled Extremity severity score	

DISCUSSION

Peripheral vascular injuries after extremity trauma although rare, possess critical challenges in management in resource-limited settings of developing countries like Nepal. Vascular injuries account for 2%-3% of civilian trauma; this can reach up to 40% to 70% of all vascular injuries treated at civilian trauma centers.[7,8] In our study out of 4280 patients treated for extremity trauma at our center, 118 (2.9%) patients presented with vascular injuries. In our center, all cases were managed by orthopaedic surgeons having skills in vascular surgery. Schackford et al. observed that limb salvage after major peripheral vascular injuries was independent of surgeons Specialty training. Procedures performed by either orthopaedics or plastic surgeons were 2.8% in the study by Schackford et al.[9,10] Majority of cases in our study were 21-40 years of age with a mean age of 30.47 years. Similar finding has been reported by Silva et al. with a mean age of 31.2 years with 75% being less than 40 years.[7] Increased incidence in this age group can be explained by the fact that people in this age group are more active and are more prone to accidents. Injuries were seen more in Males (79.4%), as observed by other authors in their series.[2,5,7] Penetrating injuries were the most common mechanism of injury in our study and were seen more commonly in upper extremity trauma. Physical assault with sharp weapons, Machinery injuries, Glass cut injuries, accidental injury by sickle, and injuries by rotating manual grass cutter were associated with penetrating injuries. Cikrit et al. reported penetrating trauma as the leading cause of upper extremity vascular trauma.[11] Similar findings were also observed by Franz et al. and Wahlgren et al.[12,13] Most of the Blunt injuries were secondary to road traffic accidents and common in the lower extremity. Crush injuries, Open fractures, and knee dislocations were associated with Blunt injuries and were common in lower extremity. Most of the patients presented within 4-6 hours after injury and revascularization in an ischemic limb or limb with critical vascularity was achieved within 8 hours. Repair in a well-

perfused limb or ligation of single artery of forearm and leg or ligation during primary amputation was achieved within 12 hours. Pre hospital delay was seen in patients who were referred late from primary treating center and tortuous hilly roads of Nepal. Delay of 2-4 hours within the hospital was observed in our study. Delay within the hospital was mainly due to missed diagnosis at the emergency department, delayed decisions of patients and patient's attendants towards treatment procedures, and financial issues. For promising results, revascularization should be done within 6 to 8 hours of injury, which is within warm ischemia time, as muscles and nerves can tolerate ischemia for only 6-8 hours.[1] Physical assault by sharp weapons was common etiology in upper extremity penetrating trauma. Isolated Ulnar artery was most commonly injured in the upper extremity. Increased number of ulnar artery injuries in our study can be explained by the fact that; defensive reflex during fight (physical assault) the ulnar border of forearm is mostly exposed. Myers et al. also reported ulnar artery as the most common artery injury followed by radial artery in upper extremity penetrating trauma.[5] Anterior and Posterior tibial arteries injuries were common in lower extremity, followed by popliteal artery injuries. An Increase in leg arterial injuries can be due to blunt trauma with crush injuries, open fractures and dislocations; this is in par with the finding of Rozycki et al.[14] Transection of vessel wall (Fig. 1 a,b,c) was the commonest pattern of vascular injuries seen in our study accounting for 64.4%; which was due to increase number of penetrating trauma. Andreev et al. and Franz et al. also observed 78% and 43% of vessel wall transection respectively in their studies.[12,15] Intimal injuries/Contusions (12.7%) were mostly associated with blunt trauma and were more common in lower extremity. Feliciano et al. reported that Intimal defects with subintimal hematomas with possible secondary occlusion were most commonly associated with blunt trauma.[8]

End-to-end anastomosis (Fig. 1) was the common method used for arterial repair in 50% of cases. In most cases interrupted suture technique was used in end-to-end anastomosis, as surgeons were more comfortable with this technique.

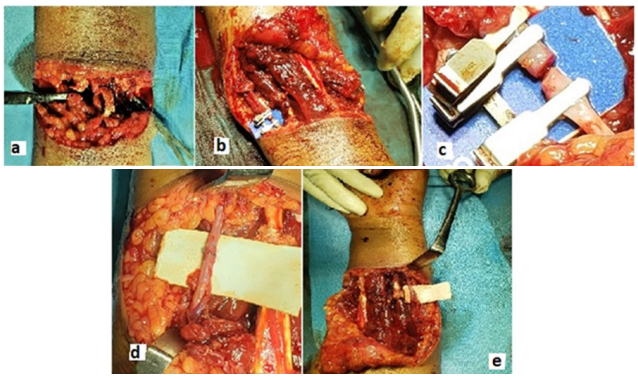

Figure 1. a. Cut injury left forearm with both Radial and ulnar artery injury (forceps), b,c. Radial artery repair using Acland clamp, d. Completion of end-to-end radial artery repair, e. Completion of ulnar artery repair

Feliciano et al. recommended end-to-end anastomosis using 6-0 or 7-0 polypropylene sutures in arteries less than 1 cm in diameter. Arteries more than 1 cm diameter can be anastamosed using an interrupted or continuous suture.[16] In our cases we have used 7-0 Polypropylene suture for radial, ulnar arteries, and Tibial arteries and 6-0 sutures for brachial and popliteal arteries. Whenever end-to-end anastomosis was not possible; an interposition vein graft was used to reconstruct arterial injuries (Fig. 2).

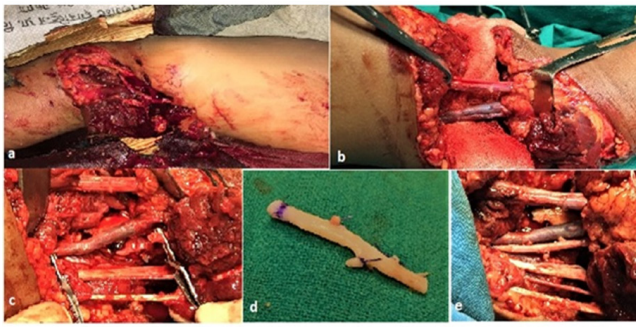

Figure 2. a. RTA with crush injury over popliteal fossa, b. Contusion of popliteal artery, c. Resection of contused segment, d. Saphenous vein, e. Repair with reverse saphenous vein graft.

Common vein grafts used in our series were forearm veins 6 (5.08%) and reverse saphenous vein graft 5 (4.23%) (Fig. 2 d). The use of vein graft in our study was less compared to other literature. Rozycki et al. reported 26 vein grafts to repair arterial injury in upper and lower extremity.[14] Similarly, Silva et al. also reported use of 39 interpositional vein grafts in their study.[7] Less use of interposition vein grafts in our study can be directly related to experience among surgeons in our center. Ligation was common after end-to-end anastomosis. Indication of ligation in our study was: Single artery injury of forearm and leg, both artery injury of forearm and leg with one artery ligation and repair of another artery and ligation of injured artery during amputation. Schippers et al. in their systematic review concluded that there is no clear benefit attempting repair of single vessel injury in forearms both artery injury. Furthermore, they found no significant difference in the patency of isolated radial or ulnar artery repairs and no significant difference in cold insensitivity in patients who underwent vessel ligation.[17] Ligation was also common in a study by Rozycki et al.[14] Although ligation was common in our center, attempt to repair injured artery was in utmost priority. Associated injuries like bony injuries (fractures and dislocation), nerve injuries, and tendon injuries were seen in our study which was managed accordingly. Bony injury fixation preceded vascular repair in our study. There is always an argument whether to fix bone or repair vascular injury first. A Meta-analysis by Fowler et al showed no statistical difference in regards to the incidence of amputation between lower extremity fixation before revascularization and/or revascularization before fracture fixation.[18] Fasciotomies were performed in cases with established compartment syndrome, who presented late and, prophylactic after vascular repair. Primary amputation

was indicated in 19 (16.10%) patients; mostly with mangled extremity due to blunt injury, with delayed presentation, with neurological deficit, with extensive soft tissue loss, with MESS more than seven, and with prolong ischemia time. In a retrospective review by Schlickewei et al showed major soft tissue injury and open fractures as predictors of amputation than ischemia time.[19] While other authors emphasized that vascular repair done within eight hours has less amputation rates than repairs done after eight hours.[1,20]

Complications like Haemorrhage, superficial infection, deep infections and arterial thrombosis were also seen in our series. Haemorrhage in the postoperative period was mainly due to leakage from the repair site and opening of thrombossed vessels. Those cases were immediately taken to the operating room and managed accordingly. Superficial and deep infections were managed by multiple debridement and antibiotics. Secondary amputation was required in deep infection and arterial thrombosis group (Table 7).

All limbs survived at follow-up. Functional outcome was dependent on the extent of soft tissue injury, peripheral nerve injury, bony injuries, and frequency of physiotherapy visits. Seekamp et al. in their study observed that functional recovery depended greatly on the social and economic resources available to the patient, which can be more of a factor than the severity of the initial injury.[21] Whatever functional outcome is predicted, effort should be made to restore and salvage the injured limb, as in country like Nepal physical integrity is much more important than function; which was seen in three of our patients who accepted functionless leg than going for amputation.

Limitation of our study include retrospective data collection from patients charts, which might be incomplete at times. Poor follow-up of patients can affect assessment of functional outcome and patency of vessel in long term.

CONCLUSION

Penetrating injuries were the most common injuries seen in our study with blunt injuries being common in lower extremity. Transection of vessel wall being common with end-to-end repair done by orthopedic surgeons was sufficient for the salvage of limbs irrespective of functional outcome. No time should be wasted on time-consuming Investigations. Rapid repair of the vascular injury saves ischemia time and minimizes devastating complications like limb loss. Amputations were common in lower extremity. Early diagnosis, prompt resuscitation, and timely intervention by primary surgeon irrespective of subspecialty training can save life and limb. In the context of Nepal; where availability of vascular surgeons outside the capital city is less, orthopaedic surgeons practicing trauma have to take up managing such injuries.

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