Management of Vascular Injuries in a Forward Hospital

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Abstract

Background : Management of vascular injuries poses a challenging problem under warlike conditions. Several authorities recommend limb revascularisation only within first 6-8 hours, as the outcome after delayed revascularisation is poor.

Methods. : A retrospective analysis of 61 consecutive patients with vascular injury in a forward hospital over a 25- month period was carried out.

Results : Vascular injuries constituted 3.1 % of all injuries. The mean injury to treatment delay (lag time) was 11 hours, and 10 patients received treatment after 12 hours. The overall amputation rate was 15%, but only 6.5% for those revascularised within 12 hours and 44% for those undergoing surgery after 12 hours (Chi-square 4.59, $p < 0.05$). Presence of associated fractures was associated with an adverse outcome (Chi-square 4.24, $p < 0.05$), as was ligation in comparison to revascularisation (Chi-square 7.86, $p < 0.005$). Popliteal injuries were associated with a high amputation rate.

Conclusions : Failure to revascularise (ligation of artery), presence of associated fracture, and restoration of circulation beyond 12 hours are associated with a high amputation rate.

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Key Words : Vascular injuries, trauma, amputation

Introduction

Vascular injuries remain a management challenge even at the turn of this century. Prompt arrest of haemorrhage and restoration of circulation by repair of the injured vessel is mandatory, if death or amputation is to be avoided. The shift from ligating an injured vessel to its primary repair resulted in corresponding fall in amputation rates from 50% in World War II to less than 2% in civilian injuries [1]. However patients continue to reach the hospital late with advanced features of ischaemia, especially during war. In addition, injuries to multiple organ systems (especially fractures and nerve injuries) are common, requiring prioritisation for treatment. Operations are performed under suboptimal conditions, often by surgeons not trained in this field. We present our experience of management of vascular injuries in a forward hospital over a 25-month period.

Patients and Methods

This forward zonal hospital located in the Northern region of the country, has been treating casualties since the onset of insurgency in this area 17 years ago. These experiences and management protocols have been standardised and reported elsewhere [2-4]. The management of vascular injuries during a 25-month period in late nineties forms the basis of this report.

Vascular injury was suspected if distal arterial pulsations were absent, there were signs of local ischemia, pulsatile haemorrhage, local bruit or an expanding haematoma. They were also deliberately sought to be excluded in trauma patients with unexplained hypotension. The patients were examined and a hand-held portable doppler instrument used to evaluate the arterial flow and to calculate arterial pressure in the injured limb. In suspected extremity vascular injury a difference of more than 20 mm Hg between the injured and contralateral limb was taken as significant [5].

The patients were resuscitated aggressively, antibiotic and antitetanus prophylaxis given, and taken to the operation theatre for surgery. Repair of the arterial or venous injury was attempted in all cases. Wide exposure and repair of the injured vessel was done by standard vascular techniques (lateral arteriorrhaphy, end-to-end anastomosis or interposition grafts using reversed saphenous vein or expanded PTFE). Venous injuries were repaired wherever feasible, but complicated time consuming venous repairs were avoided and the veins were simply ligated. The repaired vessels were covered by muscles. The wounds were debrided, and the skin left open, if the wounds were grossly contaminated. Intra-operative heparin was administered and continued post-operatively for a variable period. Fasciotomy was performed in all cases where the time from injury to repair exceeded 8 hours, or if concomitant soft tissue injuries were present. Associated fractures were stabilised by external fixation, tibial pin traction,

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or by plaster of paris (POP) casts. The patients were mostly transferred to a larger centre after few days, due to administrative reasons.

Analysis of outcome (mortality, and limb salvage in case of extremity vascular injuries) was done using the following four measures: lag time (interval between injury to revascularisation), presence of associated fractures, arterial repair versus ligation, and location of extremity vascular injury (popliteal artery versus remaining extremity arterial injuries).

Results

A total of 61 patients were treated for vascular injury (incidence 3.1% of all injuries). The age group ranged from 19-46 years with a mean age of 28 years. The injuring agent was bullet in 21 patients, splinters in 34, blast injuries in four, and blunt trauma in two cases. There were three neck injuries, four thoracic injuries, 13 abdominal injuries, and 41 extremity vascular injury cases. The location of these injuries is listed in Table 1. Associated limb fractures were present in 15 patients. Additional injuries were present in 41 out of 61 patients.

Most of the patients with extremity vascular injury had either arterial or concomitant arterial and venous injuries. Two patients had venous injury alone (Table 2). The type of arterial injury detected at operation, is mentioned in Table 3.

Majority of patients with extremity vascular injury were received several hours after injury (Table 4). Only nine patients (out of 41) were revascularised within the "golden period" of six hours.

Arterial repairs were carried out in 35 out of 39 patients of extremity vascular injury; and artery was ligated in the other four cases. A variety of vascular repairs were performed (Table

Table 1
Anatomical location of vascular injury

Location of Injury	Number
Head and Neck	3
Common carotid artery	1
Internal carotid artery	1
Internal jugular vein	1
Thoracic vascular injuries	4
Hilar injuries	2
Intercostal injuries	2
Abdominal vascular injuries	13
Abdominal aorta	1
IVC injuries	3
Mesenteric artery injuries	5
Renal pedicle injuries	4
Upper Limb	14
Subclavian	2
Axillary	1
Brachial	11
Lower Limb	27
Femoral	15
Popliteal	10
Crural	2
Total	61

5). Two patients with venous injury alone had an injury to common / superficial femoral vein which was repaired by lateral venorrhaphy. 16 patients had additional venous injuries, and most of these were repaired.

Of the patients with vascular injury in the neck, one patient (with internal carotid artery injury) was not operated as he presented with massive, dense hemiplegia and the remaining two were successfully repaired. Vascular injuries were found at thoracotomy in four cases where bleeding intercostal arteries were ligated (two patients), and a pneumonectomy / segmental resection was done in one case each. Of the abdominal vascular injuries, the great vessel (aorta/inferior vena cava (IVC)/portal vein) injuries were repaired. Bleeding

Table 2
Nature of vascular injury in limb injuries

Nature of Injury	Number
Arterial injury alone	23
Combined arterial and venous injury	16
Venous injury alone	2
Total	41

Table 3
Type of arterial injury in extremity injury

Type of arterial injury	Number
Complete transection	28
Partial tear	5
Puncture wound	3
Arterio-venous fistula	3
Total	39

Note: Two patient had only venous injury

Table 4
Interval between extremity vascular injury and repair

Time Interval	Number of patients
Less than 6 hours	9
6-12 hours	22
12-24 hours	8
More than 24 hours	2
Total	41

Table 5
Nature of arterial repairs in extremity injuries

Arterial repair	Number
Lateral arteriorrhaphy	3
End-to-end anastomosis	6
Repair AV Fistula	3
Synthetic interposition graft	20
Venous interposition graft	3
Arterial ligation	4
Total	39

Note: 2 patients had venous injuries alone. 16 patients had concomitant venous injury. Of these 18 venous injuries, 13 were repaired; remaining 5 were treated with ligation.

mesenteric vessels were ligated, observing the intestinal segment for viability. The segment was excised and end-to-end intestinal anastomosis done in case the intestinal viability was suspect. Nephrectomy was performed for four renal pedicle injuries.

Outcome

Four patients died (Table 6). The patient with internal carotid artery injury had a massive ipsilateral cerebral infarct, to which he succumbed. One patient developed crush syndrome and renal failure following successful revascularisation. Two patients with abdominal vascular injuries died of refractory shock despite successful repair of injuries. Six out of 41 patients with extremity vascular injury required a major amputation.

The analysis of outcome of limb salvage in terms of lag time (interval between injury to revascularisation), presence of associated fractures, arterial repair versus ligation, and location of extremity vascular injury (popliteal artery versus remaining extremity arterial injuries) is as follows. Of the 41 patients, circulation could be restored within 12 hours in 31 patients, and of these only two required an amputation. In 10 patients where the lag time exceeded 12 hours, four patients required amputation. This difference was statistically significant (Chi square 4.59; $p < 0.05$).

Amongst the patients who had a fracture, five out of 15 eventually required an amputation, whereas of the 26 who did not have a fracture, only one patient required amputation. This difference was also statistically significant (Chi square 4.24; $p < 0.05$).

Of the 37 patients where vascular repair was undertaken, only three required an amputation. In contrast, when arterial ligation was done, three out of four patients underwent amputation. This difference was statistically significant (Chi square 7.85; $p < 0.001$).

In this series, of the 10 patients with popliteal artery injury three underwent amputation (30% amputation rate), whereas of the 31 patients with injury to other extremity arteries, only three required amputation (10% amputation rate). This was not significant on statistical analysis (Chi square 1.05, $p = 0.15$).

Discussion

Vascular injuries are common during war and they constitute 2-5% of all injuries [6]. 61 cases of vascular injury in the present series constituted 3.1% of all injuries, similar to other reports in literature. In armed conflicts, vascular injury to extremities constitute almost 80-90%

of all vascular injuries [7-9], however they constituted 67% in this series (Table 7).

The diagnosis of major vascular injury is usually evident by the so-called 'hard signs': pulsatile external bleeding, rapidly expanding haematoma, absent distal pulse, bruit over the artery, or an ischaemic limb [10]. In a patient with such overt signs no special investigation is required, and the patient can be directly wheeled into the operation theatre after recording the doppler pressures [11,12]. Colour doppler imaging has been reported as an investigative modality in stable patients [13], with some authors suggesting this to be the imaging modality of choice [14]. This investigative modality was not available at our hospital. The role of arteriography is controversial and it has been advocated in patients with 'soft signs' of arterial injury [15], or when the diagnosis of arterial injury is in doubt [14]. Others have maintained that careful physical examination and recording of ankle arterial pressures are adequate for diagnosis, and angiography is rarely indicated [16].

Repair of an injured artery must always be attempted as, ligating the vessel carries an amputation rate of 50%, as seen in World War II [7]. This incidence decreased to less than 10% during the Vietnam War [17] where a policy of repair of arteries was followed. A variety of techniques are available for repairing the injured artery [6]. These include simple suture, lateral arteriorrhaphy, patch angioplasty, end-to-end anastomosis and interposition by a synthetic (Dacron/PTFE) or venous graft [18]. The nature of arterial injury largely determines the modality of repair. We employed most of these techniques in our cases. There is some controversy as to the use of prosthetic bypass grafts in an emergency situation as they are theoretically more prone to infection and the patency rates of venous bypass grafts are better. However some series have reported a reduced incidence of infection with prosthetic grafts, and a patency rate comparable to venous grafts [1]. The use of PTFE vascular grafts has been reported in wartime vascular injuries also [19]. We did not face any infection in the synthetic grafts used and their short term patency rates appears to be good. Concomitant venous

Table 6
Cause of death

Cause of death	Number
Massive cerebral infarction	1
Renal failure	1
Refractory hypovolemic shock	2
Total	4

Table 7
Incidence of extremity vascular injury

Conflict (ref)	Author	Year	Total vascular injuries	Extremity vascular injury
WW I (7)	Maakins	1922	1202	87%
WW II (8)	DeBaKey	1946	2471	96%
Korean (9)	Hughes	1958	324	94%
Vietnam (17)	Rich	1970	1377	91%
Afghan (31)	Gosselin	1993	23	89%
Indian	Rai	2006	61	67%

injuries should be repaired, as limb salvage rates are better [20]. We repaired 11 concomitant and two primary venous injuries and in five cases the veins injured were minor and these were ligated.

The role of arterial ligation in cases of vascular injury is limited. Isolated injury to a single forearm vessel can be treated with ligation without any adverse effects [11]. The chances of gangrene developing after superficial femoral artery or brachial artery ligation in the arm are low, since the profunda branch is adequate to maintain distal circulation in these instances [1]. Arterial ligation is occasionally indicated in a haemodynamically unstable patient with severe blood loss who may not withstand the stress of a long operation under anaesthesia. In all other situations repair of arterial injury is mandatory.

The mortality rate was 6.1% in our series (4 out of 61 patients). One patient had internal carotid artery splinter injury with massive ipsilateral cerebral infarction. He was deeply comatose on arrival with a Glasgow Coma Scale score of 3/15. In consultation with the neurosurgeon, it was felt that repair of artery and revascularisation would not achieve anything. Despite conservative measures he expired within 24 hours. The second patient had injury to femoral artery and vein, and he reported after more than 24 hours of injury. Arterial repair had been attempted in a field medical unit the previous day. On arrival, he had features of advanced limb ischemia; the limb was however judged to be potentially salvageable, and arterial and venous repair was done. Despite all measures to prevent crush syndrome (hydration, mannitol, lasix and sodium bicarbonate prior to declamping), the patient developed acute renal failure. He was subsequently air evacuated to Army Hospital (R&R), for emergency dialysis, but succumbed on the fourth postoperative day. Two patients with abdominal vascular injuries died of refractory shock despite control of haemorrhage and all supportive measures. Probably the initial hypovolaemic insult was prolonged and had led to irreversibility. The overall 6.1% mortality rate in our series is similar to that reported by other authors in military vascular injuries [9, 17].

Our follow-up is limited, as majority of the patients were transferred to other hospitals for administrative reasons. We are aware that six patients eventually required a major amputation- three of these had popliteal artery injury and one each subclavian, femoral and crural artery injury. All these patients had associated fractures and soft tissue injuries.

Limb salvage in trauma depends on several factors including extent of associated injuries, and time interval to revascularisation. Associated fractures should be stabilised by external fixation. If this facility is not available, skeletal traction (calcaneal/tibial/femoral) or

immobilisation by POP cast may be employed. Associated limb fracture and soft tissue injuries are known to be associated with a poor eventual outcome [18]. In this study amputation rate was 33% if associated fracture was present and only 4% if there was no associated limb fracture. The bony and soft tissue injury seems to contribute to the eventual outcome even after successful restoration of circulation [1, 21].

A mangled extremity score has been devised to predict outcome after limb polytrauma [21]. Primary amputation is recommended if this score is high, or the limb is irreversibly ischaemic or gangrenous. Poor predictors of limb salvage are delayed revascularisation (beyond 6-8 hours), presence of associated fractures, arterial ligation and location of injury (popliteal). Amputation rate of 15% in our study (Table 8) may appear higher than other reported series [9,16,17,22-26]. However, a careful analysis in relation to lag time shows that for a relatively high mean lag interval of 11.3 hours, an amputation rate of only 15% appears reasonable [9,19].

We attempted limb salvage irrespective of the elapsed time. Amputation rate was low (2 out of 31) when circulation could be restored within 12 hours, and high (4 out of 10) if the period exceeded 12 hours. The point to note is that even in the latter category, the limb salvage was 60%. The policy of aggressive arterial repair irrespective of time lag therefore seems to be justified unless the features of irreversible ischemia have set in [18, 24]. We feel that liberal use of fasciotomy and intra-operative anticoagulation has contributed towards our high limb salvage rates [27].

Successful vascular repair considerably decreases the chances of amputation. This was clearly demonstrated in the present study where only three patients out of 37 ultimately required amputation after vascular repair (all three had associated fracture and

Table 8
Amputation rates in extremity vascular injuries

Conflict (ref)	Patients	Lag time (hours)	Amputation Rate
World War II (7)	2471	15.2	49.3
Korean (8)	1964	9.2	13%
Vietnam (9)	1000	< 5	11%
Israeli (23)	51	Minimal	< 2%
Ireland	192	< 4	5.1%
Lebanon (24)	1008	< 3	5%
Cambodia	?	8.3	23.1%
Afghan (22)	23	34	65%
Croatia (25)	50	4.6	3.8%
Iraq (US Cas) (26)	107	Variable	9.3%*
India	41	11.3	15%

* 21 patients had a primary amputation, and are excluded from analysis. 8 patients underwent amputation after vascular repair.

soft tissue injury, and came after 12 hours). In contrast, the amputation rate was 75% (3 out of 4) when arterial ligation was resorted to. Vascular repair is therefore strongly recommended in preference to ligation. The amputation rate has fallen from almost 50% [8] to less than 2% [1, 27] in recent years because of this approach.

Popliteal artery injuries are said to be associated with poor outcome [28]. The amputation rate for popliteal artery injury in our series was 30%, in contrast to an amputation rate of 9% when the injury was to any other artery. Though this difference was not statistically significant, the contrast is obvious. Others have argued that popliteal injuries are no different from other injuries [29].

A comment regarding feasibility of arterial repair in a forward surgical centre (FSC). Failed revascularisation carries a high risk of amputation, and in one study the most significant independent risk factor for limb loss was failed revascularisation [30]. Vascular repair requires good illumination, fine suture material, atraumatic clamps, and Fogarty catheters etc. for the repair to succeed and none of these are usually available in a battle-zone forward medical unit. The only patient with extremity arterial injury who died in this series had an arterial repair in an FSC. The repair did not work, and patient underwent redo surgery for restoration of circulation. The delay in evacuation of patient (due to surgery which lasted for five hours, and associated with a fair amount of blood loss) led to acute renal failure that ultimately led to his death. When a surgeon or medical officer is faced with a patient with vascular injury in forward location, he should only control the haemorrhage, and not attempt definitive vascular repair. If limb viability is suspect, he can use temporary indwelling shunts to maintain circulation [31,32]. These can be improvised from ordinary intravenous tubing or feeding tube under field conditions.

Vascular injuries can be successfully repaired in a forward zonal hospital, provided the equipment and expertise is available. Speedy evacuation and early definitive repair surgery gives better results than ligation.

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