Treatment of vascular injuries associated with limb fractures

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ABSTRACT

INTRODUCTION The goal of therapy in all patients with combined orthopaedic and vascular injuries of the extremities is salvage of a functional limb. In this study, we have evaluated our experience with a subset of patients who had a combination of vascular injury and limb fracture.

PATIENTS AND METHODS The records of 192 patients with vascular injuries of the lower and upper limbs associated with bone fractures were reviewed. Of these, 168 were males and 24 were females; the mean age was 26 years.

RESULTS The mechanism of injury was a penetrating wound in 97 (51%) patients and blunt trauma in 95 (49%) patients. Injured vessels included 6 subclavian/axillary, 39 brachial, 14 radial/ulnar, 11 radial, 8 ulnar, 36 femoral, 43 popliteal, 35 tibial arteries. Saphenous vein graft was the most common conduit of choice in arterial repair (55%). Amputations were needed for 20 patients. The limb salvage rate was 88%. Three patients died.

CONCLUSIONS This study established that delay in surgery, blunt trauma and extensive soft tissue defect in combined orthopaedic and vascular injuries are associated with increased risk of amputation.

KEYWORDS

Vascular trauma – Limb fracture

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Fractures with arterial injury requiring vascular repair are severe injuries. This type of fracture is often associated with severe soft-tissue compromise and damage of neurological structures.^{1–3} Amputation rates after these injuries vary widely depending in large part on the degree of skeletal and soft tissue destruction. Amputation rates as low as 4% have been reported with isolated arterial injuries, although rates as high as 61% have been seen when combined vascular, skeletal, and soft tissue injuries are present.^{4–6}

In this study, we have evaluated our experience with a subset of patients who had a combination of vascular injury and limb fracture.

Patients and Methods

Between 1985 and 2002, we treated 192 patients with limb fractures and concomitant vascular injury. The records from these 192 cases were retrospectively reviewed. Data including mechanism of injury, location and severity of vascular and orthopaedic injuries, methods of vascular and

orthopaedic repair, and amputation rates were collected. Primary amputations are excluded in this study.

There were 168 men and 24 women. The mean age was 26 years (range, 3–65 years).

Upon arrival, an initial injury assessment was performed, life-threatening injuries treated, and fluid resuscitation was started. Following stabilisation, a focused extremity examination was performed. The presence of pulses in the extremities was determined by palpation. If pulses were absent, arterial Doppler signals were assessed in the emergency room using a hand-held Doppler instrument. Orthopaedic consultation was obtained for all patients. Bone injuries were classified as either open or closed and by the number of bones fractured based on physical examination and radiological studies. Open fractures were further classified according to the grading system of Gustilo *et al.*⁵ All orthopaedic injuries were stabilised in the emergency room with external splints.

Pre-operative arteriograms were used in patients in whom an arterial injury was suspected by physical findings

Figure 1 Axillary artery injury with humerus fracture after traffic accident.

but in whom critical ischaemia was not present. It was also used in patients in whom the presence of arterial injury could not readily be assessed, or when surgical exploration was difficult. It was performed by femoral puncture in the emergency room. For upper limb injuries, the indication for angiography was broadened since the excellent collateral circulation around the shoulder and elbow can often maintain pulses and a good Doppler flow.

Vascular injuries were managed by end-to-end anastomosis, interposition graft procedures, thrombectomy, or simple ligation. Ligation was reserved for those single-vessel tibial artery and radial/ulnar artery injuries. However, we preferred arterial repair whenever possible for all patients. Arterial repair preceded orthopaedic repair in stable fractures. Orthopaedic injuries were managed with either closed reduction, open reduction and internal fixation, or external fixation devices. For a neurological injury, we preferred primary repair if the wound was not contaminated. If the nerve could not be repaired, we preferred delayed repair at 2–3 weeks, only tagging the nerve ends in the acute stage.

Figure 2 Shotgun injury of popliteal artery with femur fracture.

Figure 3 Tibial arteries injuries with tibial fractures due to fall from a height.

Table 1 Localisation of arterial injuries and method of repair in vascular injuries

Artery	Patients	Primary repair	Vein graft	Ligation	Thrombectomy	PTFE graft	Total vessels repaired
Axillary/subclavian	6	2	3	–	–	1	6
Brachial	39	18	21	–	–	–	39
Radial/ulnar	14	20	6	2	–	–	28
Radial	11	8	1	2	–	–	11
Ulnar	8	7	–	1	–	–	8
Femoral	36	4	29	–	1	2	36
Popliteal	43	6	30	–	7	–	43
Anterior tibial/posterior tibial	19	4	21	5	8	–	36
Anterior tibial	3	1	2	–	–	–	3
Posterior tibial	13	1	10	1	1	–	13
Total	192	71	123	11	17	3	225

Four peroneal artery injuries were repaired by ligation.

Table 2 Skeletal and arterial injuries in upper extremity

	Proximal humerus	Humerus shaft	Supracondylar humerus	Radius	Ulna
Axillary/subclavian	4	2	–	–	–
Brachial	4	13	22	3	3
Radial/ulnar	–	–	–	27	22

Table 3 Skeletal and arterial injuries in lower extremity

	Proximal femur	Femur shaft	Distal femur	Proximal tibia	Tibial shaft	Distal tibia	Knee dislocation
Femoral	9	26	1	–	–	–	–
Popliteal	–	1	16	25	–	–	5
Tibial	–	–	–	16	15	8	–

Table 4 Skeletal injuries and treatment methods

Localisation	Number	External fixation	ORIF	Plaster + Min O	Plaster cast
Femur fracture	53	26	16	5	6
Tibia fracture	64	33	17	10	4
Humerus fracture	45	11	9	12	13
Radius fracture	27	4	6	7	10
Ulna fracture	22	2	5	5	10
Knee dislocation	5	–	–	–	5

Table 5 Mechanism of injury, associated injuries and outcome

Artery	Blunt trauma (n)	Penetrating trauma (n)	Open fracture (n)	Grade III open fracture (n)	Severe ischaemia (n)	Venous injury (n)	Nerve injury (n)	Extensive soft tissue defect (n)	Fasciotomy (n)	Amputation (n)	Mortality n, (%)
Upper extremity	44	34	47	33	8	28	43	11	6	2	–
Subclavian/axillary	2	4	5	4	2	4	5	–	2	–	–
Brachial	25	14	22	18	5	24	14	6	4	2	–
Radial/ulnar	17	16	20	11	1	–	24	5	–	–	–
Lower extremity	51	63	77	42	15	45	31	22	26	18	3,(2.6)
Femoral	16	20	24	6	2	24	3	5	4	3	2,(6)
Popliteal	19	24	24	22	9	21	5	6	11	9	1,(2)
Tibial	16	19	29	14	5	–	23	11	11	6	–

Results

Seventy-eight patients had upper limb fractures with concomitant vascular injuries. Arteriography, was performed in 3% of cases (two patients) in upper extremities (Fig. 1). Primary nerve and tendon repair were performed on 15 (34%) and 19 (86%) upper limbs, respectively.

One hundred and fourteen patients had lower limb fractures with concomitant vascular injuries. Angiography was performed on 21 (18%) patients in lower limbs (Figs 2 and 3). Primary nerve repair was performed on three lower limbs. Three of our cases died due to hypovolaemic shock, crush syndrome and head trauma.

The sites and treatment of arterial and skeletal injuries are shown in Tables 1–4, respectively. Mechanism of injury, associated injuries, outcome and remote injuries are summarised in Tables 5 and 6, respectively.

Amputation was not performed on any of the patients with subclavian/axillary and radial/ulnar artery injuries. In two patients with brachial artery injury (3%), forearm amputation was required owing to a combination of overwhelming gangrene and sepsis. Blunt trauma was the mechanism, leading to upper limb amputation. In all amputations, there was extensive soft-tissue defect and nerve injury.

Three patients with femoral artery injuries (8%) underwent amputation. Three of these patients had extensive soft tissue defect. In addition, one had severe ischaemia. The amputation level was above the knee in all cases.

Nine patients with popliteal artery injuries (21%) underwent amputation. The amputation level was above the knee in five cases, below the knee in three cases and through the Lisfranc joint in one case. Five (56%) of these cases were late referrals (9–96 h). The lesion resulted from blunt trauma in six patients (67%), and penetrating trauma in three patients (33%).

Patients with tibial artery injuries were categorised according to the number of vessels injured (tibialis anterior, posterior and peroneal). The amputation rate for patients with single vessel injury was 15% (2 patients). These patients suffered an associated, extensive soft tissue defect and infection. A 20% (three patients) amputation rate was observed for patients with two vessel injuries. Of these patients, two were admitted 8 h after their injury (8 h and 96 h) and one had crush injury. Four patients (11%) had three vessel injuries; one of these patients (25%) ended in amputation despite efforts to salvage the limb. There was an extensive soft tissue defect in this patient.

Discussion

Vascular repair should be carried out before bone stabilisation in order to decrease duration of ischaemia.⁷ We preferred to do primary vascular repair in priority cases involving stable fractures. We checked whether damage to the vascular structure existed after bone fixation; however, with an unstable bone fracture, we performed bone fixation prior to vascular repair. In tibial artery injuries, bone fixation was usually performed before vascular repair

Table 6 Remote associated injuries

	Upper extremity	Lower extremity
Head	1	5
Thorax	3	4
Abdomen	1	6
Other major vascular	–	1
Total	5	16

because of unstable fractures. In our series, external fixation has been increasingly preferred in the last few years. The advantages include requiring less operative time for immobilisation, less tissue destruction, less potential for infection in contaminated wounds, and allowing daily debridement and irrigation of the wound in cases of severe soft-tissue injury.

Early application of systemic anticoagulant therapy (heparin, 100 U/kg i.v.) reduces amputation rates. This prevents thrombosis in the microcirculation.^{1,8} In our cases, the anticoagulant treatment was initiated in the emergency room if systemic anticoagulation was not contra-indicated (active haemorrhage, coagulopathy, and craniocerebral injury).

Repair of concomitant venous injuries is recommended, as this may help in keeping the arterial repair open and prevent postoperative oedema.⁹ We repaired proximal limb vein injuries. This includes the axillary vein and mostly brachial vein injuries in the arm and the popliteal or more proximal vein injuries of the lower limb. We especially preferred venous repair in patients with massive soft-tissue injuries. Ligation was performed mainly for tibial vein injuries in the leg and for some brachial vein injuries or more distal vein injuries in the arm. Simple repairs were preferable to complex interposition grafts.

The treatment of vascular trauma also requires appropriate management of soft-tissue injury.¹⁰ The majority of our patients with soft-tissue defects required split-thickness skin grafts for final coverage. Multiple debridements were required to control infection in several of our patients with extensive soft-tissue injury. We generally tried to protect the bypass from direct contamination by placing it deep to viable muscle or in uninvolved subcutaneous tunnels. Early graft infection is usually related to exposure due to local soft tissue insufficiency or osteomyelitis.^{11,12}

The use of fasciotomy is particularly important in vascular injuries associated with orthopaedic trauma. This is because the factors of soft tissue trauma, crush injury, and venous injury or occlusion combine to increase the risk of compartment syndrome when compared with vascular injuries and ischaemia-reperfusion alone.^{7,15} In our clinic, a total of 32 (17%) cases complaining of compartment syndrome underwent fasciotomy that was performed after vascular repair. Such cases are given mannitol (500 ml/day, 20% mannitol) prior to reperfusion and until postoperative day 1, in order to reduce tissue oedema and increase urine volume. In addition, systemic anticoagulant therapy with heparin for 3 days, low-molecular weight dextran at 500 ml/day and pentoxifyllin at 300 mg/day are given.

In comparison with a previous study in our clinic, the amputation rate was diminished with liberal and early use of fasciotomy, early coverage of soft-tissue defects, aggressive

debridement of devitalised tissue, and repair of all major venous injuries in latter years.³ Limbs were salvaged in 169 patients (88%; upper and lower extremities considered together). Of these, 42 patients (25%) complained of chronic sensory or motor defects, 20 (12%) had persistent infection (osteomyelitis) with non-uniting fractures, and two (8%) had causalgia. The chronic morbidity for these patients during follow-up was 45%.

Conclusions

Result show that delay in surgery, blunt trauma and extensive soft tissue defect in combined orthopaedic and vascular injuries are associated with increased risk of amputation. Upon evaluating the literature data and the results obtained from our cases, it is concluded that the use of systemic anticoagulants, decreasing the severity of ischaemia by fasciotomy, not wasting time with pre-operative diagnostic tests, performing vascular repair before orthopaedic repair in delayed cases and pre-operative and postoperative debridement of necrotic tissue, decreases the risk of amputation.

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