Management of Combined Vascular-Orthopedic Limb Injuries

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Abstract

Background
Vascular injuries combined with fractures and/or dislocations are associated with a high rate of limb amputation. The aim of this prospective study conducted in Ghazi Al-Hariri Surgical Hospital, Baghdad, Iraq was to assess the surgical management of these injuries in this tertiary center.

Methodology
Over 7 months (16 October 2014 to 16 May 2015), 30 males with arterial and orthopedic limb injuries were studied. Clinical diagnosis was aided by routine hand-held Doppler examination and limb radiographs. Gustilo type III C fractures were operated upon by vascular and orthopedic surgeons. The fractures were mainly fixed by external devices while injured vessels were repaired via standard techniques.

Results
The age ranged between 3 and 58 years with a mean of 30±11.7. Almost all patients exhibited symptoms and signs of distal extremity ischemia. All patients except 3 had penetrating injuries. The most common arterial injuries were the brachial (n=6)) and the popliteal (n=8) whereas the most common bony injuries were the humeral (n=6) and femoral fractures (n=12). Nerve injuries were observed on 12 occasions. Most arterial injuries were repaired by end to end anastomosis (n=16) while saphenous vein grafting was performed 9 times. Seven leg or forearm arteries were ligated. All venous injuries (n=21) except 3 were ligated with good outcome**.** Most fractures were managed by external fixation (n=25; 83.3%). Three patients (10%) had secondary amputations. Limb salvage was (n=27; 90%).

Conclusions
Our limb salvage was very good when compared to the published literature. Team approach, liberal exploration, early fasciotomy and meticulous technique are emphasized.

Key Words
Vascular injuries, fractures, dislocations, extremities, limb salvage, amputation.

Introduction

Peripheral vascular injuries associated with limb fractures are severe yet uncommon, with a reported incidence of less than 3% [1]. The reported amputation rate following isolated limb arterial injuries is 4%. In contrast, combined vascular, skeletal and soft tissue limb injuries are associated with amputation rate as high as 61% [2].

Extremity vascular injuries have been documented during episodes of armed conflict as far back as the Greek and Roman civilizations and undoubtedly occurred before those eras [3]. DeBakey and Simeone calculated the amputation rate from vascular injuries in World War II as greater than 40% [3]. With the advances of surgical science, the amputation rate from vascular injury in the Korean and Vietnam Wars dropped to approximately 15% [3].

The clinical diagnosis of peripheral vascular trauma in an injured extremity is classically associated with a diligent search for "hard" and "soft" signs. "Hard" signs are an absolute indication for vascular exploration, whereas "soft" signs are an indication for angiography or sonography to rule out an injury [4].

The ankle-brachial index (ABI) is a very reliable screening modality for significant arterial obstruction following both blunt and penetrating trauma. The hand-held Doppler is also useful in assessing severity of ischemia by determining presence of an arterial and venous Doppler signal. Duplex scanning is a reliable screening tool for peripheral vascular trauma, with an accuracy rate of around 98% in detecting clinically significant injuries [4]. However, arteriography remains the gold standard in the diagnosis of extremity vascular injuries [4].

The management of extremity trauma is a team effort, involving aspects of vascular, orthopedic, and plastic surgery. Thus, the extent and sequencing of the vascular, orthopedic, and plastic procedures should be carefully planned and orchestrated [4].

Orthopedic injuries are managed with closed reduction, open reduction and internal fixation, or external fixation devices. External fixation has been increasingly preferred in the last few years [2].

Fascial compartments in extremities with extensive bone and soft tissue damage may contain a significant amount of edema and hematoma, indirectly compromising uninjured vessels and further impeding blood flow [1]. Maintaining a very low threshold for fasciotomy in injured limbs is always in the patient's best interest [4].

In severe traumatic injuries to the extremities, it is often a difficult decision to attempt heroic efforts aimed at limb salvage or to amputate primarily [1]. Despite several attempts to develop objective criteria, severity scales, and indications for primary amputation, this remains very much a matter of judgment [4].

One study evaluated the epidemiology of vascular injury in the wars of Iraq and Afghanistan using data from The Joint Theater Trauma Registry. It found that the rate of vascular injury in these modern battles was 5 times higher than in previous wars [3].

The aim of this prospective study was to evaluate the management of extremity vascular injuries associated with fractures and/or dislocations in a tertiary surgical center in Iraq with reference to the published literature.

Methodology

Over a 7 month period (16 October 2014 to 16 May 2015), 30 male patients with arterial and orthopedic limb injuries were prospectively studied. A thorough clinical assessment of every patient was performed. The diagnosis was made mainly on a clinical basis. Preoperative hand-held Doppler examination was routinely performed, while angiography was reserved for hemodynamically stable patients with a doubtful diagnosis provided no further delay was incurred. Fractures were radiographically confirmed and initially immobilized by plaster of Paris. Gustilo type III C fractures were elected for surgery. Adequate cross-matched blood was prepared. All acute injuries were initially treated with local hemostasis, intravenous fluid, blood transfusion, tetanus prophylaxis and antibiotic therapy followed by urgent exploration under general anesthesiavia standard incisions. The chronic cases were operated upon electively. Definitive management was carried out in collaboration with the orthopedic surgeon. The sequence of repair (vessel or bone first) was based on individual case circumstances; vascular repair proceeded fracture management in subacute or chronic cases; otherwise, fracture stabilization proceeded first. The fractures were mainly fixed by external devices. In regard to arterial repair, standard methods were followed. The type of repair included lateral arteriorrhaphy, end to end anastomosis, interposition venous grafts and occasionally ligation. Associated venous injuries were repaired when feasible, otherwise they were ligated. Fasciotomies were performed when indicated. The wounds were only partially closed unless they were very clean cases. Postoperative care involved close observation of limb viability. Patients were discharged once they were stable, usually within a week. Late follow-up was performed via visits to the consultation clinics or phone calls to patients living remote from the hospital. In this study, limb salvage was defined as the number of patients with functional viable limbs following vascular repair and fracture management. Amputation performed prior to vascular repair was considered primary. Any amputation performed after an attempt at vascular repair was considered secondary..Statistical Analysis was performed using Z Test for 2 population proportions and Student T-Test for 2 independent means.

Results

All patients were males. The age ranged between 3 and 58 years with a mean of 30±11.7 years. The majority were young people (83.3% under the age of 40) **(Table 1).** Almost all patients exhibited symptoms and signs of distal extremity ischemia (6 Ps) with clinical features of fractures and/or dislocations. One patient had a pulsatile swelling in the thigh with a viable lower limb. (He was a man of 24 with a false aneurysm of SFA associated with fractured tibia and fibula following multiple shell injuries 1 month earlier. The fracture was already immobilized by external device while the aneurysm was initially overlooked. Aneurysmectomy and arterial end to end anastomosis was performed with an uneventful recovery). External bleeding was noted in 24 patients (80%) whereas the remaining 6 patients (20%) had arterial contusions and thus had no significant external bleeding. Neurological deficits were found in 12 patients (40%). Nine patients (30%) had injuries in other body regions.

Limb salvage could be achieved in all patients who had arterial repair 6 hours or less following the injury (n=17, 56.7%) **(Table 2)**. All patients except 3 had penetrating injuries. The lower limbs were predominantly injured (22/30; 73.3%). All blunt injuries were in the lower limbs **(Table 3)**. In the upper limb, there were 8 arterial, 5 venous and 12 bony injuries. The most common arterial injury was the brachial (6/8 patients; 75%) whereas the most common bony injury was humeral fracture (6/12; 50%) **(Table 4)**. In the lower limb, there were 25 arterial, 16 venous and 29 bony injuries. The most common vascular injury was the PA (n=8) and PV (n=7) while femoral fracture was on the top of the list (n=12) **(Table 5)**. Nerve injuries were observed in 12 occasions; the most common was the tibial nerve (n=5) **(Table 6)**. Most arterial injuries were in the form of complete transection (25/33) and mostly repaired by end to end anastomosis (n=16) while RGSV grafting was performed 9 times. Seven leg or forearm arteries were ligated. All venous injuries except 3 were ligated with good outcome **(Table 7)**. Most

fractures were managed by external fixation (n=25; 83.3%) mostly before vascular reconstruction (n=20; 80%). Almost half the patients had fasciotomies mainly in the lower limb (n=12) and mostly post-repair (n=12) **(Table 8)**. Three patients (10%) had secondary amputations (2 above-knees and one above-elbow) most likely due to late presentation and doubtful limb viability at the time of repair **(Table 9**). Nearly 75 percent of patients stayed in the hospital for 1 week or less with no significant early complications. Patients with salvaged limbs (n=27; 90%) had no late complications during a follow-up period of 3 to 10 months. There were no deaths in this study.

Discussion

For comparison, we selected 3 previous studies concerning combined vascular-orthopedic limb injuries and summarized the results in **Table 10a** and **Table 10b**.

Table 10a : Summary of Relevant Studies on Combined Vascular-Orthopedic Limb Injuries

Parameter	Present study, 2015, Iraq	Al-Museilih, 2004, Iraq [5]	Hachem MM et al, 1990-1994, KSA [1]	Cakir et al, 2005, Turkey [2]
Aetiology: penetrating, blunt	27, 3*	61, 6	8, 24*	97, 95
In upper & lower limbs	(n=8; 26.7%) (n=22; 73.3%)	21.7%, 43.7%	68.8%, 31.2%	99, 117
Most frequently fractured bone in upper & lower limbs	Humerus, Femur	Humerus, Femur	Not mentioned	Humerus, Femur
Most frequently injured artery in upper & lower limbs	Brachial, PA	Brachial, SFA	Brachial, PA	Brachial, PA

*The Z-Score is 5.1586. The p-value is 0. The result is significant at p <0.05.

Age& Gender

Like other studies, most of the patients were young [1] [2] [5]. For example, 87.5% of the patients in the Saudi study were young [1], while 83.3% of our patients were under 40. All of our patients were male. Likewise, males constituted the majority of patients in the study of Al-Museilih, as they are usually more involved in violence than females [5]. Thissimulates the results of most published studies [1] [2] [5]. Twenty nine out of 32 patients were males in the Hachem et al study [1]. Similarly, the study from Turkey involved 168 males and 24 females [2].

Prevalence

In the present study, combined vascular-orthopedic injuries in lower limbs far exceeded those in the upper limb (almost 75 % of cases). In a study of 67 extremity vascular injuries in Basra, Iraq, Al-Museilih found such injuries to be associated with fractures and/or dislocations in 43.7% of cases in the lower limb and in 21.7% of cases in the upper limb [5]. In a study from Turkey, Cakir et al had a similar

finding, but the difference was small [2]. Interestingly, Hachem MM et al had an opposite finding with almost two thirds of his cases involving the upper limbs [1].

Clinical Features

Although significant vascular injuries may present with no external bleeding, arterial and/or venous hemorrhage is an alarming and serious presentation in most acute vascular injuries [6], and should be dealt with appropriately.

Mechanism of Injury

Penetrating trauma far exceeded blunt trauma (61:6) in the Al-Museilih study [5], much like the present study in which the vast majority of patients had penetrating injuries (27: 30). However, both penetrating and blunt traumas were almost equally encountered in the Turkish study (97:95) [2]. In contrast, three fourths of cases in the Saudi study were blunt injuries, as road traffic accidents were predominant [1].

Table 10b : Summary of Relevant Studies on Combined Vascular-Orthopedic Limb Injuries

Parameter	Present study, 2015, Iraq	Al-Museilih, 2004, Iraq [5]	Hachem MM et al, 1990-1994, KSA [1]	Cakir et al, 2005, Turkey [2]
Commonest arterial injury, method of repair	Transaction, end to end repair.	Transaction	Not recorded	RSVG
Vein injuries	Mostly ligated with good outcome.	Mostly ligated with good outcome.	20/24 repaired 4/24 ligated, 2 had morbidity	Proximal limb veins were repaired.
Fasciotomy	50% mostly in lower limb post-repair	13/67: 19.4%, mostly intra-operative	8/32; mostly at end of op.	32/192; 16.6% mostly in lower limb
Fracture fixation	External fixation mostly pre-arterial repair	EF in a separate operative session.	Internal fixation mostly pre-arterial repair	Mostly external fixation.
Limb salvage rate	90% @	94.6%	85% @	88%

@ The Z-Score is Nan. The p-value is 0. The result is significant at p <0.05.

Injury to Repair Time Interval vs. Limb Outcome

All patients (n=17, 56.7%) who had their arterial injuries repaired 6 hours or less following the injuries had successful repair with limb salvage. In the Saudi study, the delay from the time of accident to arrival in the operating room ranged from 2 to 30 hours, with the median time being 7 hours and 15 minutes [1]. However, four of their patients had missed arterial injuries with delayed presentations 3, 10, 10 and 21 days following the injury [1]. Although our patient with false aneurysm of the SFA had his limb saved after repair, Shi believes that delayed intervention in major arterial injuries is associated with a higher risk of amputation [7]-[9].

Fasciotomy

Al-Museilih performed 13 fasciotomies (19.4%) mostly in the lower limb (n=12) and mainly intraoperatively (n=10) [5]. Hachem et al did fasciotomy in one quarter of their patients [1], whereas only 16.6% of patients in the Turkish study had fasciotomy [2]. Compared to these studies, the present study was more liberal in performing fasciotomy (50%), with most fasciotomies (12 out of 14) done post-arterial repair.

We agree with Hachem et al that early fasciotomy should be considered in most cases of combined upper and lower extremities injury. The devastating nature of these injuries, largely due to violent forces, the associated muscle damage and the often considerable preoperative and operative warm ischemia time, all favor the development of tissue edema that may progress to a compartment syndrome that may seriously jeopardize an otherwise successful arterial reconstruction [1] [10].

The Associated Injuries

For most patients in whom vessel trauma is associated with nerve and soft tissue injury, it is the nerve function that determines the outcome [11]. In this study, there was a significant number of nerve injuries (n=12 in 33 arterial injuries). Hachem et al reported a higher rate of nerve injuries in their study (17 out of 32 cases) [1]. Primary nerve repair is advised in only the clean cases.

Method of Vascular Repair

Controversy exists about the number of vessels to be revascularized in the leg or forearm. Some advocate one vessel repair only [4] while others believe that 2 vessel revascularization is necessary [1]. We think that having one patent or successfully repaired leg or forearm artery is sufficient provided that other adjuvant measures such as wound debridement and fasciotomy are undertaken.

Despite the ongoing controversy about the ideal management of venous injuries in association with limb fractures, we believe that simple venous repair is better than ligation. This opinion is also shared by others [1][2]. However, complex venous repair procedures in critically ill patients should be avoided. Most limb veins can be ligated with minimal morbidity provided elastic support and limb elevation are used. In the Al-Museilih series, most injured veins were ligated with good outcome [5].

Methods of Fracture Stabilization

In our study, most patients received external fixation. We share the same opinion as Cakir et al, believing that external fixation has been increasingly preferred in the last few years. The advantages include requiring less operative time for immobilization, 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 [2].

Bone or Vessel First?

Vascular injuries associated with fractures need repair of the vessels and reduction and fixation of the fracture. The sequence of repair (vessel or bone first) depends on the individual case. If the patient presents late, the priority is for vessel repair. Otherwise, the fracture can be managed first followed by vascular repair [6] [12]-[14]. In this study, most of the patients who received external fixation (20/25; 80%) had external fixation before vascular reconstruction, as most of our patients had presented early (n=17; 56.7% within 6 hours of the injury). Similarly, Hachem et al performed bone fixation before vascular repair in 26/32 patients [1].

Amputation

In the present study, no primary amputation was performed. Three patients had secondary amputations (2 above-knees and one above elbow). Careful study of these three cases reveals that all had presented late. Though fasciotomy was performed in each case, it was done after arterial repair. We think it is better to do early intra-operative fasciotomy to ensure viable leg or forearm muscles before proceeding to arterial repair. Thus, tissue viability was most likely questionable at the time of repair. Therefore, primary amputation was a better option.

Duration of Hospitalization

Nearly 75 percent of our patients stayed in the hospital for 1 week or less. In contrast, patients from the Saudi study stayed for 18 to 52 days with a mean of 25 days [1]. This may be related to the smooth postoperative course in our patients which permitted early discharge from the hospital and/or the rapid turnover of the patients due to the high rate of terrorism-related casualties.

Morbidity

Early complications were nil. The 27 patients with salvaged limbs were carefully followed by frequent visits to the consultation clinic and via direct phone calls to those living remote from the hospital. Few patients who could attend regular follow up visits were clinically and ultrasonographically assessed. No significant late complications were observed during the follow up period that ranged between 3 and 10 months. The duration of follow-up was relatively short (3 to 10 months). Phone calls do not replace the proper clinical and sonographic evaluation.

Mortality

There were no deaths in this study. In the study from Saudi Arabia, one patient with popliteal artery injury died on the 30th postoperative day (3%) due to severe metabolic acidosis and acute renal failure in spite of high above knee amputation on the 17th day postoperatively. The limb dysfunction was related to nerve injury rather than vascular injury or bone fracture [1]. In a study from Turkey, 3/192 patients died (1.6%) [2].

We think that a dead limb should be amputated rather than preserved. Arterial repair for such a limb would not succeed; on the contrary, it may lead to acute renal failure. The patient may need multiple operations and may eventually die because of sepsis. Therefore, keeping a dead limb may endanger the patient's life.

Limb Salvage

The 90% limb salvage rate of patients with combined vascular-orthopedic injuries in this study is very good compared to other published studies. Limb salvage was 85% in the Saudi study [1] and 88% in the study from Turkey [2]. Cakir et al attribute the decline in the amputation rate in their clinic to liberal and early use of fasciotomy, early coverage of soft-tissue defects, aggressive debridement of devitalized tissue, and repair of all major venous injuries [2].

Conclusions

Very good limb salvage in combined vascular-orthopedic injuries can be achieved by a team approach, meticulous surgical technique, liberal use of surgical exploration, early fasciotomy and repair of major venous injuries. Dead limbs should be primarily amputated rather than preserved as keeping such limbs would endanger the patient's life.

Conflict of Interest

None Declared.

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Table 1: Age Distribution							
Age (years)	3-10	11-20	21-30	31-40	41-50	51-60	Total
N (%)	1 (3.3)	3 (10)	14 (46.7)	7 (23.3)	3 (10)	2 (6.7)	30 (100)

Table 2 Injury to Repair Time Interval vs. Limb Outcome			
Time interval	Patient n (%)	Saved limb n (%)	Amputation
≤ 6 hours	17 (56.7)	17 (56.7)	0
7 hrs-12 hrs	6	4	2*
13 hrs-24 hrs	5	5	0
More than 24 hrs	2	1	1@
Total	30	27	3

* Both patients had popliteal artery and vein injuries and had above knee amputation despite arterial repair due to doubtful limb viability at the time of repair.

@ One patient had above elbow amputation following late repair of brachial artery injury. We think the underlying cause was late presentation of the patient.

Table 3: Mechanism vs. Site of Injury			
Type of Injury	Upper limb n	Lower limb n	Total n (%)
Penetrating	8	19	27 (90)
Bullet	3	13	16
Shell	5	6	11
Blunt	0	3	3 (10)
Total	8	22	30 (100)

Table 4: Skeletal and Arterial Injuries in Upper Extremity

	Proximal humerus	Shaft of humerus	Supracondylar humerus	Shoulder dislocation	Elbow dislocation	Radius	Ulna	Total bone injuries
Axillary/subclavian (0)	0	0	0	0	0	0	0	0
Brachial (5)	0	4	1	0	0	1	0	6
Deep brachial (1)	1	0	0	1	0	0	0	2
Radial and ulnar (2)	0	0	0	0	1	2	1	4
Total (8)	1	4	1	1	1	3	1	12

Table 5: Skeletal and Arterial Injuries in Lower Extremity

Vascular injury (n)	Femoral fracture	Tibial fracture	Fibular fracture	Knee dislocation	Total bone injuries (n)
EIA/CFA (1)	1	0	0	0	1
DFA (0)	0	0	0	0	0
SFA (7)	6	1	1	0	8
PA (8)	5	4	1	1	11
PTA (3)	0	2	3	0	5
ATA (0)	0	0	0	0	0
ATA and PTA (2)	0	1	2	0	3
PTA and Peroneal artery (1)	0	1	0	0	1
Total (22)	12	9	7	1	29

EIA: external iliac artery, CFA: common femoral artery, DFA: deep femoral artery, SFA: superficial femoral artery, PA: popliteal artery, PTA: posterior tibial artery, ATA: anterior tibial artery.

Table 6: The Associated Injuries.

Injury	Number of patients
Vein	21
In Upper limb	5 (all were brachial vein injuries)
In Lower limb	16 (SFV n=4, PV n=7, tibial veins n=5)
Nerve	12 (median n=3, radial n=3, tibial n=5, peroneal n=1)
Head and Neck	1
Chest	4
Abdomen and pelvis	4
Total	42 ■

■ The number of injuries exceeded the number of patients as some patients had multiple injuries.

Table 7: Type of Vascular Injury vs. Method of Repair vs. Outcome

Type of Vascular Injury	Number of injuries	Method of management	Outcome
Complete cut	25	RGSV graft (n=4)	Very good (n=24) Amputation (n=1)
		End to end repair (n=14)	
		Ligation (n=7) @	
Lateral tear	1	End to end repair.	Very good.
Arterial contusion	6	RGSV graft (n=5)	Salvaged limb (n=3) Amputation (n=2)
		End to end anastomosis (n=1)	Very good.
False aneurysm	1	Aneurysmectomy & end to end anastomosis.	Very good.
Vein injury	21	All were ligated except 3.	Very good.

@ All ligated arteries were in the forearm or leg.

Table 8: Details of Orthopedic Management

Method of bone fixation	External device	N= 25	N/B. POP was used for a child with inter-trochenteric femoral fracture (spika), a patient with fractured proximal tibia and a patient with fractured radius.	
	Plaster of Paris	N= 3		
	None	N=2	N/B. Both patients had fibular fractures required no specific method of immobilization.	
Fasciotomy	Done (n=14)	In upper limb (n=2)	Before arterial repair (n=2)	
	Not done (n=16)	In lower limb (n=12)	After arterial repair (n=12)	
Time of bone fixation	Before arterial repair (n=20)	N/B. The remaining 5 patients had no insertion of external bone devices.		
	After arterial repair (n=5)			

Table 9: Details of Patients with Secondary Amputation

Case	Mechanism of injury	Injury to repair time	Type of vascular injury	Associated injuries	Definite treatment	Outcome
Case 1: 23 yrs.	Shell	4 days	5 cm contused brachial a & vein injury	Compound comminuted # humerus & median n injury	RGSV graft of art, ligation of v, EF of # and fasciotomy. Followed by multiple WE	Above-elbow amputation. @
Case 2: 19 yrs.	Shell	8 hrs	Transaction of popliteal art & v.	# distal femur, tibial n cut	RGSV graft of art injury, vein ligation, fasciotomy (after art repair) & EF of bone (after art repair)	Above-knee amputation 2 days postoperatively.
Case 3: 42 yrs	Blunt trauma due to RTA	7 hrs	Popliteal art contusion 5 cm & PV tear.	# tibia & fibula.	RGSVgraft, lateral venorrhaphy, fasciotomy & EF (post repair).	Above-knee amputation after 3 days.

@ See Figure 1

Figure 1: Severe compound comminuted fracture of humeral shaft associated with brachial artery contusion, brachial vein and median nerve injuries due to shell injury 4 days prior to admission. Despite repair of artery by RGSVG, forearm fasciotomy and external fixation of the fracture, the patient had secondary above-elbow amputation 17 days later due to dead muscles. Late presentation and doubtful tissue viability at time of repair are to be blamed.