In Israel, many terrorist acts, like combat incidents, involve explosive devices and result in vascular trauma. Complex vascular trauma of the extremities (CVTE) is a reflection of the amount of energy (a) released by the injuring agent and (b) absorbed by the vital tissues. Such trauma includes extensive arterial and venous lacerations with loss of substance, comminuted fractures, neural injury and extensive soft tissue loss. The rate of limb loss with such trauma approaches 40%. Current treatment of CVTE in the civilian is in many ways similar to that in the military population. Still, these two populations differ significantly with respect to diagnostic methods, injuring agents and management.

Management of vascular trauma was a major issue during World Wars I and II, when ligation was the accepted approach. Vascular repair had a high complication rate, usually from thrombosis and haemorrhage. The classic World War II report by DeBakey and Simeone in 1946 analysed 2471 arterial injuries in American casualties in Europe. Almost all were treated by ligation with a subsequent overall amputation rate approaching 50%. For popliteal artery injuries there was an amputation rate of 73%. During the Korean conflict, which paralleled the evolution of contemporary vascular surgery, the first successful vascular reconstructions were accomplished. With the Vietnamese war came the establishment of the principles of modern vascular reconstructive surgery. The results were monitored through the Vietnam Vascular Registry. The objective of contemporary trauma surgery is to maintain correct priorities. Initial treatment of vascular trauma is similar to the treatment of any major trauma. Special attention is placed on control of external haemorrhage, fracture and spinal stabilisation, and rapid transport.

Vascular trauma of the torso is usually an immediate threat to life, whereas injury to an extremity vessel is more often a threat to the affected limb. The diagnosis of vascular injury in the extremities is clear when the patient arrives with external bleeding from a wound, such as in the thigh, which is controlled by application of external pressure. The classical presentation of limb ischaemia is encountered rarely in the context of vascular trauma. The soft signs of suspected vascular trauma in an otherwise stable patient can be evaluated with objective tests such as continuous Doppler-signal analysis, colour-flow duplex scan and angiography. Angiography is still considered the "gold standard" for diagnosis of vascular injury.

The importance of a careful history combined with thorough physical examination in establishing the correct diagnosis is often underscored in authoritative reviews. Unfortunately, in victims of mass casualty from explosive trauma and even in an individual patient with haemorrhagic shock, these didactic approaches are not always applicable. Haemodynamically unstable patients with exsanguinating vascular injuries need to be expediously transferred to the operating room while the airway is being secured. The haemorrhage is usually controlled by direct pressure over the site of bleeding using digital pressure or an instrument such as sponge forceps. Blind clamping in the bleeding wound is ineffective and may cause damage to adjacent structures and exsanguination. Manual compression of the external bleeding site must be maintained until proximal and distal control are formally obtained. Through a limited aseptic field, proximal vascular control is obtained while the patient is being resuscitated with fluids and blood products. Following successful resuscitation and comprehensive examination for additional injuries, attention is then turned to the injured site.
The patient is prepared for the definitive vascular reconstruction by prepping and draping the entire injured extremity and the contralateral healthy limb and in certain cases an upper limb as a potential donor for autogenous veins.

Management of CVTE is optimally conducted by a specialised vascular team. The head of the vascular team is responsible for the whole management of the patient, from the initial diagnosis to prioritisation of different interventions and the choice of methods of revascularisation and other reconstructions. The usual sequence of events is: control of bleeding, immediate restoration of blood supply and venous return by temporary indwelling arterial and venous shunts, skeletal fixation, permanent vascular reconstruction, muscle coverage of exposed vessels and vascular grafts and fasciotomy when indicated.

Once all bleeding is under control, the next step is to restore blood flow to the ischaemic extremity. A significant number of patients reach the operating room following a long period of limb ischaemia caused either by the arterial injury or by the prolonged application of a tourniquet. The objective at this stage is to prevent irreversible tissue damage. The restoration of arterial blood supply and venous return is achieved by the use of temporary indwelling arterial and venous shunts. Temporary shunts are advantageous because they enable the anaesthetists to overcome the metabolic consequences of reperfusion. The vascular team can prepare and tailor the autologous vascular conduits on the “back table” while the orthopaedic team is stabilising bone fractures. Skeletal fixation is imperative as it limits ongoing blood loss from unstable fractures. In addition, it gives the vascular surgeon a stable, relatively dry field for effecting the permanent vascular repair.

In rare cases, with limited arterial injury, it is possible to debride the vascular edges and approximate healthy tissue, end-to-end. However in the vast majority of complex vascular trauma the extensive loss of arterial and venous tissue demands the use of interposition grafts. Autologous venous grafts, preferably from the contralateral uninjured limb or in selected cases from the upper limb veins, are usually used. For arterial replacement we do not hesitate to use synthetic material, such as PTFE, when an appropriate venous conduit is not available.

The patient with concomitant vascular and skeletal trauma is vulnerable to infectious complications of the vascular graft (autologous or prosthetic) and orthopaedic endoprostheses. External fixation devices can also create a portal of entry for hospital acquired organisms. Aggressive wound debridement, copious irrigation, administration of short-term prophylactic antibiotics and the deliberate coverage of the grafts with a rotational muscle flap are indispensable in the initial management of the traumatised limb. The viable muscle mass covers the graft and anastomotic sites and fills the space between the fracture fragments. These measures should reduce the risk of secondary complications such as anastomotic haemorrhage or further bacterial contamination. Moreover, laboratory evidence suggests that a muscle flap may expedite eradication of an underlying infection. Unexplained fever in the first postoperative week in a patient with extensive soft tissue and skeletal injury is an indication for urgent re-exploration of the wound, further debridement, drainage and additional rotational muscle coverage. Lessons learned from elderly patients with infected vascular grafts have been successfully applied to this group of traumatised patients. This aggressive approach also provides defense against infection of any orthopaedic endoprosthesis.

Reconstruction of major venous injuries of the extremities and the pelvis is a major undertaking and deserves special attention. The diagnosis of isolated venous injuries is often missed or delayed unless expressed as overt bleeding or late thrombosis. The majority of venous injuries are associated with adjacent arterial injuries. The optimal management of peripheral venous injuries remains controversial, and repair of completely disrupted major veins in patients with complex vascular trauma has been most challenging for vascular surgeons. Some authors propose that failure to repair associated major venous injuries of the lower extremities contributes to less-than-optimal limb salvage in these complex injuries. The abrupt increase in distal resistance due to ligation of a major vein impedes arterial flow and may lead to early failure of the associated arterial repair. Venous ligation also seems to predispose patients to compartment syndrome. When massive tissue destruction has occurred (e.g. high velocity missiles, blunt vascular trauma) a dramatic reduction in bleeding is observed when the clamps are released after successful venous reconstruction. The late sequelae of venous ligation (oedema, chronic venous insufficiency, venous stasis ulceration) also contribute to less-than-optimal function in successfully salvaged extremities.

Reconstructive surgery in the low pressure, low velocity venous system is different from that in the high pressure, high velocity arterial tree. Venous reconstructions are notoriously unforgiving, and any technical impurity is reflected in thrombotic complications. The classical saphenous venous conduit either reversed, or in the valvulotomised antegrade
orientation, when subjected to systemic arterial pressure can tolerate a moderate mismatch in diameter, relative redundancy in length and a limited degree of rotation. In addition, the patency of the arterialised conduit can be extended by secondary interventions such as thrombolytic therapy, surgical thrombectomy and segmental revisions. The whole graft can be replaced in selected cases by a prosthetic conduit. Interposition grafts in the low flow venous system are subject to different rules that are more demanding and have lesser degrees of latitude. Exact graft length and diameter and proper alignment are imperative. In addition, careful and precise excision of venous valves is essential when tailoring the spiral or panelled grafts. Such meticulous reconstructions demand an experienced surgical team and must wait until the patient has been stabilised. The fastidious venous environment is hostile to the prosthetic graft which is prone to immediate or early thrombotic failure.

Venous injury is not uncommon, with an incidence of about 30% (15–51%) among all vascular injuries. It is quite surprising, therefore, that conflicting observations and opposing approaches persist despite continued interest and debate. We believe that the reconstruction of injured veins constitutes a more complete anatomical and physiological restoration and may be associated with better short and long-term outcome.

Review of our vascular trauma registry from January 1985 to June 1997 at the Hadassah University Hospital identified 47 patients with 48 extremity and pelvic major venous injuries that were treated operatively. Venous injuries comprised 43 (36%) of the total 119 vascular injuries reported under the heading of penetrating and blunt trauma. Penetrating trauma, with a preponderance of high velocity missile injury, accounted for 38 injuries (79.2%). Six (12.5%) injuries were due to blunt trauma, while four (8.3%) injuries were iatrogenic. These four patients are part of a similar size group of patients registered as iatrogenic vascular trauma. Lower extremity and pelvic veins were injured in 43 (89.6%) instances. Associated injuries in the same extremity occurred in 43 patients. Isolated vein injury occurred in 10 instances, including three iatrogenic injuries. An arteriovenous fistula was present in five cases. Twenty-seven patients were hypotensive on arrival (systolic blood pressure <80 mmHg). Arteriography demonstrated arterial injuries in seven patients and arteriovenous fistulae in four patients. None of the patients underwent preoperative venography. Indications for operation were related to the accompanying arterial injury and isolated venous injuries were found on exploration for bleeding. After isolation of blood vessels and before skeletal stabilisation, temporary venous shunts were placed in 12 cases and arterial shunts in 10 cases.

The dominant venous injury was repaired in 46 (95.8%) limbs and ligated in two (4.2%) limbs. Vein grafts were used in 35 instances and included spiral (n = 7), panel (n = 8), interposition (n = 12) and patch venoplasties (n = 8). Ligations were performed in those patients with coagulopathy, abdominal injury and superficial femoral vein transection and for deep femoral vein transection. Arterial injuries were repaired by saphenous interposition graft in 29 cases, with PTFE in four cases, saphenous patch in one case and end-to-end anastomosis in one case of axillary injury. All fractures were fixed during the initial operation. External fixation was employed in 12 cases. Intramedullary nailing was used in four cases and plating in one case. Calf fasciotomy with immediate coverage with split thickness skin grafts was performed in 23 limbs at the initial operation.

There were no operative deaths. Two patients underwent delayed amputation of the injured limb. Early reoperation was performed in eight cases for arrest of secondary bleeding (two cases), a femoropopliteal bypass for a missed superficial femoral artery injury in one case. In all others, further debridement, and wound coverage with muscle flaps and skin grafts were performed as required. Of the 46 limbs that were salvaged, 39 regained full function. In the lower extremity three patients had drop-foot, one of them transient, one had sensory pedal loss and one developed reflex sympathetic dystrophy. Thirty-day patency was evaluated by duplex scanning (n = 17), continuous wave Doppler (n = 32) or venography (n = 3) in 32 patients. Venous occlusion was found in four cases; in two of these, operation was delayed by more than 24 h. Four patients had transient leg oedema and two of these had patent venous reconstructions. Long-term evaluation of venous patency was available for 27 patients by means of duplex scanning (n = 18), continuous wave Doppler (n = 9) and venography (n = 2) for a mean period of 27.7 ± 30.6 (range 1–94) months. Only one occlusion was found 6 weeks after spiral graft repair of a common femoral vein injury sustained during repair of an inguinal hernia. All other venous reconstructions were patent.

In conclusion, venous reconstruction for trauma with frequent use of spiral or panel vein grafts is possible with high early and late patency rates and good functional results. All venous occlusions were identified in the early postoperative period. Those reconstructions that outlived that critical period have high likelihood of long-term patency.
References


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