Tactical Surgical Intervention With Temporary Shunting of Peripheral Vascular Trauma Sustained During Operation Iraqi Freedom: One Unit's Experience

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Background: **Rapidly restoring perfusion to injured extremities is one of the primary missions of forward military surgical teams. The austere setting, limited resources, and grossly contaminated nature of wounds encountered complicates early definitive repair of complex combat vascular injuries. Temporary vascular shunting of these injuries in the forward area facilitates rapid restoration of perfusion while allowing for deferment of definitive repair until after transport to units with greater resources and expertise.**

Methods: **Standard Javid or Sundt shunts were placed to temporarily bypass complex peripheral vascular injuries encountered by a forward US Navy surgical unit during a six month interval of Operation Iraqi Freedom. Data from the time of injury through transfer out of Iraq were prospectively recorded. Each patient's subsequent course at Continental US medical centers was retrospectively reviewed once the operating surgeons had returned from deployment.**

Results: **Twenty-seven vascular shunts were used to bypass complex vascular injuries in twenty combat casualties with a mean injury severity score of 18 (range 9–34) and mean mangled extremity severity score of 9 (range 6–11). All patients survived although three (15%) ultimately required amputation for nonvascular complications. Six (22%) shunts clotted during transport but an effective perfusion window was provided even in these cases.**

Conclusion: **Temporary vascular shunting appears to provide simple and effective means of restoring limb perfusion to combat casualties at the forward level.**

Key Words: **Military, Combat, Vascular, Forward surgery.**

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Extremity wounds account for 50 to 75% of all combat injuries and 10% of fatal combat injuries.[1–5] Although the bleeding from some of these injuries can be arrested by tourniquet, direct pressure, and/or hemostatic dressing application in the field allowing for Casualty Evacuation (CASEVAC) to definitive vascular surgical capability, ongoing hemorrhage and distal ischemia can result in loss of life or limb if expedient surgical intervention is not provided.[5,6] The provision of rapid extremity hemorrhage control to save life while concurrently restoring distal perfusion to salvage limb is consequently one of the primary missions of and greatest challenges to forward surgical teams. An austere working environment, limited instrumentation, lack of angiography, limited operating room (OR) availability, and relative severe and grossly contaminated nature of trauma encountered complicates the performance of definitive vascular repairs in the forward setting.[4,7] Additionally problematic is the minimal recent vascular experience of most general surgeons staffing these small surgical units. Temporary vascular shunting (TVS) of major extremity vascular injuries requiring complex repair has the potential advantage of facilitating rapid control of hemorrhage and restoration of flow at the forward level while permitting deferment of definitive repair to higher echelons of care where greater resources and expertise are available.

Although a number of authors have published in-hospital experiences with TVS, minimal experience has been reported with the placement of shunts to provide distal perfusion around severely traumatized extremity vessels during MEDEVAC to higher levels of care.[8–14] The experience of two co-located United States Marine Corps Forward Resuscitative Surgical Systems (FRSS) with TVS during a 6-month rotation of Operation Iraqi Freedom (OIF) is examined in this report to assess the efficacy of the technique in the forward surgical management of complex military peripheral vascular injuries.

METHODS

The FRSS is a small mobile trauma surgical team designed to provide forward surgical support to modern United States Marine Corps (USMC) combat units. The composition and methodology of the FRSS and associated forward emer-

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The opinions and conclusions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the United States Marine Corps, United States Navy, or the Department of Defense.

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gency medical unit of the Shock Trauma Platoon (STP) has been previously described.[4] The basic role of the FRSS is to provide tactical surgical intervention, the selective use of damage control or definitive trauma surgery close to the forward area, to minimize time between wounding and surgical intervention. When the USMC returned to the Iraq Theater in 2004, several FRSS teams were placed throughout the Area of Responsibility to facilitate rapid surgical treatment of combat casualties. Two FRSS teams, along with a supporting STP, were positioned at Al Taqaddum, a former Iraqi military airbase strategically located between the volatile cities of Fallujah and Ramadi. This task-oriented unit was dubbed the Surgical Shock Trauma Platoon (SSTP) and its staff included one orthopedic and three general surgeons.

After initial hemorrhage control and wound debridement, severely injured extremities were critically evaluated by both an orthopedic and general surgeon and the decision of limb salvage versus primary amputation mutually agreed upon. Patients undergoing limb salvage attempts of significant lower extremity trauma next routinely underwent distal four compartment fasciotomies. Emphasis was placed on avoidance of iatrogenic injury to the saphenous system during this to preserve as much collateral venous drainage as possible. Fasciotomies of the upper extremity and thigh were selectively performed only when there was some evidence of compartment syndrome. Adequate resuscitation before reperfusion was deemed essential to minimize the risk of potentially fatal acute reperfusion-induced metabolic complications. This was also thought to help decrease the risk of thrombotic complications which compensatory peripheral vasoconstriction in under-resuscitated patients can otherwise predispose to.[15]

Before restoration of arterial inflow, attempts were, in most instances, first made to preserve the major venous outflow of the extremity either by repair or shunting of venous injuries. In patients with significant systemic metabolic acidosis or limb ischemia times of more than 60 minutes approximately 200 cc of distal venous blood was removed before restoration of flow into the proximal vein to help minimize reperfusion insult.

After passage of an embolectomy catheter and removal of any clot, arterial injuries requiring complex repair underwent temporary shunting with a 5.7/3.3 mm diameter, 27.5 cm long Javid Shunt (IMPRA, Tempe, AZ) or a 5/3.5 mm diameter, 30 cm long Sundt Shunt (Integra Neurosciences, Plainsboro, NJ) based on surgeon preference. In the few instances shunting below the elbow or knee was deemed necessary, smaller diameter shunts were constructed from intravenous (IV) tubing or 2.7-mm diameter pediatric feeding tubes. Systemic heparin was not used, but local instillation of heparinized saline was used in instances of poor back bleeding. The shunts were placed so they lay straight. This typically resulted in a significant length of shunt lying within the lumen above and below the site of injury, providing the additional advantage of increasing stability of placement, lessening the risk of dislodgment during subsequent transport. Each shunt was secured proximally and distally with silk sutures tied around the shunt and vessel wall at their interface (Fig. 1). Placement of ligatures further away from the site of injury on the native vessel was avoided to minimize the length of subsequent bypass graft required. Any remaining portion of native vessel wall was left intact to help maintain stability of the indwelling shunt. Care was taken to ligate any arterial branches from or venous tributaries to the portion of the native vessel lying between the two sutures securing the shunt in place, as significant bleeding could otherwise occur around the shunt. The presence of at least biphasic distal flow was then confirmed with the Doppler probe.

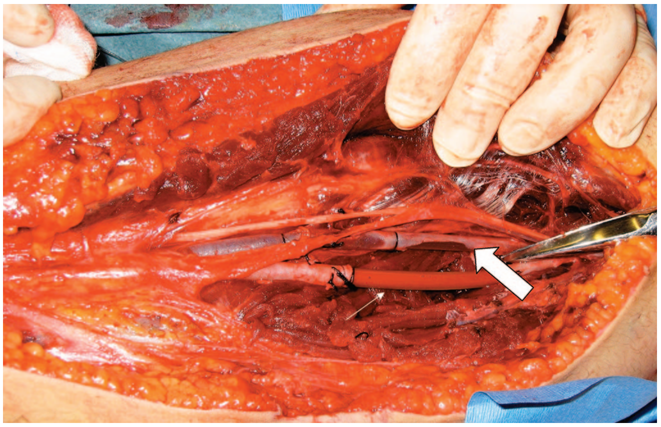

Fig. 1. *Femoral Artery (narrow arrow) and vein (wide arrow) shunts in place. Proximal is to the reader's right.*

After sufficient recovery and communication with the receiving facility, casualties underwent MEDEVAC accompanied by an en-route care nurse who continued resuscitation during the flight and who had been briefed on the location of each shunt and steps to take if bleeding occurred during the MEDEVAC mission. Definitive vascular repair was then performed at higher echelon units in Baghdad or Balad.

The age, sex, admission vital signs, initial Glasgow Coma Score, and mechanism of injury of each patient were recorded at admission and prospectively entered into a database. Revised Trauma Scores (RTSs), Injury Severity Scores (ISSs), and Mangled Extremity Severity Scores (MESSs) were tabulated to facilitate outcome comparisons with other units and experiences. The time course of care proceeding and during the patient's SSTP admission were recorded as were the specific injuries determined in each case. Details concerning the subsequent course of patients were obtained by e-mail correspondence with the surgeons providing subsequent care, chart review, phone contact with the patients, and, whenever possible, by follow-up exams.

RESULTS

Between September 1, 2004 and February 25, 2005, 293 combat casualties with 582 injury sites underwent surgical intervention at the SSTP. There were 223 (76%) patients who required operations for 409 extremity injuries with 66 (23%) having sustained injury to named vessels. One patient with diminished pulses but persistence of biphasic distal Doppler signals with no ongoing hemorrhage, gross contamination, or other indication for early surgical intervention underwent MEDEVAC to a higher echelon facility without undergoing vascular exploration at the SSTP. He was ultimately found to have a contained brachial artery injury for which a reversed saphenous vein (RSV) graft was placed with an uneventful postoperative course. The remaining 65 patients underwent exploration at the SSTP.

There were 20 patients with a mean ISS of 19 (range 9–50), median RTS of 7.108 (range 5.235–7.841) and a mean MESS of 10 (range 8–11) who required amputation of 22 extremities for unreconstructable nerve, soft tissue, and/or osseus injuries accompanying their vascular injury. There were 10 below-knee amputations, six above-knee amputations, five above-elbow amputations, and one below-elbow amputation. The remaining 45 patients had a total of 79 major vascular injuries and underwent limb salvage procedures at the SSTP. As summarized in Table 1, 37 (47%) of these injured vessels were ligated whereas 13 (16%) underwent primary repair.

The remaining 29 injuries (37%) could not be repaired primarily without producing greater than 25% stenosis and were managed with temporary vascular shunting (TVS). In two cases, damage control TVS was used to control extremity hemorrhage concurrent with resuscitative thoracotomy for patients who arrived in cardiac arrest as a result of massive blood loss in the field secondary to ileo-femoral vascular trauma. Although cardiac activity and distal perfusion were transiently restored in each case, both patients ultimately died before leaving the OR. The remaining 20 patients had a mean ISS of 18 (range 9–34), median RTS of 6.085 (range 4.21–7.841) and mean MESS of 9.[6–11] Details concerning the condition at admission of these patients are listed in Table 2. The majority of patients had evidence of significant blood loss in the field with eleven patients (55%) having a SBP of 90 or less on arrival and a base deficit of −6 or worse on initial blood gas analysis. Thirteen patients (65%) arrived with temperatures of 35°C or less.

Table 1 Summary of Vessels Injured

Vessel	Ligation	Primary Repair	Shunt
Axillary vein	1		
Brachial artery			1
Brachial vein	2	1	1
Radial artery	6		
Ulnar artery	3		1
Common iliac artery			1
Common iliac vein	1	1	
External iliac artery		1	1
External iliac vein	2	1	
Internal iliac vein	1		
Femoral artery		2	8
Femoral vein	1	1	6
Profundus femoral artery	4		
Profundus femoral vein	5		
Popliteal artery			3
Popliteal vein		1	3
Posterior tibial artery	2	1	3
Posterior tibial vein	7		1
Anterior tibial artery	1		
Anterior tibial vein	1		
Peroneal artery		2	
Peroneal vein		2	
Total	**37**	**13**	**29**

The time between wounding and arrival at the SSTP was known in all but two patients and averaged 61 minutes (range of 16–150). The total ischemia time between wounding and restoration of extremity perfusion could be accurately determined in 16 of the 18 patients who required arterial repair or shunting with a mean of 158 minutes (range 30–285) observed. Fourteen patients had tourniquets placed in the field. In one patient the tourniquet time was not documented. The mean duration of tourniquet use in the remaining 13 patients (including intraoperative pneumatic tourniquet use after removal of field tourniquets in 9 of these patients) was 122 minutes (range 30–276). Eleven of thirteen tourniquet patients underwent successful limb salvage.

In nine cases the vascular injury requiring TVS was associated with an unstable osseus injury stabilized with external fixation. Two patients had complete median nerve transections whereas a partial laceration of the sciatic nerve was observed in a single casualty. One patient had clinical evidence of common peroneal nerve injury without inspection of the nerve intraoperatively at the SSTP. Clinically obvious compartment syndromes were appreciable on presentation in three cases (1 leg, 1 thigh, 1 forearm).

Excluding the two patients who arrived in cardiac arrest, all patients survived. No shunt displacement or bleeding complications occurred postoperatively or during the subsequent MEDEVACs which lasted a mean of 33 minutes (range 20–50). All patients were taken back to the OR within six hours of being received by the next echelon, with the majority being taken back within an hour of arrival. Attempts to more specifically track the time courses of patients after they left the SSTP were unsuccessful. At definitive revascularization 21 of 27 (78%) shunts were open and four arterial and two venous shunts were clotted. Probable etiologies of clotting and the eventual outcome of these cases are summarized in Table 3.

Eleven patients developed 22 complications which are summarized in Table 4. Two patients (patients 2 and 20) developed thrombosis of initial RSV grafts as a result of technical complications. Both of these were revised successfully with good outcome at discharge. One patient (patient 3) with a popliteal artery transection was noted on follow-up angiography to have a patent RSV graft but poor run-off through the distal anterior and posterior tibial arteries. Flow

Table 2 Shunt Patients

Patient	Mechanism	Vessel(s) Shunted	ISS	RTS	MESS	Fracture Grade
1	IED	Popliteal vein	11	7.55	6	IIIa
2	Mortar	Posterior tibial artery	9	7.55	8	IIIc
3	RPG	Popliteal artery	27	6.085	8	N/A
4	IED	Brachial vein	13	6.085	6	N/A
5	Mortar	Common iliac artery	29	4.21	10	N/A
6	IED	Ulnar artery	13	7.841	7	N/A
7	Gunshot wound	Superficial femoral artery Popliteal vein	16	7.841	8	N/A
8	Gunshot wound	Superficial femoral vein	9	6.817	10	IIIc
9	Gunshot wound	Posterior tibial artery	18	7.108	10	IIIc
10	IED	Common femoral artery	20	5.148	10	IIIc
11	Gunshot wound	Superficial femoral vein	13	5.148	10	N/A
12	Mortar	Popliteal artery Popliteal vein	9	7.841	9	N/A
13	IED	Common femoral artery Common femoral vein	34	6.817	11	IIIc
14	Gunshot wound	Brachial artery	17	5.148	11	N/A
15	IED	Superficial femoral artery	25	7.841	6	N/A
16	Gunshot wound	Superficial femoral artery Superficial femoral vein	16	6.085	10	N/A
17	Gunshot wound	Superficial femoral artery Superficial femoral vein	29	6.085	11	N/A
18	IED	Posterior tibial artery Posterior tibial vein	17	7.841	8	IIIc
19	Gunshot wound	Superficial femoral artery Superficial femoral vein	25	6.085	10	IIIc
20	Gunshot wound	Popliteal artery	9	7.841	9	N/A

IED, improvised explosive device; ISS, Injury Severity Score; MESS, Mangled Extremity Severity Score; RPG, rocket propelled grenade; RTS, Revised Trauma Score.

through the peroneal artery was sufficient however, to maintain viability of the patient's foot.

Three (15%) patients required amputation. One of these (patient 9) clotted a posterior tibial artery shunt and subsequently underwent below knee amputation (BKA) without further attempt at revascularization when a previously unappreciated tibial nerve transection was visualized. A patient with similar distribution of injury (patient 18) underwent successful restoration of perfusion but ultimately required BKA as a result of delayed tissue necrosis attributed to microvascular and cellular injury from blast cavitation effect. One additional patient (patient 13) with more proximal injuries required hip disarticulation one week after injury as a result of similarly extensive delayed muscle necrosis. This patient presented in profound hemorrhagic shock with grossly contaminated wounds after an improvised explosive device was set off below his vehicle, blowing a large amount of fragmentation, gravel, and sand through his leg, shredding 12 cm of his femoral artery and 15 cm of his femoral vein. Both arterial and venous shunts placed at the SSTP remained open and technically uncomplicated RSV grafts were placed to each in Baghdad. Despite palpable distal pulses, the patient's leg developed evidence of significant delayed blast cavitation effect which ultimately produced near complete necrosis of

Table 3 Clotted Shunts, Etiologies, and Outcomes

Shunt Patient	Vessel(s) Shunted	Predisposing Factors to Clotting	Ultimate Result
9	Posterior tibial artery	Small vessel, Vein ligation Lack of fasciotomies	BKA without further attempt at revascularization due to tibial nerve injury
14	Brachial artery	Vein ligation Bent arm kinking shunt	RSVG to artery with good result
17	Superficial femoral artery and vein	Shunt against vessel wall	RSVG to artery and vein with good results
18	Posterior tibial artery and vein	Small vessels	RSVG to artery with good macrovascular flow achieved but ultimately required BKA due to ongoing tissue necrosis

BKA, below knee amputation; RSVG, reversed saphenous vein graft.

Table 4 Complications

Shunt Patient	Complications
1	Superficial wound infection
2	Initial graft thrombosis
3	Delayed thrombosis of distal anterior and posterior tibial arteries despite patent proximal graft
	Runoff from peroneal artery sufficient to salvage limb
8	Heterotrophic ossification at wound site
	Urethral stricture
9	BKA due to unrecognized nerve transection
10	Prolonged ileus
	Inguinal lymphocele
13	Failed limb salvage due to extensive soft tissue necrosis
	Rhabdomylinolysis
	Renal failure requiring 1 month of dialysis
	Acalculous cholecystitis
	Wound infections (abdominal wall and disarticulation sites)
	Pneumonia
	Line sepsis
16	Lymphocele
18	Failed limb salvage due to extensive soft tissue necrosis
	Wound infection at subsequent BKA site
19	Thrombosis of vein graft
	Sacral decubitus ulcer
	Empyema
	Heparin-induced thrombocytopenia
20	Initial graft thrombosis

BKA, below knee amputation.

the posterior thigh compartment, necessitating hip disarticulation one week after injury.

DISCUSSION

The approach of TVS was first well-described in the 1971 report of Eger et al., in which they described their in-hospital use of arterial shunts constructed from simple polyethylene tubing to rapidly restore perfusion to the ischemic extremities of 36 combat casualties from the Israeli-Egyptian conflict.[8] Despite an average time to definitive repair of ten hours, only 8% of patients ultimately required amputation in this series. Several subsequent reports from civilian centers have focused on similar in-hospital use of TVS as a means to restore and maintain distal perfusion for extremity arterial trauma while concurrent complex orthopedic injuries are addressed, with decreases in warm ischemia time and need for amputation being observed.[9–11] Others have reported on the use of TVS as a damage-control procedure, with several documenting shunt patency for more than 24 hours in multiply traumatized patients.[12–14]

With the exception of Johansen and Hedges' 1989 report describing a 950 mile MEDEVAC of a patient with a femoral artery shunt,[16] there has been no published experience with TVS as a temporizing measure to provide limb perfusion during transfer to higher levels of trauma care from rural hospitals or forward military medical units. The potential for rapid and relatively straightforward restoration of perfusion makes TVS an attractive alternative to prolonged initial CASEVAC which increases the risk of irreversible ischemia or earlier definitive surgical intervention by centers with limited resources which could increase the risk of inferior definitive repair.[17] Although the current series is too small to provide definitive conclusions, the absence of mortality or bleeding complications, the 85% limb salvage (with no limbs being lost secondary to ischemic complications), and 78% shunt patency rates appear to support the option of TVS by forward surgical teams as an effective means of obtaining rapid control of extremity hemorrhage while simultaneously re-establishing distal flow.

Performance of TVS is relatively straightforward but several technical considerations appear to be beneficial in maximizing shunt patency. The significant extent of soft tissue trauma involved with the majority of combat extremity injuries, the propensity of the leg to develop compartment syndrome with reperfusion, and the difficulty of closely following the limb's status postoperatively when receiving multiple other casualties and during subsequent MEDEVAC argue strongly for performance of distal fasciotomies in all combat casualties requiring forward intervention for vascular trauma to the leg.[18,19] The importance of this was emphasized by Johansen and Hedges in the case report of their patient who made if through a 16 hour MEDEVAC with a patent femoral artery shunt only to ultimately require amputation as a result of complications from compartment syndrome.[16] In the current series, fasciotomies were omitted in one case (Patient 9) to expedite care of one of the nine other seriously injured patients who presented concurrently. In addition to a clotted shunt and pulseless foot, the patient had a clinically obvious compartment syndrome on arrival at the next echelon. At re-exploration he was found to have a tibial nerve injury not appreciated at the SSTP and below the knee amputation was consequently performed without further attempt at revascularization.

Re-establishment of major venous outflow before arterial shunting in cases of concurrent arterial and venous injuries also seemed to play a role in maintaining shunt patency. We encountered 12 cases of combined arterial/venous injuries of which two underwent arterial shunting after venous ligation (patients 9 and 14) with both of these arterial shunts clotting before definitive revascularization. Early in our experience we also observed several arterial shunts to clot intraoperatively when inserted without prior re-establishment of venous outflow. Others have observed a similar tendency for the relatively small diameter of the arterial shunts to thrombose in the absence of venous outflow.[11,15,17,20–22] Additionally, although the majority of civilian peripheral venous injuries appear to be adequately managed by ligation,[23–26] the greater soft tissue and collateral venous loss seen in a high percentage of military extremity injuries appears to warrant attempt at venous reconstruction unless ongoing hemodynamic instability precludes it.[20,27,28] TVS of complex peripheral venous injuries helps facilitate this subsequent venous reconstruction. We consequently advocate shunting of any major venous injury not amenable to venorrhaphy whenever necessary to preserve major venous outflow from the limb, unless the patient has significant ongoing systemic instability. The vein can subsequently be ligated or bypassed at the higher echelon vascular surgeon's discretion. As the vast majority of these patients will return to the OR for multiple washouts, a potential additional option is to simply leave the venous shunt in, removing it and ligating the vein after an interval allowing for development of collaterals has passed.

The manner in which the shunt is inserted and left to lie also appeared to be an important technical consideration. We avoided looping of the shunts to help minimize both resistance to flow and likelihood of dislodgment after both complications occurred intraoperatively early in our experience. To ensure the shunt lies straight, it's often necessary for a significant length to lie within the vessel lumen above and below the site of injury. This has the added benefit of decreasing the risk of dislodgment or bleeding around the insertion points, the importance of which is illustrated by our need to re-operate on a patient (patient 16) who had a superficial femoral artery shunt placed at another forward surgical unit. While undergoing ground transport as a result of inclement weather, the patient developed recurrent arterial bleeding as a result of partial displacement of the shunt's relatively shallow distal insertion. The hemorrhage resolved immediately with shunt re-insertion to a deeper level at the SSTP and the patient ultimately did well. These benefits of deep shunt insertion must be considered in light of the potential for iatrogenic injury and thrombosis if side branches are entered or the end of the shunt comes to lie against the vessel wall.[15] This appeared to be the primary factor producing thrombosis of superficial femoral artery and vein shunts placed in a multiply traumatized 14-year-old Iraqi patient (patient 17). The distal portion of the shunt in this case came to lie relatively close to the vascular trifurcation despite the proximal ends lying as far proximal as they could be passed without resistance. At the time of definitive revascularization approximately 8 hours postinjury, both shunts were clotted. They nonetheless appeared to have provided a significant period of perfusion as the patient underwent successful RSV grafts to both vein and artery with minimal systemic reperfusion effects, no tissue loss and ultimate functional outcome. Subsequent to this, we began shortening the shunts whenever greater than 7 cm lay within the vessel lumen both proximally and distally or if the shunt was thought to be encroaching on major branch points.

Despite taking careful measures to ensure a straight, low resistance internal lie of the shunt, external angulation of the extremity appears to have the potential to produce significant flow resistance and thrombosis. The previously mentioned patient (patient 14) with a brachial artery shunt which crossed the elbow was recognized in retrospect to have been transported with the arm slightly bent, likely contributing to the shunt clotting. Splinting extremities at risk for angulation may be helpful in minimizing the risk of thrombosis in selected cases.

A prior investigation with B Mode ultrasound imaging in normal, uninjured adults supports the use of 3.5–5 mm shunts as satisfactory for the majority of adult peripheral vascular trauma.[29] The Javid and Sundt shunts were utilized as they are of the appropriate diameter, are of adequate length to address long segment injuries such as that seen in patient 13, and were readily available for bulk purchase by the military when the FRSS equipment was being selected. The internal diameter of these shunts is sufficient to maintain distal blood flow at approximately 50% of normal which provides adequate oxygenation given compensatory local increases in oxygen extraction.[15] This diameter is not, however, sufficient to produce palpable pedal pulses in most instances. Nonetheless, at least biphasic distal flow through arterial shunts should be detectable by hand-held Doppler. Absence of distal Doppler signals after shunting should prompt a search for a technical complication before leaving the OR.

The standard shunt diameters were too large in four instances: three in which the posterior tibial artery required shunting as a result of concurrent posterior and anterior tibial arterial injuries (patients 2, 9, and 18) and one in which a brachial to ulnar artery shunt was placed for concurrent radial and ulnar artery transections (patient 6). Shunts fashioned from IV tubing or 2.7 mm pediatric feeding tubes were used in these cases. The feeding tubes are easier to insert and have the helpful aspect of having a rounded tip which acts as an effective vessel dilator before being trimmed off and inserted as a shunt. Others have successfully employed 2.7 mm ventriculoperitoneal shunts for this use.[30] Whatever the conduit, shunting of tibial level injuries appears to be associated with a high failure rate and a number of patients with concurrent soft tissue and osseus injuries at this level will likely regain the ability to walk more expediently with BKA and prosthesis as compared with multiple complex limb salvage procedures.[31–33] This is thought to be a decision best made at higher echelons; however, thus initial limb salvage attempt at forward units is thought to be the most appropriate course of action provided it does not put the patient's life at risk.

The FRSS was designed for use during dynamic, expeditionary maneuver types of operations such as the invasion phase of OIF when initial CASEVAC times to traditional surgical capability tend to exceed four hours.[4] The benefit of forward surgical units in a static theater such as that present during the study period, where additional flight time to reach more robust, higher echelon units was only on the order of 30 minutes, is likely less significant. It is probable that a number of patients who underwent TVS at the SSTP would have made it safely to the next echelon without a worsened outcome, however more than half of the cases were hypotensive, hypothermic, and/or acidotic on arrival from proximal vascular injuries not amenable to tourniquet control making further delay in definitive vascular control potentially fatal. Direct transfer was also problematic in many instances when the higher echelon facilities had already received multiple casualties.

CONCLUSION

The approach of the forward-based military surgeon in regards to complex extremity vascular trauma can be concisely summarized as: stop the bleeding, restore the flow, and burn no bridges for the next team. TVS is a relatively simple approach which appears to effectively accomplish this. Further experience is needed to more definitively determine the usefulness of TVS in trauma patients requiring operative intervention for complex extremity vascular injuries before MEDEVAC to higher levels of care.

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