The Use of Temporary Vascular Shunts as a Damage Control Adjunct in the Management of Wartime Vascular Injury

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Background: **While the use of vascular shunts as a damage control adjunct has been described in series from civilian institutions no contemporary military experience has been reported. The objective of this study is to examine patterns of use and effectiveness of temporary vascular shunts in the contemporary management of wartime vascular injury.**

Materials: **From September 1, 2004 to August 31, 2005, 2,473 combat injuries were treated at the central echelon III surgical facility in Iraq. Vascular injuries were entered into a registry and reviewed. Location of shunts was divided into proximal and distal, and shunt patency, complications and limb viability were examined.**

Results: **There were 126 extremity vascular injuries treated. Fifty-three (42%) had been operated on at forward locations and 30 of 53 (57%) had temporary shunts in place upon arrival to our facility. The patency for shunts in proximal vascular injuries was 86% (n = 22) compared with 12% (n = 8) for distal shunts ($p < 0.05$). All shunts placed in proximal venous injuries were patent (n = 4). Systemic heparin was not used and there were no shunt complications. All shunted injuries were reconstructed with vein in theater and early viability for extremities in which shunts were used was 92%.**

Conclusions: **Temporary vascular shunts are common in the management of wartime vascular injury. Shunts in proximal injuries including veins have high patency rates compared with those placed in distal injuries. This vascular adjunct represents a safe and effective damage control technique and is preferable to attempted reconstruction in austere conditions.**

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Historically wartime surgical experience has lead to advances in the treatment of traumatic vascular injury.[1–7] Past military conflicts have provided lessons on vascular trauma that have been applied to civilian and military surgical practice. From routine injury ligation in World Wars I and II, to the principles of rapid air evacuation and in theater repair of arterial and venous injuries in Korea and Vietnam, limb salvage has steadily improved.[1–7] Military operations in support of Operation Iraqi Freedom (OIF) represent the first mature military conflict since Vietnam to allow assessment of contemporary practices such as vascular shunts in the management of wartime vascular injuries.

Eger et al. in 1971 were among the first to report the use of temporary vascular shunts to treat combat related vascular injuries listing six benefits of this surgical adjunct.[8] Since this publication, understanding of the usefulness of shunts has come from case reports and small series mostly from civilian centers (Table 1).[9–16] This experience supports the early exploration of the injured vessel(s) and use of shunts in certain cases as part of an overall strategy in the management of vascular injury. This strategy also includes thrombectomy, administration of heparin to the injured vessel and fasciotomy of the injured extremity.

Shunts in the arterial position allow for perfusion of the extremity during transport or fixation of associated orthopedic injuries. For injury patterns involving an artery and vein, shunts placed in the venous position provide drainage and decrease venous hypertension that can compound tissue ischemia and bleeding. Despite this experience, the role of temporary vascular shunts in a present-day military vascular registry has not been reported and the frequency, pattern of use, safety, and efficacy remain unknown.

The purpose of this study is to describe a 12 consecutive month experience with temporary vascular shunts at the central Level III echelon facility in Iraq. Specifically, the objective of this report is to describe the frequency of shunt use throughout in-theater echelons of care. Included are the patterns of use, types of shunts and anatomic locations of shunt placement. A final objective is to examine the patency of vascular shunts in specific anatomic locations, as well as their safety and efficacy.

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Table 1 Shunt Small Series

Authors	Publication	Patients	Series
A. Hossny*	*J Vasc Surg* 2004;40:61–66	n = 9	Civilian
S. Sriussadaporn*, R. Pak-art	*J Trauma* 2002;52:1129–33	n = 7	Civilian
T. Granchi, Z. Schmittling, J. Vasquez	*Am J Surg* 2000;180:493–6	n = 19	Civilian
P. Reber*, A. Patel, N. Sapio	*J Trauma* 1999;47:72–76	n = 7	Civilian
A. Husain*, J. Khanderparkar, A. Tendolkar	*J Postgrad Med* 1992;38:68–69	n = 5	Civilian
I.M. Khalil, D.H. Livingston	*J Vasc Surg* 1986;4:582–587	n = 5	Civilian
J. Nichols, J.A. Svoboda, S.N. Parks	*J Trauma* 1986;26:1094–1096	n = 13	Civilian
K. Johansen, D. Bandyk, B. Thiele	*J Trauma* 1982;22:395–402	n = 10	Civilian
M. Eger*, L. Golcman, A. Goldstein	*Surg Gynecol Obstet* 1971;132:67–70	n = 36	Combat

* International experience.

MATERIALS AND METHODS

During 12 consecutive months form September 1, 2004 through August 31, 2005 10,794 patients were evacuated through the central Level III echelon (332nd EMDG/Air Force Theater Hospital) facility in Balad Air Base, Iraq. The 332nd EMDG is the first Air Force Theater Hospital since the Vietnam War (Fig. 1). Vascular injuries identified in extremities where limb salvage was attempted were entered into a registry (Balad Vascular Registry) and retrospectively reviewed. Vascular injuries associated with mangled extremities amputated in the field or upon arrival to our facility were not included in the registry.

Features of temporary vascular shunts were recorded in the Balad Vascular Registry, including anatomic location of shunt, type of shunt, shunt related complications, and the patency of the shunt upon exploration of the injury. Pulse and Doppler exams were performed on the extremities of shunted injuries; however, these data were not consistently recorded or readily obtained for the study. In contrast the more practical variable of shunt patency was noted in the record in all cases. Therefore, despite the fact that a patent shunt does not assure distal perfusion it was identified as a primary endpoint for the study. Shunt patency at the time of exploration was confirmed by continuous wave Doppler examination of the shunt as well as the presence of antegrade and retrograde bleeding upon shunt removal. For the purposes of the study, the definition of shunt related complication included dislodgement and hemorrhage and not shunt thrombosis.

Students *t* test was used to determine difference in patency between proximal and distal shunts, as well as early limb viability between the groups (proximal vs. distal shunts) with a p value of <0.05 defined as significant.

Fig. 1. *The 332nd EMDG, Balad Air Base Iraq which is the first Air Force Theater Hospital since the Vietnam War.*

RESULTS

Incidence and Distribution of Vascular Injury

During the study period, 10,794 patients were evacuated through the 332nd EMDG and 2,473 (23%) had battle related injuries. During the same period 163 major vascular injures were identified for a rate of 6.6% (Fig. 2). The anatomic distribution of major vascular injury is illustrated in Figure 3 with 126 of the injuries occurring in extremities where limb salvage was attempted. Of theses extremity vascular injuries 83 (66%) were in the lower extremity while 43 (34%) were in the upper extremity, and nearly half (n = 53; 42%) had been

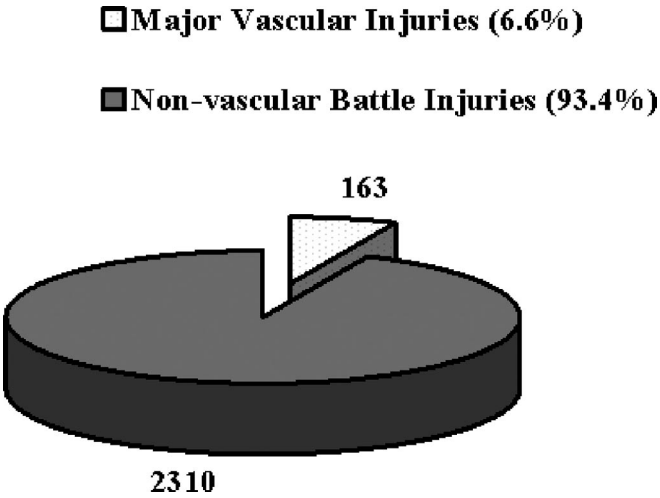

Fig. 2. *Percentage of major vascular injuries in relation to total battle related injuries. Of the 2,473 battle related injuries treated at or evacuated through the AFTH, 163 had major vascular injuries (6.6%).*

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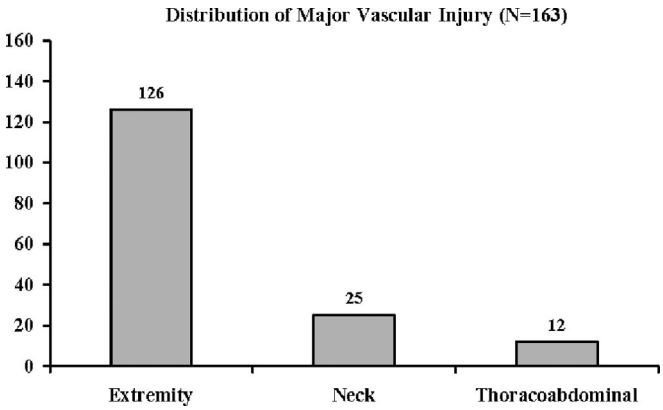

Fig. 3. *Anatomic distribution of 163 major vascular injuries treated at or evacuated through the Air Force Theater Hospital during the study period.*

treated previously at one of the five Level II echelon facilities in theater before arrival at the Air Force Theater Hospital.

Frequency and Use of Temporary Vascular Shunts

During the study period there were 30 temporary vascular shunts recorded in the Balad Vascular Registry (24% of extremity vascular injuries), and all but two had been placed at Level II echelon facilities before evacuation to our facility. The frequency of shunt use throughout the 12 month study period is illustrated in quartiles in Figure 4 and reflects a decreasing trend over time. In all cases where a temporary shunt had been placed, local thrombectomy had been performed, regional heparin administered to the injured vessel and a fasciotomy completed. Types of vascular shunts were nearly evenly divided between Javid (n = 16) and Argyle (n = 12) in line shunts while Sundt vascular shunts were used on two occasions. In 26 of 30 cases, shunts were secured in position by heavy silk ties (Fig. 5) and rubber vessel loops were used on four of the shunts. None of the cases of temporary vascular shunting were in patients receiving systemic anticoagulation.

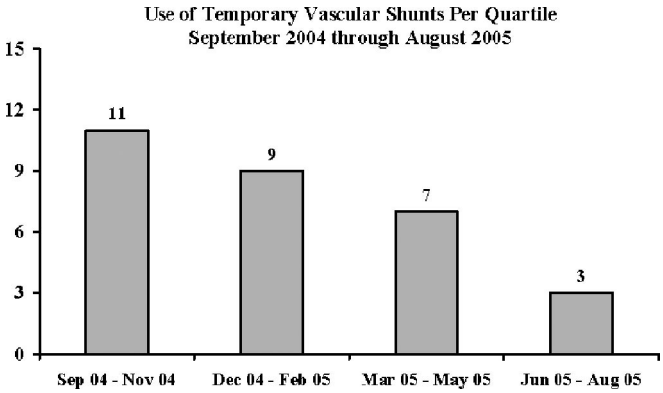

Fig. 4. *Frequency of shunt usage throughout the 12 month period in quartiles.*

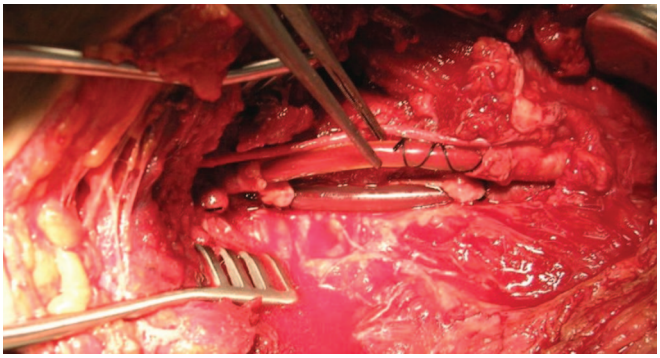

Fig. 5. *Right thigh penetrating injury resulting in disruption of superficial femoral artery and vein. Javid shunts were placed in both injured vessels at a forward Level II echelon facility and secured by silk ties before evacuation to the Air Force Theater Hospital. Both the arterial and venous shunts were patent upon arrival.*

Anatomic Distribution of Vascular Shunts

Twenty-two of the 30 shunts were proximal and eight shunts were distal. Proximal vascular injuries were defined as femoral or popliteal in the lower extremity and axillobrachial in the upper extremity. Distal vascular injuries were defined as those of the tibial arteries, or below the antecubital fossa in the lower and upper extremity, respectively. While accurate shunt times were difficult to record 28 of the 30 shunts were in place for less than 2 hours. In two cases, proximal shunts were placed in vascular injuries and the wounded patients were managed in the intensive care unit during mass casualty events, as operating rooms were used for more immediate cases. In both of these instances Javid shunts were used in the superficial femoral artery for 14 and 18 hours each and both were patent upon exploration and definitive vascular reconstruction.

Patency and Efficacy of Temporary Vascular Shunts

As illustrated in Figure 6, the patency rates were 86% for proximal shunts compared with 12% for distal shunts ($p < 0.05$). All four venous shunts placed in either femoral (n = 3) or popliteal (n = 1) veins were patent upon exploration. The pressure gradient across the three femoral vein injuries measured before repair was greater than 30 mm Hg in each case. All cases where temporary vascular shunts had been placed underwent definitive vascular repair at the Air Force Theater Hospital using autologous vein and no patients with shunts were evacuated out of the Iraqi theater. There were no instances of shunt related complication. Twenty-eight of the 30 (93%) extremities in which temporary vascular shunts were used were viable at the time of discharge from the AFTH while two required amputation (early amputation rate of 7%). There was no difference in early limb viability between the proximal and distal shunt groups (95 and 88%, respectively; p = NS; Fig. 6).

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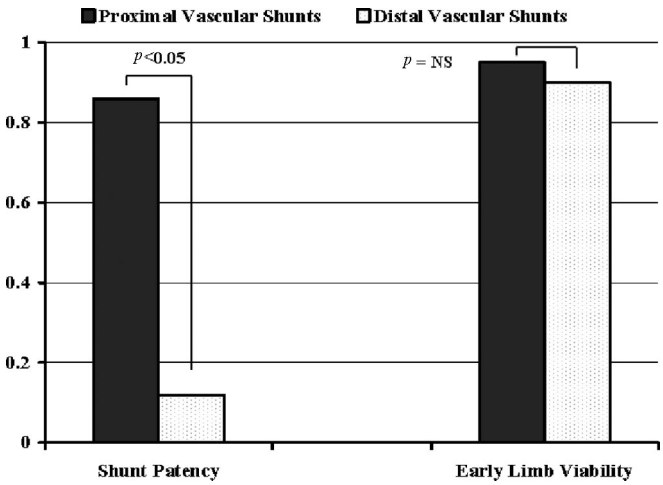

Fig. 6. *Shunt patency rates and early limb viability in cases with shunts placed in proximal vascular injuries versus distal vascular injuries.*

DISCUSSION

This report describes the role of temporary vascular shunts as a damage control adjunct in a modern wartime vascular registry. Vascular shunts are used in nearly a quarter of extremity vascular injuries and their use is primarily as an adjunct applied at forward echelon locations. Observations from this report demonstrate that the use of shunts varies over time depending upon casualty load and surgical expertise at these locations. Finally, the current study demonstrates that shunts are safe, that those placed in proximal injuries including veins have high patency rates, and that even distal shunts which often thrombose do not negatively impact early limb viability.

While Eger was among the first to report the use of temporary vascular shunts in the management of combat related vascular injuries, the technique was advocated earlier than his experience by the French in the Algerian War of 1959. The use of shunts in this era was abandoned because of long evacuation times and the high incidence of shunt thrombosis.[17] The findings of this study confirm and extend the original report of Eger from 1971 that pioneered the use of temporary vascular shunts in combat related vascular injuries.[8] While Eger's experience used shunts as a stabilizing measure during the management of associated injuries at the same facility and did not include air evacuation many of the advantages for temporary shunts noted then remain true more than 30 year later. In data from our registry and communication with surgeons at forward echelon locations where the most shunts were placed it is apparent that thrombectomy, application of heparin to the injured vessels and fasciotomy accompanied shunt placement.[18] Vascular injuries treated at Level II echelon facilities were explored within 30 minutes and it may be that this early and aggressive practice played as important a role in certain injuries as the shunts themselves. This may be especially the case in instances where the shunt failed but the limb remained viable.

Patency of Proximal and Distal Shunts

The observation of patency rates between proximal and distal shunts deserves comment and may reflect both the technical challenge of the placement of these shunts in small vessels as well as associated austere conditions. Distal vessels which are small at baseline are prone to significant spasm in injured patients who are cold and in shock which limits outflow and patency. Proximal shunts in contrast were in larger vessels more technically suited for shunt placement and with higher flow rates which reduce the likelihood of shunt failure.

Indications for Distal Shunts

It is valid to question the indication for shunt placement in the distal vascular injuries and to note that some may have been ligated without loss of eventual viability. Many distal injuries such as those to the tibial arteries (anterior tibial, posterior tibial, and peroneal), the forearm arteries (radial and ulnar) and even the brachial artery distal to the profounda may be ligated with adequate collateral circulation to maintain a viable extremity.[1] In cases of distal injury continuous wave Doppler is a proven and useful tool to assess collateral flow and evaluate the need for shunt placement or formal revascularization.[19] In the setting of distal vascular injury and an audible Doppler signal in the foot or hand, placement of a shunt is not necessary if the limb can be reassessed within a number of hours.

The eight distal shunts in this series were placed at forward Level II facilities in the setting of open and exposed vascular injuries. In these cases Doppler was not feasible and patency of other distal collaterals was in question. Shunts were inserted rapidly in lieu of ligation thinking they may provide benefit and the patient quickly evacuated. From discussions with a skilled Level II team (Marine Corps Forward Resuscitative Surgery System or FRSS) lead by Chambers et al. the option of ligation was difficult at times as conditions limited utility of Doppler and did not permit repeat examination of unconscious patients.[18]

Although some distal injuries may have been ligated without limb compromise it does not appear that use of shunts in distal injuries was detrimental. Early limb viability rates were no different for the distal shunts than in proximal shunts (Fig. 6) and exploration of the injuries was often simplified by the presence of the shunt. Even in cases where they failed, shunt removal followed by thrombectomy, regional heparin, and reconstruction at the Air Force Theater Hospital was possible. While it may be true that some distal vascular injuries may have been ligated with no adverse outcome, it is also clear that certain proximal injuries would have resulted in amputation without such an aggressive approach including shunts.

Use of Temporary Shunts Over Time

The finding that the use of shunts varied over the course of the time (Fig. 4) reflects several factors. The majority of

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shunts recorded in the registry occurred during and after the Fallujah offensive of November 2004 when large numbers of casualties were treated at the Level II echelon facility near the offensive.[18] The need for this damage control adjunct as a method of stabilizing and moving patients was greatest during this time. In addition, surgical experience and expertise on the ground during this offensive made the more frequent use of the adjunct possible. As casualty numbers decreased over the course of 12 months, conditions became less austere and a greater percentage of injured became Iraqi forces or civilians the need for shunts or our ability to record their use diminished.

Study Limitations

The limitations of this study are apparent in the paucity of follow up of patients having had shunts as damage control adjuncts. While projects are ongoing to assess the longer-term implications of temporary shunts the short-term experience on safety and efficacy has merit. This study is also limited in the multiple echelons through which patients with shunts were treated. With an increasing number of treatments sites the collection of data becomes more difficult. Despite this limitation the central location of the Air Force Theater Hospital as the main air evacuation facility allowed for the establishment of a practically inclusive vascular registry from which this data were collected. Lastly although this description of 30 patients is large by comparison to recent series and case reports the numbers are too small to draw conclusions with regard to the efficacy of temporary shunts and limb salvage. Undoubtedly improved limb salvage rates observed in theater are because of system wide advances such as forward allocation of surgical assets, rapid air evacuation and in theater repair of vascular injuries with vein.

In conclusion temporary vascular shunts were used for damage control in approximately one quarter of patients with vascular injuries in the extremities treated at the Air Force Theater Hospital in Balad, Iraq over a 12-month period. Shunts placed in proximal vascular injuries have high patency rates although failure of distal shunts does not appear to decrease early limb viability. The use of this vascular adjunct represents a safe and effective damage control technique and is preferable to attempted reconstruction in austere conditions.

REFERENCES

1. DeBakey ME, Simeone FA. Battle injuries of the arteries in World War II. *Ann Surg.* 1946;123:534.
2. Hughes CW. The primary repair of wounds of major arteries; an analysis of experience in Korea in 1953. *Ann Surg.* 1955;141:297–303.
3. Hughes CW. Acute vascular trauma in Korean War casualties; an analysis of 180 cases. *Surg Gynecol Obstet.* 1954;99:91–100.
4. Jahnke EJ Jr, Hughes CW, Howard JM. The rationale of arterial repair on the battlefield. *Am J Surg.* 1954;87:396–401.
5. Rich NM, Hughes CW. Vietnam vascular registry: a preliminary report. *Surgery.* 1969;65:218–226.
6. Rich NM, Baugh JH, Hughes CW. Popliteal artery injuries in Vietnam. *Am J Surg.* 1969;118:531–514.
7. Rich NM, Baugh JH, Hughes CW. Acute arterial injuries in Vietnam: 1,000 cases. *J Trauma.* 1970;10:359–369.
8. Eger M, Golcman L, Goldstein A, et al. The use of a temporary shunt in the management of arterial vascular injuries. *Surg Gyn and Obst.* 1971;132:67–70.
9. Hossny A. Blunt popliteal artery injury with complete lower limb ischemia: is routine use of temporary intraluminal arterial shunt justified? *J Vasc Surg.* 2004;40:61–66.
10. Sriussadaporn S, Pak-art R. Temporary intravascular shunt in complex extremity vascular injuries. *J Trauma.* 2002;52:1129–1133.
11. Granchi T, Schmittling Z, Vasquez J, et al. Prolonged use of intraluminal arterial shunts without systemic anticoagulation. *Am J Surg.* 2000;180:493–497.
12. Reber PU, Patel AG, Sapio N, Ris HB, et al. Selective use of temporary intravascular shunts in coincident vascular and orthopedic upper and lower limb trauma. *J Trauma.* 1999;47:72–76.
13. Husain AK, Khandeparker JM, Tendolkar AG, et al. Temporary intravascular shunts for peripheral vascular trauma. *J Postgrad Med.* 1992;38:68–69.
14. Khalil IM, Livingston DH. Intravascular shunts in complex lower limb trauma. *J Vasc Surg.* 1986;4:582–587.
15. Nichols JG, Svoboda JA, Parks SN. Use of temporary intraluminal shunts in selected peripheral arterial injuries. *J Trauma.* 1986; 26:1094–6.
16. Johansen K, Bandyk D, Thiele B, Hansen ST Jr. Temporary intraluminal shunts: resolution of a management dilemma in complex vascular injuries. *J Trauma.* 1982;22:395–402.
17. Rich NM, Spencer FC. *Vascular Trauma.* Philadelphia, PA: WB Saunders, 1978.
18. Chambers LW, Rhee P, Baker BC, et al. Initial experience of US Marine Corps forward resuscitative surgical system during Operation Iraqi Freedom. *Arch Surg.* 2005;140:26–32.
19. Lavenson GS Jr, Rich NM, Strandness DE Jr. Ultrasonic flow detector value in combat vascular injuries. *Arch Surg.* 1971; 103:644–647.

DISCUSSION

Dr. Christopher J. Dente (Atlanta, Georgia): In this study, the authors describe their experience in a central Level III Air Force facility in Iraq with the treatment of soldiers who have had temporary vascular shunts placed in forward facilities.

In the manuscript, the stated goals are to describe both the frequency and patterns of use of these shunts, as well as their patency, safety and efficacy, with the latter being measured presumably by limb salvage rates.

The study boils down to a review of 30 patients who received temporary shunts over a 12-month period. This was from a population of 126 patients with initially salvageable extremities after a major extremity vascular trauma.

No patients were anti-coagulated while the shunt was in place, and the vast majority of shunts were in place for two hours or less, according to the manuscript.

For proximal shunts, patency was very good at 86 percent compared to 12 percent for distal shunts. Limb salvage was also excellent with only two early amputations.

It is nice to see that a technique, originally described by a military surgeon and a technique that is now widely used in civilian centers, is still being used to help salvage extremities in our young men and women in Iraq.

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I have several comments and questions for the authors. Number 1, several different types of shunts were used, presumably based on the experience and preference of the forward surgeon.

I, personally, favor the Argyle shunt for its simplicity and have had good results with it. You state in the manuscript that there were no shunt specific complications, but was there any difference in the patency rates, or were there any cases of shunt dislodgement?

What was the caliber of the shunts that were used? Which shunt do you personally recommend? Number 2, you had two early amputations. Were these the result of a failed shunt? Please elaborate.

Number 3, the vast majority of your shunts were in place for less than two hours and placed mostly to allow for transport out of a forward setting. The two-hour time frame seems surprisingly short to me.

In civilian centers, shuts are generally placed to allow for perfusion during orthopaedic fixation or during a true damage control procedure to allow a patient to recover homeostasis.

I would think your patient population is more akin to the former of these two. For damage control, as the term is used in civilian centers, most shuts stay in longer than two hours with excellent patency. And in one report a shunt was left in for as long as ten days.

What was the rush to get these shunts out? How sick were these patients when they arrived in your operating room? Were these patients all isolated vascular injuries without bony involvement? And do you allow your orthopaedics to fixate the bones prior to definitive revascularization?

Are there situations you would leave a shunt in longer? Is this truly a damage control adjunct, as stated in the title of your paper, or is it more correctly a mass casualty management adjunct?

Finally, I read with interest your discussion on the eight distal shunts. From my review of the literature, we have very limited experience with shunts distal to the popliteal or brachial artery. I could find only one such shunt in the series I reviewed.

In fact, most would agree that distal vessels can be safely ligated, although it is noted that in less austere settings, we are better able to follow an extremity's viability after ligation.

You state in the manuscript that the forward surgeons placed these shunts in open and exposed vascular injuries with the patency of other distal collaterals was in question.

Furthermore, you state that attempted shunting could be justified because it didn't alter limb salvage rates. Still, after only two hours, only one of these shunts was patent.

I ask then, can you really make the statement that it didn't alter limb salvage rates with an experience of only eight patients? Do you have any data on patients who underwent ligation of these distal vessels at the forward facilities in your database? And did these patients tolerate ligation?

I think it boils down to whether or not it's really worth the extra five minutes it takes to shunt the patient if most of these shunts are going to thrombose, especially when you're dealing with mass casualties.

Is it worth the risk of shunt dislodgement and blood loss if it is not going to work? All this being said, do you still recommend your forward surgeons use this technique for patients with distal injuries?

Dr. Todd E. Rasmussen (Lackland AFB, Texas): Regarding the type of shunts, the vast majority used in theater are Argyle or Javid. The Javid shunts were used in the superficial femoral artery and vein most commonly.

The Argyle shunts were used in the tibial and brachial arteries. Both the Argyl and Javid are inline shunts while the few Sundt shunts we saw in theater were either in-line or looped.

We did not see any differences in patency rates between the different types of shunts, although we didn't look specifically at that, because the numbers were small. I will say that all of the distal shunts were Argyles, which come in eight, ten, twelve, and I believe fourteen French. If the patency rate was less in one type of shunt versus another, I don't think it was probably due to the type of shunt itself but more likely from vessel size and other factors.

Of the two early amputations which occurred in shunted limbs, one occurred because of distal thrombosis of the outflow. This patient was taken back early in our experience and the shunt found to be patent. Definitive reconstruction was performed with interposition vein, but perfusion of the distal leg and foot failed. It was difficult to tell whether or not it was related to specifically to the shunt. Again, the shunt, on re-exploration, was patent.

It is difficulty to comment on limb salvage rates, for sure. The numbers in the study are too small and the follow up is too limited. We used the term "early limb viability" meaning that the graph was open, the limb was well perfused at the time of their discharge. We're currently working with the folks a Walter Reed and Bethesda to track some of the patients and get meaningful numbers on limb salvage.

The short two-hour placement of the shunts probably speaks to their relative effectiveness and the lack of damage from some of the distal shunts that may have thrombosed. The fact is that in the theater as it currently stands, the evacuation patterns are fast enough that the shunts are removed and definitive repair performed within hours which is a pretty short period of time.

With regards to the condition of the patients when they arrive at our facility, the shunts were left in place until they were stable enough to undergo reconstruction. So if they were too unstable or had head injury or other urgent operations that needed to be done or just even if they simply required resuscitation, those measures were performed while the shunt was left in place and then vascular reconstruction performed when they were more stable.

Approximately one-third of our patients had associated orthopedic injury. In these we would leave the shunts in place

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while the orthopedic injuries were stabilized and then perform definitive vascular repair.

As I've written over the manuscript here the last week or two, the term "damage control" versus "mass casualty" is -debatable and your point is well taken. We looked at, and there is in the manuscript, a trend of the use of shunts over time. The volume of shunts were clearly the greatest during the Fallujah campaign, Operation Phantom Fury and several of the major offensives where the casualty flow exceeded the capacity of the air evaluation system. In this setting of high casualty flow many casualties were treated out of necessity at Level II facilities. In these settings, temporary vascular shunts were, in a sense, used as a mass casualty technique or strategy almost as much as a damage control strategy, so again your point is well taken.

Dr. Henry J. Schiller (Rochester, Minnesota): In Operation Iraqi Freedom II, there was really a discouragement of Army FST surgeons operating, because it was felt that FSTs were static, we had air superiority and that evacuation times were so short that time spent at the FST was really just going to introduce delay and lead to hypothermia and acidosis coagulopathy.

I guess my question is, were the placement of these early shunts a useful thing, or should the patient have just been transported? And did you see hypothermia, acidosis and coagulopathy?

Do you have any idea, were these coming from more robust Navy surgical companies or from relatively austere forward surgical teams from the Army?

Dr. Todd E. Rasmussen: The answer to your last question first: the vast majority, probably two-thirds of the shunts, came from Lowell Chambers and the Level II Navy group near Fallujah. They were exceptionally skilled and aggressive and I think because of casualty numbers often times used shunts out of necessity. Colonel Don Jenkins may be able comment more appropriately but at times the ability to get patients out of the Level IIs or get them to Level IIIs was limited because of casualty flow, casualty evacuation capacity and, at even times, the weather.

As you know, we can't fly the choppers during the sandstorms or during other adverse weather conditions. But most of temporary vascular shunts were placed by a select two or three different Level IIs that were very aggressive and skilled at it.

I've gone round and round with Dr. Rich about the effectiveness of the Level IIs facilities in theater. He has fascinating insight, because the forward deployment of Level II resources is arguably a new concept since his vast experience in Vietnam. He often points out that there weren't defined Level IIs so-to-speak in Vietnam, and the vascular injuries were explored at what today would be a Level III facility.

I think that there are times when the Level II skill, such as Dr. Chambers and team, is critical during mass casualties when there are major offensives going on, longer distances from Level IIIs. In these conditions I think that the use of the shunts and the demployment of Level II skill is critical. In contrast to that, when the air evacuation system is not stressed, there are no major offensives, and an isolated injury occurs 45 minutes from a Level III facility, then a Level II is less critical.

But I think it's important, as you know, to review this type of experience and to communicate the information so we can make appropriate changes and not have an injured soldier or airman stop at Level II when it's not needed. But I think it changes or it's fluid with events on the ground.

Dr. Jeff Casher (Philadelphia, Pennsylvania): In my prior experience before coming back to the states with Joram Kluger In Israel, we placed about four or five shunts in the multi-dimensional trauma, blast injury patients that we saw in Tel Aviv.

I just want to emphasize that I think this is a very important adjunct in damage control. My gut feeling is that it seems to be very under-utilized.

It's very tempting in many of these multiply-injured patients, when you've already exposed the artery, to go ahead and do your repair in the face of your fasciotomy.

I think that in a multiple injured patient with other damage control procedures, such as the orthopedic, the abdomen, associated head injury, pulmonary injuries, this is a very important adjunct to keep in mind in these patients to go ahead and put the shunt in and come back to live another day.

Dr. Todd E. Rasmussen: Certainly Edger's report and the Israeli experience have been important. One thing I will say, is that the use of the shunts in the veins is impressive and was new to me. I was naïve and the first several Javid shunts that we saw in the superficial femoral vein, we thought for sure would be thrombosed which was not the case. Temporary vascular shunts into the proximal veins were nearly always patent.

When one brings this finding up to Dr. Rich, he points out that it may be as important to shunt the vein as the artery to decreased venous hypertension and bleeding from the injured extremity.

Dr. Bruce Bennett (St. Paul Minnesota): One question that came from my partner in Fallujah was given the unknown time to definitive repair or patients with isolated vascular injuries, is it worthwhile giving them a dose of low molecular rate heparin or even unfractionated heparin sub-q, i.e., a therapeutic dose, prior to their leaving the 2E? Could you comment on that?

Dr. Todd E. Rasmussen: I don't know if I mentioned the answer to one question about shunt dislodgement. We didn't have any episodes that we were aware of, of shunt dislodgement. Most of the shunts were secured with silk ties which seemed kind of rough, but again, none of the shunt became dislodged or precluded definitive repair.

With regards to the heparin, what we've shown is that they don't require this type of anticoagulation to remain patent. There is also some risk to the use of lovenox in these

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cases, especially with the relative inability to reverse a therapeutic dose of low molecular rate heparin or even systemic heparin in theater.

For these reasons, I would not advocate using heparin. It may also depends upon on the length of evacuation. But if shunts can be anticipated to be removed in two to four hours, I would not use anticoagulation, only because I think it may increase the risk of shunt related complications.

If on the other hand, and we've had several shunts from Afghanistan sent to Germany during OEF, one anticipates a longer and stable air evacuation anticoagulation may be reasonable. However our goal now in Iraq is that no the shunts leave theater.

The early experience from OEF in Afghanistan, where there were a few shunts that were air evacuated nine or ten hours to Germany were not part of this report. I think in those cases, if it's an isolated extremity injury and you don't anticipate isolated vascular injury, and one does not anticipate shunt removal within two to four hours, then heparin would be a reasonable option.

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