

The Experience of the US Marine Corps' Surgical Shock Trauma Platoon With 417 Operative Combat Casualties During a 12 Month Period of Operation Iraqi Freedom

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Background: The Forward Resuscitative Surgical System (FRSS) is a small, mobile trauma surgical unit designed to support modern US Marine Corps combat operations. The experience of two co-located FRSS teams during 1 year of service in Operation Iraqi Freedom is reviewed to evaluate the system's efficacy.

Methods: Between March 1, 2004, and February 28, 2005, two FRSS teams and a shock trauma platoon were co-located in a unit designated the Surgical Shock Trauma Platoon (SSTP). Data concerning patient care before and during treatment at the SSTP was maintained prospectively. Pro-

spective determination of outcomes was obtained by e-mail correspondence with surgeons caring for the patients at higher echelons. The Los Angeles County medical center (LAC) trauma registry was queried to obtain a comparable data-base with which to compare outcomes.

Results: During the year reviewed there were 895 trauma admissions to the SSTP. Excluding 25 patients pulseless on arrival and 291 minimally injured patients, 559 of 579 (97%) combat casualties survived; 417 casualties underwent 981 operative procedures in the two SSTP operating shelters. There were 79 operative

patients with a mean injury severity score of 26 (range, 16–59) and mean revised trauma score of 6.963 (range, 4.21–7.841) who had sustained severe injuries. Ten (12.7%) of these casualties died while 43 of 337 (12.8%) deaths were seen with comparable cases treated at LAC.

Conclusions: Small task-oriented surgical units are capable of providing effective trauma surgical care to combat casualties. Further experience is needed to better delineate the balance between early, forward-based surgical intervention and more prolonged initial casualty evacuation to reach more robust surgical facilities.

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Current US Marine Corps (USMC) tactics involve frequent use of dynamic combat operations that can result in injuries occurring at great distances from traditional surgical units.^{1,2} To prevent this from causing inordinate delays in surgical intervention and resultant worsened outcomes, the US Navy and USMC developed rapidly mobile eight person trauma surgical teams called the Forward Resuscitative Surgical System (FRSS) designed to work in relative close proximity to combat operations.

Initial use of the FRSS and its associated forward emergency medical unit called the Shock Trauma Platoon (STP) with 90 operative casualties sustained during the invasion phase of Operation Iraqi Freedom (OIF) produced good results with no coalition deaths through discharge from Echelon V continental US medical centers and only one possibly preventable Iraqi death.² This provided encouragement of the system's efficacy but the relatively small number of cases prevented definitive analysis of performance. When the USMC returned to Iraq to assist with the ongoing security and stabilization phase in March 2004, surgical support in the USMC area of responsibility included two FRSS teams and a STP co-located in a unit dubbed the Surgical Shock Trauma Platoon (SSTP). The SSTP was strategically located at Al Taqaddum, a former Iraqi airbase midway between the volatile cities of Ramadi and Fallujah. The purpose of this report is to document the experience of this unit during 1 year of OIF (between March 2004 and March 2005) and assess the effectiveness of trauma surgical care provided.

METHODS

The methods of the FRSS and task-oriented units created by combining FRSS teams such as the SSTP have been previously described.^{2,3} The fundamental strategy of these units is tactical surgical intervention, the selective use of damage control or definitive trauma surgery for combat casualties in the forward setting as dictated by the physiologic

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status of the patient, the number and condition of other concurrently received casualties, the status of the unit's resources, and the overall tactical situation. The SSTP was staffed by one orthopedic and three general surgeons and, because of the relatively static nature of ongoing operations, was supplemented by basic digital X-ray capability not typically utilized by the FRSS. A summary of the personnel manning the SSTP during the interval examined is listed in Figure 1. Postoperatively patients underwent rotary wing medical evacuation (MEDEVAC) to the closest next higher echelon surgical units which during the period under discussion were the Echelon III units of an Army Combat Support Hospital (CSH) in Baghdad and an Air Force Expeditionary Medical Group based at Balad.

Data concerning admission and care of each SSTP patient was maintained prospectively. The subsequent course of all coalition operative patients at each echelon through discharge from continental United States medical centers was obtained by prospective e-mail correspondence with the surgeons treating them at higher echelons and by subsequent review of the patients' medical records. Follow-up on Iraqi operative patients was limited to their discharge from the Echelon III medical units in Baghdad and Balad.

To provide a roughly equivalent civilian patient population with which to compare outcomes, the Los Angeles County, CA (LAC) medical center's trauma database was queried from 2000 through 2005 for all males between the ages of 15 to 30 with gunshot wounds and an ISS >15. All LAC patients with penetrating head trauma were excluded as were all patients with ISS >59 as neither of these categories of patients received operative intervention at the SSTP. Patients who arrived pulseless at LAC were tabulated to compare with the SSTP subset but were excluded from further operative mortality analysis. Utilizing injury severity scoring both SSTP and LAC patients were then grouped as severe (ISS 16–24) or very severe (ISS >24) trauma and the mortality of the two groups compared with χ^2 analysis.

The cases of SSTP operative patients who ultimately died were carefully analyzed and formally presented to a panel of trauma surgeons at the 11th Annual San Antonio Trauma Symposium in August 2005, to obtain assessment of preventability of death in each instance.

RESULTS

Between March 1, 2004 and February 28, 2005, 1096 patients were seen at the SSTP. There were 895 trauma admissions the breakdown of which is listed in Figure 2. There were 291 patients with relatively minor wounds who rapidly returned to duty that were excluded from further analysis and from mortality calculations. Twenty-five patients presented to the SSTP in cardiac arrest because of traumatic mechanisms which are tabulated in Table 1. All 11 of these patients with injuries limited to the torso and or extremities underwent resuscitative thoracotomy and other operative procedures in attempts to revive them with transient

- **Operative Team** (FRSS x 2)
 - General Surgeon – 3
 - Orthopedic Surgeon – 1
 - Anesthesia Provider – 2
 - Critical Care Nurse – 2
 - Surgical Technician – 4
 - Basic Corpsman – 2
 - Advanced Corpsman – 2
- **Administrative Team**
 - Administrative Officer – 1
 - Patient Admin Clerk – 2
 - Supply Petty Officer – 1
- **Triage/Resusc Team** (STP)
 - EM Physician – 2
 - EM Nurse – 1
 - Physician Assistant – 1
 - Basic Corpsman – 16
 - Marines – 5
(Comms, Utilities, Drivers)
- **En-Route Care Nurse** – 4
- **Ancillary Services Team**
 - Basic X-ray Technician – 2
 - Basic Lab Technician – 1

Abbreviations: EM – Emergency Medicine
FRSS – Forward Resuscitative Surgical System,
STP – Shock Trauma Platoon

Fig. 1. Surgical Shock Trauma Platoon (SSTP) Composition.

success in eight but none were ultimately salvaged. During the 5 years analyzed 35 of 230 (15%) male patients between 15 to 30 years of age with gunshot wounds to the torso and/or extremity who were pulseless on arrival at LAC underwent formal operative intervention with three survivors.

Excluding patients who were pulseless on arrival, there were 579 significantly injured casualties evaluated at the SSTP of which 559 (97%) survived while 20 (3%) died. Nine patients who ultimately died and 164 surviving patients underwent MEDEVAC to the next echelon without undergoing formal operative intervention at the SSTP and the indications for MEDEVAC in these cases are listed in Table 2. Of the nine nonoperative deaths six had penetrating head injuries and three had greater than 80% total body surface burns.

There were 417 patients who underwent 981 operative procedures in the two SSTP operating shelters, a summary of which is listed in Table 3. There were 408 (98%) of operative casualties that were males with mean and median ages of 26 and 23 years (range, 5–70), respectively. The majority of casualties undergoing operative intervention at the SSTP were American military (72%); however, civilians (13%), insurgents (11%), and Iraqi military members (4%) were also treated. The primary mechanism of injury of operative casualties is represented in Figure 3. High energy mechanisms of wounding were present in 394 (94%) of all operative patients with improvised explosive devices (IEDs) causing 65% of

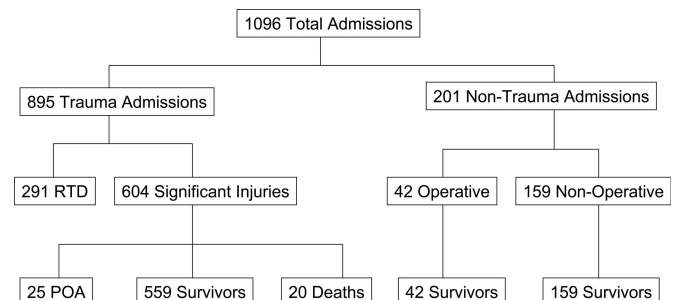


Fig. 2. Patient Summary. Abbreviations: POA – Pulseless on Arrival, RTD – Returned to Duty.

Table 1 Mechanisms of Injury in SSTP Patients Presenting in Cardiac Arrest

Pathogenesis of Death	No. of Cases
Torso hemorrhage	10
Penetrating head trauma	9
Neck hemorrhage	4
Extremity hemorrhage	1
Electrocution	1
Total	25

American operative injuries and high velocity gunshot wounds causing 68% of Iraqi injuries. There were 327 (78%) operative cases performed on patients with ISS <16 with one (0.3%) death. The single death in the low to moderately traumatized group by ISS grading occurred in an Iraqi insurgent who sustained a significantly destructive abdominal wall injury with multiple enterotomies (Fig. 4). Tactical considerations caused significant delay in casualty evacuation (CASEVAC) and the patient was in shock when he finally arrived at the SSTP 6 hours after injury. He initially stabilized after a damage control celiotomy and abdominal wall debridement and was stable throughout subsequent MEDEVAC to the CSH. Despite initial debridement back to healthy appearing and bleeding tissue followed by multiple subsequent debridements, the patient ultimately died from a rapidly progressive abdominal wall necrotizing fasciitis. Because of the prolonged delay in initial CASEVAC his death was regarded as potentially preventable from a trauma system standpoint but nonpreventable from a unit efficacy standpoint by the San Antonio panel.

Including patients who were pulseless on arrival there were 90 patients with severe or very severe trauma who underwent operative intervention at the SSTP with an overall mortality of 23%. A breakdown of SSTP operative mortality relative to the anatomic severity of injury is listed in Table 4 alongside similarly injured patients treated at the LAC Level I trauma center with equivalent mortality being demonstrated in each subset. A similar analysis excluding patients pulseless on arrival is presented in Table 5, again with equivalent outcomes being noted. The mean ISS and mean revised

Table 2 Summary of Nonoperative MEDEVAC Patients' Injury Patterns

Reason for MEDEVAC	No. Transferred	No. Deaths
Soft tissue wound care	47	0
Neurosurgical consult	34	6
Fracture care	23	0
Ophthalmology consultation	18	0
Diagnostic imaging	15	0
OMF/ENT consultation	13	0
Burn care	9	3
Chest tube care	9	0
Nonsurgical critical care	5	0
Total	173	9

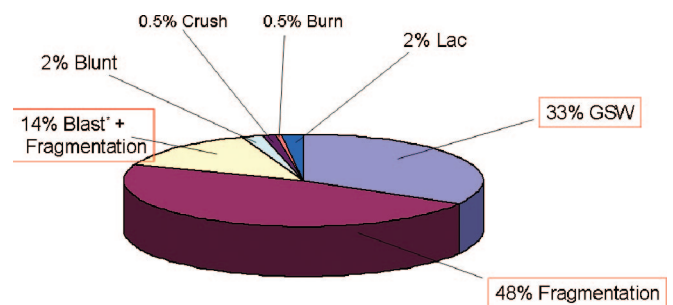
Table 3 Summary of Operative Procedures

Procedure	Total
Head and neck	53
21 Thoracotomies	33
31 Damage control celiotomies	166
45 Definitive celiotomies	
Torso DID	106
Major amputation	26
Extremity major vascular	62
Fasciotomy/escharotomy	45/2
External fixation	54
Digit amputation	13
DIS	160
DID	261
Total	981

Abbreviations: DIS, debridement, irrigation, and splinting; DID, debridement, irrigation, and dressing.

trauma score (RTS) of each subset are listed in Table 6 demonstrating comparable anatomic and physiologic severity of injuries seen at the SSTP and Level I trauma center. The subset of patients who died after arriving with a pulse from both facilities' experiences were also comparably injured with a mean ISS of 35 (range, 20–59) and mean RTS of 5.918 (range, 3.63–7.841) at the SSTP as compared with a mean ISS of 31 (range, 16–54) and a mean RTS of 5.948 (3.221–7.841) at LAC.

The 11 SSTP operative deaths were formally presented in detail to a panel of five trauma surgeons during the 11th San Antonio Trauma Symposium in August 2005. From a trauma system standpoint, six deaths were felt to be nonpreventable while four deaths were viewed as potentially preventable along with one preventable death. The major factor contributing to mortality in three of the potentially preventable deaths were prolonged delays in transport (mean 160 minutes with range 55–360 minutes). Excluding this factor and considering the condition of the patient on arrival for evaluation of surgical unit efficacy, nine deaths were deemed



Note: Blast + Fragmentation denotes patients with primary and secondary blast injuries while Fragmentation denotes secondary blast injuries only.

Fig. 3. Mechanism of Injury, All Operative Cases (n = 417). Note: Blast + Fragmentation denotes patients with primary and secondary blast injuries while Fragmentation denotes secondary blast injuries only.



Fig. 4. Casualty with Abdominal Wall Destruction.

nonpreventable, one potentially preventable, and one preventable. Both the potentially preventable and preventable death resulted from complications occurring at higher echelon medical facilities after the patient left the SSTP.

The maximum number of casualties received simultaneously was 14, the most received within 24 hours was 44 and the maximum number of operative cases in a single day was 17. At no point were SSTP resources overwhelmed. Although a number of rocket attacks near the SSTP position occurred no unit members became casualties.

DISCUSSION

Civilian trauma systems have been shown to reduce trauma-related mortality by decreasing delays to expert trauma care and by concentrating care of severely injured patients to centers with high levels of experience with and an institutional emphasis on trauma management.⁴⁻⁷ Although there are many similarities between civilian and military trauma care, multiple additional logistic challenges unique to the combat environment cause increased difficulty in effectively managing multiply traumatized casualties of war.⁸

One of the largest obstacles faced in dynamic warfare such as that experienced in Desert Storm and the initial invasion phase of OIF is the extremely rapid movement of combat elements. This tends to result in delays of greater than 4 hours in transporting combat casualties from the site of injury to traditional military surgical units such as the surgical companies and clearing houses utilized by the Navy in recent conflicts before OIF.⁹⁻¹¹ Bellamy's review of the Wound Data Munitions Effectiveness Team data from Vietnam suggests that approximately 15 to 25% of combat casualties die from exsanguination during this time frame.⁸ Similar observations were made by Gofrit in the Lebanon War.¹² A recent retrospective review of the Pennsylvania trauma registry demonstrated a one percent increase in mortality rate for each minute of delay to celiotomy up to 90 minutes in isolated abdominal trauma patients with

Table 4 Severe Trauma Operative Mortality, SSTP and LAC Including Patients Pulseless on Arrival

Trauma Severity	SSTP Mortality	LAC Mortality	<i>p</i>
Severe (ISS 16–24)	2/38 (5.3%)	15/191 (7.9%)	0.75
Very severe (ISS >24)	19/52 (36.5%)	60/181 (33.1%)	0.74
All (ISS 16–59)	21/90 (23.3%)	75/372 (20.2%)	0.56

Abbreviations: ISS, Injury Severity Score; LAC, LA County Hospital; SSTP, Surgical Shock Trauma Platoon.

hypotension on initial presentation.¹³ Such observations underscore the importance of providing more proximate trauma surgical capability during dynamic combat operations than that afforded by traditional surgical units. The US Navy and Marine Corps response to this challenge was development of the FRSS. These single OR, eight person trauma surgical teams were designed to be set up within 1 hour by an experienced team and to be capable of performing up to 18 major operative procedures within 48 hours without relief or re-supply. Both parameters were found achievable with good outcomes during the invasion phase of OIF.^{2,3} To enhance preoperative triage and postoperative holding capability each FRSS is, by doctrine, deployed with a supporting STP that is a 25 person forward emergency medical unit. Before the initial deployment of the FRSS in the invasion phase of OIF the relatively limited capacity of a single team was recognized and emphasis was placed on providing more robust (but equally maneuverable) units in areas where large numbers of casualties were anticipated. This is readily accomplished by co-locating two or more FRSS teams in task-oriented fashion. Orthopedic surgeons or other specialists can then fill one of the surgical positions, allowing for some specialization of care without diminishing the effectiveness of the basic general trauma surgical mission. This worked well during the invasion phase of OIF with the majority of forward operative care in the Marine Corps Theater being effectively provided by two co-located FRSS teams. Forward surgical capability was felt to contribute to the historically low mortality rates seen in the Marine Corps Theater during that time with a minimum of nine percent of operative cases felt to represent salvages which would not have occurred had the FRSS not been utilized.²

Impressed with the success of the FRSS-based model of combat surgical care during the invasion phase, the US Navy and Marine Corps elected to again rely heavily upon these units when returning to the Iraq theater in March 2004, placing a task-oriented combination of two FRSS teams and

Table 5 Severe Trauma Operative Mortality, SSTP and LAC, Excluding Patients Pulseless on Arrival

Trauma Severity	SSTP Mortality	LAC Mortality	<i>p</i>
Severe (ISS 16–24)	1/37 (2.7%)	8/184 (4.3%)	0.644
Very severe (ISS >24)	9/42 (21.4%)	35/153 (22.9%)	0.842
All severe (ISS 16–59)	10/79 (12.7%)	43/337 (12.8%)	0.98

Abbreviations: ISS, Injury Severity Score; LAC, LA County Hospital; SSTP, Surgical Shock Trauma Platoon.

Table 6 Anatomic and Physiologic Injury Severity of Operative Cases, SSTP, and LAC

Severity Class	SSTP Mean ISS (range)	LAC Mean ISS (range)	SSTP Mean RTS (range)	LAC Mean RTS (range)
Severe	18 (16–24)	18 (16–24)	7.118 (3.92–7.841)	7.549 (2.93–7.841)
Very severe	33 (25–59)	31 (25–59)	6.840 (3.63–7.841)	7.075 (2.93–7.841)
All severe (ISS 16–59)	26 (16–59)	24 (16–59)	6.963 (3.63–7.841)	7.33 (2.93–7.841)

Abbreviations: ISS, Injury Severity Score; LAC, LA County Trauma Center; RTS, Revised Trauma Score; SSTP, Surgical Shock Trauma Platoon.

a STP in tactical position at Al Taqaddum in a unit now designated the Surgical Shock Trauma Platoon. Consequently, these units which were designed for use during a dynamic theater were now tasked for use within a static theater. This has some potentially negative effects in regards to resource allocation and overall trauma system efficiency. In a static theater a good argument can be made for concentrating significant casualty receiving at a few Echelon III trauma surgical facilities rather than scattering it among multiple smaller units which, in the current static theater, offer an average difference in transport time to surgical capability of only about thirty minutes. Nonetheless, the experience of these units with multiple severely injured casualties during the study period presents the opportunity to critically analyze their effectiveness in trauma management with important implications for medical planners considering deploying these units in the more doctrinal use of future dynamic combat operations.

Comparing the SSTP outcomes with published reports of civilian trauma center efficacy is difficult as the majority of patients cared for fall into a fairly specific subset. It was consequently felt to be necessary to generate a “gold standard” data-base of comparable cases from a civilian Level I center recognized as a center of excellence in trauma management with which the SSTP outcomes could be compared. While it would have been more ideal to match patients based on the specific combinations and locations of injuries seen, this was not found to be possible in most instances because of the unique pattern of combat injuries. Both survivors and those who died in the SSTP experience did have a similar demographics as well as comparable physiologic (as indicated by the RTS) and anatomic (as measured by the ISS) severity of injury on presentation as the LAC group, however. The equivalent mortality between the SSTP and civilian trauma center in all subsets therefore supports the hypothesis that capable trauma surgical care can be delivered utilizing these small, mobile trauma surgical systems.

There are several limitations to this analysis. Although not discoverable, it is likely that obesity, a factor recognized to worsen outcomes in trauma patients,¹⁴ was more prevalent in the civilian group. On the other hand, recent data from Israel demonstrated a worse prognosis for patients having sustained high energy blast injuries relative to patients with similar injury severity scores from nonblast mechanisms.¹⁵ There were 62% of SSTP patients who presented after such high energy blast (48% secondary injuries, 14% combined primary, and secondary injuries) because of improvised

explosive devices, rocket-propelled grenades, or mortars; mechanisms that were not seen in the LAC experience. Of note a number of blast injuries occurring in SSTP patients occurred in vehicles or outdoors limiting comparability to the Israeli data much of which involves closed space blasts.

The lack of a single preventable death at the SSTP as determined by an independent panel of trauma surgeons provides further evidence of the adequacy of trauma care delivered by the unit. Equally important is the observation of three deaths felt to be potentially preventable with further refinements of care at the presurgical level.

Multiple factors were felt to contribute to the good results obtained at the SSTP. Probably most important was the dedicated nature of the unit. Although nontrauma surgical urgencies were also addressed by the unit as they arose; the organization, construct, and day-to-day functioning was dedicated to management of combat trauma. Additionally felt to be important was the staffing of the unit at all times with at least one surgeon with significant prior experience in management of combat trauma. Although a number of other team members did not have significant prior trauma experience, the majority underwent a period of intensive training shortly before deployment at the Navy Trauma Training Center located at LA County Hospital, an experience that proved extremely beneficial by the subjective assessment of the surgeons manning the unit. Although a thorough discussion of the resuscitative and operative approaches used in the SSTP is beyond the scope of this paper, a number of technical issues related to these appeared important including: minimization of crystalloids, use of fresh whole blood transfusions and recombinant Factor VIIa for coagulopathic patients or those requiring greater than six units of packed red blood cells, and control of hypothermia with hyperthermic ORs and postoperative enclosure of critical patients in improvised transport pockets created by modifying the body bags available in theater. Allowing an interval of recovery and stabilization before transport as well as continuation of close monitoring and resuscitation of severely injured casualties during subsequent MEDEVAC with en-route care nursing appeared to be critical points in postoperative care.

Constant process improvement was also deemed essential. Whenever possible a nurse or corpsmen was designated to carefully record the time-line of events occurring with each patient. These time-lines were critically analyzed after each case and were formally presented the following day to all of the unit’s officers and senior enlisted for review and discus-

Table 7 SSTP “Salvage” Cases

Patient #	Mechanism	TTP	Major Injury	RTS	ISS	Major Intervention
1	GSW, abdomen	37	Internal iliac vein lacerations	6.376	18	DC celiotomy
2	GSW, abdomen	90	Mesenteric hemorrhage	5.439	50	DC celiotomy
3	Tertiary blast injury, abdomen	53	Grade 4 renal and spleen lacerations	5.439	41	DC celiotomy
4	Fragmentation, abdomen	60	Common iliac artery laceration	4.21	29	DC celiotomy vascular shunting
5	Fragmentation	45	Proximal above knee amputation	5.235	50	Completion amputation
6	GSW, abdomen	45	Mesenteric bleeding	5.148	41	DC celiotomy
7	GSW, thigh	74	Proximal femoral artery laceration	5.148	20	Vascular shunting
8	GSW, thigh	80	Proximal femoral artery and vein laceration	5.148	16	Vascular shunting
9	Fragmentation and blast, thigh	41	Proximal femoral artery and vein laceration	6.817	34	Vascular shunting
10	GSW, arm	?	Brachial/axillary artery and vein laceration	5.148	17	Vascular shunting
11	GSW, abdomen and thigh	?	Grade 3 liver laceration proximal femoral artery and vein laceration	6.085	29	DC celiotomy vascular shunting
12	GSW, pelvis	50	Proximal femoral artery and vein lacerations	6.085	25	Vascular shunting

Abbreviations: DC, damage control; GSW, gunshot wound; ISS, Injury Severity Score; RTS, Revised Trauma Score; SSTP, Surgical Shock Trauma Platoon; TTP, time to presentation.

sion of how to improve the care being delivered. Feedback from the surgeons and other physicians providing subsequent care for the SSTP patients at higher echelons was aggressively sought via e-mail and phone correspondence and was incorporated in similar fashion.

With good evidence that capable trauma care can be delivered by small task-oriented four surgeon, two OR units like the SSTP, the natural tendency of line commanders is to disperse them liberally throughout the theater to improve proximity to sites of wounding. Were surgical resources unlimited this would certainly be prudent. These resources are, like any other military resource, of limited availability, however and must be allocated wisely to ensure optimal employment. Balancing the benefits of the enhanced proximity afforded by small, mobile forward surgical units against the disadvantages of dispersing resources and experience demands careful consideration of the context within which operations are being conducted. With fairly well established CASEVAC and MEDEVAC routes during the security and stabilization phase of OIF, the additional flight time to take patients directly to an Echelon III facility rather than stop at the SSTP was only about 30 minutes. This tends to argue for consolidation of resources at these higher levels of care. The difficulty with this is that ongoing tactical issues resulted in significant delays in a number of seriously injured casualties reaching even the more proximate SSTP. During the reported interval there were 12 operative survivors with a mean ISS of 31 (range, 16–50), and RTS 5.52 (range, 4.21–6.871) received within a mean of 58 minutes (range, 37–90) after injury who, in the opinion of the surgeons treating them

at the SSTP, would not have survived the approximately 30 minute additional transport time needed in the current theater to reach an Echelon III facility. A summary of these patients is presented in Table 7. Extrapolating the SSTP experience to a dynamic combat phase scenario in which transport to the next echelon is 4 to 6 hours would have, again by the consensus of the SSTP surgeons, resulted in 35 lives and seven limbs salvaged. The injury patterns of these “hypothetical saves” are listed in Table 8.

It should be cautioned that the favorable experience with the four surgeon, two OR SSTP does not necessarily translate to smaller, single OR units being used in some operations. The synergism produced by having two operating shelters and four surgeons was felt to result in a whole that was greater than the sum of its parts. A similar review of outcomes data from smaller units is needed to evaluate their efficacy.

In conclusion, the SSTP experience supports the hypothesis that capable trauma surgical care can be delivered in small four surgeon, two OR forward surgical units with results similar to that achieved in civilian Level I Trauma centers. It appears that three percent of operative casualties in a static combat theater

Table 8 Injury Patterns of Hypothetical Life Salvage Cases Assuming Dynamic Warfare Conditions

Injury Site	Number of Cases
Torso	20
Femoral	10
Axillary	3
Neck	2

and six percent of operative casualties in a dynamic theater who would otherwise die during more prolonged CASEVAC can be salvaged by these units. To maximize resource utilization these units must be used within the context of a theater-wide trauma system overseen by surgeons with significant clinical trauma experience.

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EDITORIAL COMMENT

Dr. Chambers and his co-authors from their 52 person Surgical Shock Trauma Platoon are to be congratulated for successfully recording the clinical presentation and outcomes of approximately 900 patients injured by gunshot wounds and explosions during their year in Iraq.

The results of their small mobile surgical unit were superior. This group has set the standard, as they simultaneously present an outstanding example of combat casualty care *and* combat casualty care reporting from a single unit. They rigorously recorded all their admissions, comparing initial physiology, short-term outcomes, injury mechanisms

and distribution, and severity scoring and compared them to an urban Level I Trauma Center, showing no differences in outcome between cohorts. Of critical importance, and with much difficulty, they reported on the ultimate clinical outcomes of the casualties they treated who were evacuated to hospitals in the US. The reasons for their outstanding outcomes were: (1) a senior surgeon on the team who had recent significant trauma experience, (2) a recent rotation of the team through a trauma center, (3) a continuous performance improvement program based on rigorous data collection, (4) minimizing crystalloid resuscitation and early, liberal use of blood components, fresh whole blood and rFVIIa, (5) hypothermia prevention, (6) widespread use of multiple damage control maneuvers, and (7) dedicated critical care nurse assets who provided a high standard of en route care during helicopter transport between levels of care (2b to 3).

The role of this Surgical Shock Trauma Platoon was significant in the military's effort to establish a functional Joint Theater Trauma system, exemplified by utilizing the trauma registry forms, close communication between hospitals, performance improvement, sharing of morbidity and mortality information, rapid feedback, and loop closure with reasonable solutions that could be effected at their level.¹ Importantly, most of these innovations occurred during their time in Iraq.

CDR Chambers et al. have succinctly documented important trauma techniques and system concepts that have been transferred to the entire theater of operations. The trauma leadership in Iraq and Afghanistan has implemented these and many other advances. It is now time to translate this trauma care information back to the civilian community. New trauma knowledge gained during protracted wars has frequently prompted significant improvement in civilian trauma care.^{2,3} However, diffusion of this new trauma knowledge into the civilian community has usually occurred over many years.⁴ Many now understand that military experience should be both pushed and pulled into the civilian community, transferring these hard won lessons into civilian health care systems as rapidly as possible. The Global War on Terrorism has been ongoing for almost 5 years, has caused >18,000 US wounded or dead and thousands more non-US casualties, all cared for by military health care professionals. This experience has created a vast reservoir of gunshot wound, explosion injury, and mass casualty triage knowledge within the military that will likely resemble the injuries from the next terrorist event that happens on our home soil. Hopefully, our homeland defense efforts will benefit from the current significant knowledge residing in our Military Trauma system.

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DISCUSSION

Dr. Michael J. Sise (San Diego, California): Dr. Chambers and his colleagues reported this morning on a well-designed study, thoughtfully constructed, rigorously completed, with conclusions well supported by the data.

Dr. Chambers, to you and your colleagues, I can only speak for myself, but I'm sure I echo the sentiment of everyone in this audience, especially those of us who have had some part in training you and your colleagues, how very proud I am of what you've accomplished.

Your senior colleague, Dr. H.R. Bohman, led the effort to change the way the Navy and Marine Corps cared for casualties well before the first Marine crossed the frontier into Iraq.

I spent 20 years in the military, and I know that change comes slowly, and yet you made it happen against all odds. All of you went into harm's way to be close to the combat to care for the injured.

You were there to care for our fallen Marines, and yet you treated friend and foe alike. You leaned, adapted and changed, all, literally, in the heat of combat.

You continually analyzed your results, real-time, and then, when you had the opportunity from a distant, cool and safe vantage point, you looked back, rigorously and critically analyzing the results against civilian benchmarks.

Now it is your turn to teach us the practical lessons about limiting crystalloid, blood transfusion strategies, early use of recombinant factor VII, avoiding hypothermia, rapid-cycle real-time performance improvement and expert panel review.

I have many, many questions, so many that I'm sure we can't answer them all today. Each of them is related to how fast can we adopt those lessons you've learned to our civilian centers.

There are so many implications from this experience and your report. First of all, how quickly do surgeons learn to be efficient and focused with limited resources and numerous casualties? How steep is the learning curve?

What about operating outside the usual realm of the general surgeon's experience—thoracic, vascular, urologic and other injuries so commonly managed with the help of subspecialists in civilian centers?

What elements of the preparation at L.A. County, U.S.C. and other centers should we adopt for our civilian trauma surgeons, who work at trauma centers where these injuries are much less common but when they present can be devastating?

Is advanced trauma operative management a refresher course we should all take on a periodic basis? How do we import the senior experienced surgeon model that you wrote about in your manuscript?

Basically, there was a senior experienced surgeon always present for young surgeons rotating through. How do we import that into our civilian trauma centers? What can you recommend to us in the centers?

These are just a few of the questions that come to mind when we hear your experience. We look forward to you and your colleagues giving us future detailed reports of your experience and helping us adapt them in civilian trauma centers.

Most of us in this audience were drawn to trauma surgery because we wanted to meet the challenge of being the ones to turn to when the risk is high and life is in the balance. We all hope to measure up when called upon. We all strive to do better.

I'm honored to be in the company of men and women, you, my colleagues, who so thoroughly delivered on the promise to be ready, to act boldly, to stand, deliver and answer for your results.

Dr. Lowell W. Chambers (Fallbrook, California): Dr. Sise, I'm humbled and honored by your kind words and appreciate your insightful questions. In regards to learning efficiency in working with limited resources the most important factors are continually keeping track of how your supplies are doing, thinking "outside the box" at how to conserve resources without compromising care, and focusing on things that really matter rather than the form of things. Several examples come to mind: the first of which concerns dressing supplies. Dressings were among our most frequently used items and several times we got a bit short on them. To minimize this issue we routinely used left over/unused lap pads for wound dressings at the end of the case, the rationale being that so long as the count was correct before dressing the wound, what difference did it make if the superficial dressing is a lap? At one point we got short on Bovie tips but recognized this in time to start saving them for reuse after washing and disinfection. Most OR nurses would likely regard this as a most grievous action but realistically what is the difference between a sterile VS a disinfected bovie in the grossly contaminated wounds we were dealing with?

The walking blood bank is another example. For 3 months we struggled to get Fresh Whole Blood capability at our unit but had multiple struggles obtaining the viral titer results we were told we had to have before doing this. After the team at the CSH had to play catch-up for us on several patients who became coagulopathic we finally stopped waiting on this, appealing to risk-benefit ratio (tiny risk of transmitting HIV or hepatitis from a population vaccinated against Hep. B and regularly screened for HIV VERSUS the very real potential for these casualties to bleed to death) and, once we were convinced of the accuracy of our typing capability, proceeded without the titers (which never did materialize). Although we lack the numbers at this point to prove it scientifically, we anecdotally observed this to make a significant difference in several of our most severely injured patients.

In regards to the learning curve to becoming efficient and effective in a limited resource situation I think it primarily depends on preparation and attitude. If one goes in mentally

prepared to “adapt and overcome” and is given some practical guidance (that they are receptive to) on how to do this from surgeons who have been there, the learning curve is very minimal—probably only a few cases as demonstrated by Dr. Stockinger’s team who took over for us with a very smooth transition after an intensive week of indoctrination which they received collegially. If one goes in without the benefit of such instruction but they have an open mind and adapt it’s probably about 5 to 10 cases (based on personal observations from OIF1).

If one fails to have some humility and an open mind they never adapt and spend their entire tour complaining about everything they don’t have rather than finding ways to get the job done with what they have—resulting in poor outcomes and degeneration of team morale.

The learning curve to developing and maintaining the knowledge and technical skills necessary to perform these procedures at a moment’s notice after long periods of relative clinical inactivity is a more complex issue. What seemed to work well for me may not work for all but the only way I know to answer this is to relate what I did. The initial thing I did was seize any opportunity given to get hands on experience. The Navy Trauma Training Center located at LA County enabled my team and I to get a substantial trauma refresher that we vitally needed and we are very much in debt to Dr. Rhee, Dr. Demetriades, and the entire trauma/critical care department at USC/LAC for helping prepare us. To ensure I maximized this learning I found it additionally helpful to record the technical tips learned taking care of patients at the Civilian Level 1 Center in note form in a single inclusive source. Dr. Thal’s atlas worked best for this as it is an outstanding atlas and he left lots of room for notes in it. I would then frequently review this “master reference” source taking time to visualize the maneuvers in my mind each time breaking down each move to a systematic sequence. With time I found these skills would become reflexive for me even though in many instances I had never actually performed them or performed them only a few times. (A notable example of this is total hepatic isolation. Dr. Rhee went over the technique with me one time at LAC. The first time I actually performed it was over 6 months later in Iraq but because of this “review and visualization” was able to perform this relatively advanced procedure within 14 minutes.) Although I think making a frequently reviewed personal reference such as this is probably the most effective tool, it requires a more significant time commitment than may often be practical to commit. An alternative which is perhaps more practical is the production of high quality videos/DVDs of experienced trauma surgeons performing procedures. I think such videos, particularly if accompanied by dubbed narration from the operating surgeon running concurrent with the procedure, would be very useful in helping both military and civilian surgeons overcome the learning curve more rapidly. Also very helpful in my opinion are “cut to the chase” “how I do it” publications like Drs. Hirshberg and Mattox’s “Top Knife” which each of the surgeons on our rotation found very helpful.

Regarding the basic elements that made the unit successful and possible applications to civilian trauma, I think the first and probably most important characteristic of our unit was its dedicated nature. Although we took care of other surgical urgencies such as appendicitis as they came up, the day-to-day functioning, the layout, the training, the reason we existed was dedicated to the trauma management of combat casualties. A second point of importance was the fact we had an experienced surgeon and by experienced I mean with prior *combat* surgical tours present at all times in the unit. This was particularly helpful in regards to triage and resource allocation issues.

One technical issue that we think was important was operating in hyperthermic operating rooms. I think we keep our ORs much too cold in most civilian centers being too focused on operator comfort and not enough on avoiding hypothermia in critical patients. Most folks probably wouldn’t like operating in our field ORs very much because with critical patients we seldom let the temperature much below 100 degrees. This is quite physiologically challenging for the operators but it seemed very beneficial in avoiding the hypothermia portion of the “Triangle of Death” for the casualties. Some patients died in my OR but none died cold. Despite leaving the OR normothermic, early on we were finding patients were becoming hypothermic during transport. This seemed related to significant convection currents passing over them from the open gun portals on the transport helicopters. To offset this we began encasing our patients in body bags with holes cut for the head/ET-tube and with warmers on the inside and saw almost 100% resolution of this problem with this change.

Just as important was a constant process improvement process that was guided by feedback from the higher echelon teams. I feel very indebted to my colleagues who were at the Army CSH based in Baghdad, the Air Force EMG at Balad and the team at Landstuhl Regional Medical Center who were very good at expediently providing this crucial feedback. We had to seek it a bit more aggressively with our CONUS colleagues but after 5 to 6 e-mails I would eventually get the needed follow-up.

Dr. James M. Betts (Oakland, California): About 2 weeks into the war, we were contacted by a field hospital in Nazaria that the Air Force had a 9-year old child, who was critically injured. He had picked up ordinance and had blown both of his hands off. His entire abdominal wall had a 40% burn, and he had shrapnel to his head.

After several weeks of care there, they had requested that he be air-evacuated out, and after a 36-hour flight to Oakland, CA, to Children’s Hospital, he spent 3 months in our intensive care unit and 6 months in the hospital.

It’s amazing because you look back at the care, and it was under Jay Johannigman’s group with the Air Force at that time. It was amazing the care that they were able to provide there.

Within 10 days of his arrival in Oakland, there were wanted posters in Tallile with him and his dad, his dad came over, because they were traitors.

Since that time he is now out, integrated into the school system, and with the State Department and military assistance, we were able to bring the rest of his family over as well.

Dr. Lowell W. Chambers: Certainly those type cases go a long way to showing those folks over there that there is a difference in kind of how we look at things.

Dr. Richard J. Mullins (Portland, Oregon): FRSS offers battlefield surgery capability, and you implied that you should compare yourself to Level I trauma centers in the United States as the gold standard. I don't agree with that.

You provide surgical care within the context of a tactical operation. Commander, in fact, the Number 1 decision-maker in the battlefield should be the Colonel in charge of the military operations.

So, I think we have to be realistic about what we're trying to do here. So, do you, in fact, disagree with me on that issue? This is battlefield surgery. You have to provide the care within the context of the tactical operation.

I'd just like to take the opportunity of the microphone to say that when I was in Iraq in 2003, there were six of us, six general surgeons, and I was 55, and there was only one of those six that was younger than me.

I'm getting out here in the next month, and there is a shortage of reservists willing to serve in the military. So I have a second question.

Do you find that civilians, who are reservists, have difficulties working within the context of the military? What can we do to convert trauma surgeons to military surgeons?

Dr. Lowell W. Chambers: In regards to the first question, I don't disagree with you at all Captain. Certainly the tactical scenario has to always be the primary concern; ultimately the focus has to be winning the battle. But I just think it's important for us to validate what we're doing surgically; if our mortality rates are poor, then we probably need to be doing something differently. I think well developed civilian trauma systems are the "gold standard" we need to compare our results with, recognizing we are operating in somewhat different circumstances.

Certainly there are some physical constraints involved in military surgery, particularly during dynamic combat operations. It's somewhat exhausting just functioning in Flak and Kevlar, let alone putting up tents wearing them under dangerous and austere circumstances. I'm still relatively young and in reasonably good shape but putting those tents up within an hour was exhausting. So physical fitness is an issue. The other thing I think military medicine has to look at is giving up a bit of control. There is currently very tight, stringent control exercised over military physicians typically by administrative officers who lack clinical understanding and don't think anything about pulling medical providers into a theater months before operations commencing, allowing them to sit clinically inactive for prolonged intervals before calling on them to care for severely injured combat casualties. We've got to find a way to avoid such prolonged periods of clinical inactivity which I think will eliminate a lot of the

reason physicians are leaving the military in fairly high percentages currently.

Dr. Timothy Woods (Landstuhl, Germany): I can tell you from our guys here at Landstuhl, you guys did excellent care. We took care of all your patients, and I can promise you your work was very much appreciated. My comment is when you look back at the information on the guys who came in with head injuries and had to obviously be sent to a higher echelon, referencing Dr. Jenkins' earlier talk, would they have benefited to go straight to that higher echelon? Did you see a change you know with the initiation of this program?

Dr. Lowell W. Chambers: Yes, absolutely. Basically, the reason guys would stop at our level were, why we saw head trauma was one of two, if they came to us by ground, that is, they came to us by ground, then they got on a bird.

In other instances, if they had respiratory compromise or something and were actively dying in the helicopter. Early on, we were getting a lot more head trauma.

Later on, it basically didn't exist except when it came by ground, so, I think the protocols put in place by Dr. Jenkins and his team were definitely making a difference in how the patient evacuation team directed patients.

Dr. C. William Schwab (Philadelphia, Pennsylvania): You've had a chance to look at what you did in the heat of battle, what your training, what your psycho-motor skills, what your techniques brought to bear during that picture. In probably no more than 20 minutes' time of those critical dying people, you and the other surgeons and team saved their lives.

The question is, what training, what techniques from vascular, thoracic, neurosurgery, orthopedics, or facial surgery do we need to give you, the surgeon, at that time, to use to decrease death?

Dr. Lowell W. Chambers: I think the overriding principle in regards to general surgeons addressing specialty related trauma in the forward theater is keeping things simple. In regards to vascular injuries requiring complex repairs, we placed temporary shunts that worked well, permitting deferment of definitive repair to higher echelons while providing perfusion during the subsequent interval. In regards to thoracic procedures emphasis should be placed on nonanatomic resections, tractotomies, and control of great vessel bleeding. For the orthopedic injuries seen, we always had an orthopedic surgeon with us to provide external fixation and guidance for management of the large numbers of severe fractures we treated. This is a model that should be continued. In regards to urologic injuries; ureter and complex bladder injuries were simply drained while simple bladder injuries were closed. Probably the most important point here is being sure you recognize the presence of the injury and whether it's something that should be definitely addressed or not. In regards to neurosurgical cases, we are set up (that is we have the equipment) for rudimentary craniotomies so I think some review of how to decompress intracranial bleeds is helpful although in all instances during the currently examined experience we were able to get them relatively expediently to true neurosurgical capability.