Military Trauma and Surgical Procedures in Conflict Area: A Review for the Utilization of Forward Surgical Team

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ABSTRACT Introduction: Forward surgical teams (FSTs) have been used as highly mobile surgical facilities that provide "damage control" medical support in modern wars. FST regiments differ greatly in different armed services and nations. We systemically reviewed the utilization of FSTs around the world with an emphasis on the medical conditions and workloads encountered by FSTs in modern wars. Materials and Methods: We searched for terms related to FSTs, such as "Forward Surgical Team" and "Field Surgical Team," in the PubMed, EMBASE, Web of Science, and MEDLINE databases and collected any articles that provided numerical data on the organization of medical personnel combat casualty characteristics, including the casualty composition, injury types and locations, and mechanisms of injury, and surgical procedures performed. Technical articles, case reports of specific types of injury or disease, and literature reviews of previous experiences and logistical theories were discarded. Results: We identified 24 articles involving 29 FSTs that were included in the analysis. The FSTs were typically composed of 8–20 medical personnel and had limited medical capacity. Battle-related injuries constituted approximately two-thirds of all injury types treated by the FSTs. The extremities, torso, and head and neck were the three most frequently injured sites and accounted for approximately 51.1%, 16.6%, and 13.2% of all wounds, respectively. The three most frequent injury mechanisms were fragments or explosive injuries (44.8%), gunshot wounds (28.1%), and motor vehicle accidents/road traffic accidents (9.1%). Soft tissue surgeries (41.0%) and orthopedic operations (31.6%) were the two procedures that were most frequently performed by the FSTs. The average numbers of surgical procedures performed by small FSTs (1.27/unit·day) and full FSTs (1.28/unit·day) seemed to be comparable. Conclusion: Modern conflict may require more flexible small FSTs, especially during the initial phases of war. More orthopedic surgeons should be included in FSTs, and orthopedic skill training should be intensified before deployment. The utilization of FSTs and level III facilities must be evaluated within the context of the battlefield conditions, medical care requirements, and evacuation efficiency.

INTRODUCTION

During World War II (WWII), Dr. Robert Zollinger of the US Army proposed the concept of mobile surgical units that were capable of performing 100 major operations on combat casualties near the front lines before being resupplied.[1] The late Dr. Charles Rob of the Royal Army Medical Corps established the first airborne forward surgical teams (FSTs), which were deployed with the British 1st Airborne Division in the North Africa campaign.[2] Early in the Falklands campaign 1982, the British Army had already used FSTs to support the land forces on the East Falkland Islands.[3] Before the wide use of the FSTs, the mobile army surgical hospital (MASH) was the major field surgical facility that provided initial resuscitative surgery and medical treatment for critically injured military members during WWII, the Korean War, and the Vietnam War in the US Army.[4] Due to their large sizes and poor maneuverability, the MASHs did not satisfy the medical requirements of modern conflicts such as the Grenada War and the Gulf War. After small-scale employment in Panama, Haiti, and Kosovo, US forward operation units, including the Army FST, Navy Forward Resuscitative Surgical System (FRSS), and Air Force Mobile Field Surgical Team (MFST), or the Expeditionary Medical Support System have nearly replaced MASHs as the level II medical facilities during the War on Terrorism.[1,2,5]

A modern FST is a highly mobile surgical facility that was designed to perform lifesaving and limb-saving "damage control" trauma surgical procedures and to support brigades and regiments as well as special forces near the frontline.[2,6] According to US logistical principles, FSTs are routinely used as level II military medical facilities that provide initial trauma surgical support at 3–5 km behind the combat units and accommodate casualties that are directly evacuated from the front or arrive through the medical company during the primary invasion and maneuver phase.[6,7] When the combat situation has stabilized, level III surgical units, such as combat support hospitals (CSHs), can be established to provide advanced and sophisticated medical care. However, various FST regimens have been selected by different nations to meet specific requirements of military trauma care under different conditions. The conventional US Army FST is a 20-person team designed to perform 42 surgical procedures in two operating rooms (OR) over a 72-h period.[1] The US Navy FRSS (eight-person team) is equipped to perform up to 18 major surgical procedures over 48 h

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without relief or resupply,[6,8] whereas the more lightweight five-member Air Force MFST team can perform 10 major procedures over a 24-h period.[1] In contrast, the French FST (12- or 14-person team) has an initial endowment (equipment/drugs) that is designed to support the performance of 12 surgical acts over a period of 48 h.[9,10] Although there are several reviews that have detailed the operational experiences of US Army FSTs in Iraq and Afghanistan, the profiles of FST utilization around the world, especially in modern wars or humanitarian relief, have not yet been fully depicted.[2,6,11] In this article, we systemically reviewed the published data focusing on the medical personnel organizations, the workloads, and the treatment capacities of FSTs in different wars, and we discuss rational utilization, composition optimization, and training course improvements that can be implemented in the future.

METHODS

We retrospectively analyzed previous studies that reported the combat casualties that have been treated and the surgical care provided by FSTs around the world. We searched for terms related to FSTs including "Forward Surgical Team," "Field Surgical Team," "Forward Resuscitative Surgical System," "Mobile Field Surgical Team," and "Expeditionary Medical Support" in the following databases: PubMed, EMBASE, Web of Science, and MEDLINE. Initially, we identified 1247 articles.

We read the titles and/or abstracts and then collected any articles that described the medical personnel organization; combat casualty characteristics, including the casualty sources, injury types and locations, and mechanisms of injury; and surgical procedures performed within a period of war. For the purpose of this review, we discarded technical articles and case reports on specific types of injury or disease, literature reviews of past experiences and logistic theories related to FSTs, and other military medical teams.

Subsequently, a total of 66 articles were screened for further analysis. After carefully evaluating the full texts, we identified 24 articles published from 1983 to 2016 that fulfilled the above-mentioned criteria and provided valid data that were obtained from 29 FSTs. We then extracted these data and attempted to combine the same measurements into a single analysis. The distributions of subtypes of each item regarding combat casualty characteristics and surgical burdens were calculated based on the available data. The average number of surgical procedures performed per surgical unit was also calculated by dividing the total procedures by the number of days of deployment and the number of team units that had been recorded in the selected articles.

RESULTS

In total, 17 US surgical units (11 Army FSTs and eight Navy FRSSs), five UK units, four French units, and one Australian unit were included in the this article. The teams are named according to their military designations or as FST– (FRSS)-mission/war zone-deployment year, e.g., the US 250th FST that participated in Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) was named 250th-OIF and 250th-OEF to create a distinction between the two operations. Table I presents the missions attended and the deployment dates and durations for these teams. Eleven teams that participated in OIF from 2003 to 2005 and one team that was deployed in Operation New Dawn (OND) in Iraq are described. Seven teams performed surgical care missions during OEF in Afghanistan from 2001 to 2009. Five UK teams were employed during the Falklands War or the Gulf War, and three French teams were deployed in Mali and the Central African Republic (CAR) in support of the military operation in 2014. Another two teams provided humanitarian relief in Afghanistan and Africa. We also included an Australian team that provided surgical care during the Kokoda-Buna Campaigns of the WWII. The service durations varied greatly between the different teams and lasted from approximately 10 d to 15 mo.

Organization and Equipment

The detailed organizations of each FST are detailed in Table II. Conventional full US Army FSTs, such as the 555th, 250th, 320th, and 102th teams, were composed of 20 members including two to three general surgeons, one to two orthopedic surgeons, two nurse anesthetists, one intensive care unit (ICU) nurse, one emergency room (ER) nurse, one OR nurse, and several medical technicians, licensed practical nurses, or medics. The 541th and 912th FSTs also conducted split operations at separate locations.[18,24] The split 912th FST was further divided into a main body and a "jump team" that consisted of four medical personnel during OND. Additionally, the US Navy FRSSs were composed of eight medical personnel including two surgeons, one anesthesiologist, one ICU nurse, two OR technicians, and one independent duty corpsman or one physician's assistant, and one basic corpsman. The French Army FSTs normally consisted of 11 or 13 medical professionals including the following: one anesthesiologist, one general surgeon, one orthopedic surgeon, two nurse anesthetists, one OR nurse, two ward nurses or two ICU nurses, and three auxiliary nurses, or three emergency medical technicians. The UK FSTs comprised one to two surgeons, one to two anesthetists, four to five medical technicians, and several nurses and medical assistants.

The conventional US Army FST had three dependently running sections that included the advanced trauma life support section, the operation room section with two operating tables, and the recovery section with a four-bed ICU. Each team also had minimal self-supporting and technical facilities that provided basic X-ray, laboratory, and blood transfusion capacities as well as power generation and food and water.[14] The main medical equipment for each FRSS

included one portable operating table with lights, one portable oxygen generator, one draw-over anesthesia vaporizer, three portable ventilators, and five monitors.[5,15] For rapid mobility near the frontline, each Army FST required six high-mobility multipurpose vehicles (HMMVs) due to the heavy weight and substantial bulk of the equipment, whereas the split FSTs required only three HMMVs. The US Navy FRSS had one HMMV and one HMMV ambulance with trailers.[5,15] One fixed-wing aircraft and one heavy helicopter should be used for the strategic transport of an FST and an FRSS, respectively. The French FST was equipped with a three-bed ICU, an eight-bed hospitalization unit, an OR, and a two-bed recovery room.[10] The diagnostic equipment included a mobile digital X-ray machine, a portable ultrasound machine, and a limited blood analysis laboratory.[26,27] The team also carries a blood bank with packed red blood cells and lyophilized plasma.[26] The UK FST teams were normally equipped with a four-table resuscitation section, a two-table operation section, a two-bed ICU with basic diagnostic facilities (one X-ray unit, one ultrasound scanner, and one gas, hematocrit, and electrolyte analyzer), and damage control surgical capacity.[3,13] The tactical mobilities of these teams depend on 13 light trucks.[13]

Casualty Composition and Injury Types

There were 12 articles that provided details about casualty compositions and gender in 20 FSTs. After pooling the data recorded by the different FSTs, we found that the casualties were mainly composed of host-nation military members, civilians, local friendly forces, and coalition soldiers in addition to enemy combatants. Patients were predominantly male (Table III). Table IV illustrates the injury types and their anatomical locations as reported from 18 FSTs. Overall, the percentage of battle-related injuries was significantly greater than the percentage of non-battle injuries encountered by the FSTs, and this finding is consistent with the data recorded by the US Navy-Marine Corps Combat Trauma Registry during OIF.[29] Regarding the injury locations, the three most frequently injured sites were the extremities, the torso, and the head and neck, which accounted for approximately 51.11%, 16.55%, and 13.16% of all wounds treated by the FSTs, respectively. These findings are consistent with the overall injury patterns observed in modern wars during the latter half of the 20th century, such as those in Northern Ireland, the Falkland Islands, the Gulf War, and the Afghanistan War.[30] The percentages of injuries involving other anatomical sites were all lower than 10%, and simple vascular injuries and urinary wounds were two least frequent medical affairs treated by the FSTs (Table IV).

Mechanisms of Injury

Table V reveals that there were 10 types of injury mechanisms that were commonly encountered by the 21 FSTs. In general, the three leading types were injuries due to fragments or explosive injuries (FEIs), gunshot wounds (GSWs), and motor vehicle accidents/road traffic accidents. The

TABLE I. Basic Characteristics of the FSTs Included for Analysis

Team Designation	Nation	Deployment Date	Duration	Mission and/or War Zone
FST-Kokoda[12]	Australia	July 1942	10 d	The Kokoda-Buna Campaigns, New Guinea, WWII
FST 1, FST 2, FST 5, FST 6[3]	UK	May to April 1982	1 mo	The Falklands war
FST-Telic-2003[13]	UK	February 2003	1 mo	Operation Telic of Gulf War, Kuwait
555th[14]	US	March 2003	23 d	OIF
FRSS -OIF-2003[15]	US	March 21 to April 22, 2003	1 mo	OIF
FRSS -OIF-2003 (six teams)[5]	US	March 21 to May 1, 2003	1 mo	OIF
250th-OIF[16]	US	2003	11 mo	OIF
FRSS-OIF-2004, 2005 (two teams)[8,17]	US	March 1, 2004 to February 28, 2005	12 mo	OIF
912th[18]	US	May to December 2011	8 mo	OND
250th-OEF[19]	US	October 20, 2001 to April 2, 2002	6 mo	OEF
320th[1]	US	October 2001 to February 25, 2002	5 mo	OEF
274th[20]	US	October 14, 2001 to May 8, 2002	7 mo	OEF
102th[21]	US	August 2002 to March 2003	7 mo	OEF
FST -OEF-2005[22]	US	December 1, 2005 to November 15, 2006	12 mo	OEF
772th[23]	US	2007–2008	15 mo	OEF
541th[23,24]	US	2008–2009	15 mo	OEF
126th[25]	US	May to November 2011	6 mo	Humanitarian, Afghanistan
FST-Ivory-2002[9]	France	September 2002 to August 2012	10 yr	Humanitarian, Ivory Coast
FST-Mali-2013[26]	France	February 2013 to August 2014	18 mo	Operation Serval in Mali
7th-Mali[27]	France	February 20 to May 28, 2014	3 mo	Operation Serval in Mali
7th- CAR[27]	France	September 2 to November 19, 2014	2 mo	CAR
14th[10]	France	December 6, 2013 to February 28, 2014	4 mo	CAR

TABLE II. Medical Personnel Configuration for Different FSTs

Team Designation	Medical Personnel Configuration[a]
US	
250th[16]	One general surgeon/orthopedic surgeon (commander), two general surgeons (three if commander is orthopedic surgeon), and one orthopedic surgeon (unless commander) Two nurse anesthetists, one ICU nurse, one ER nurse, one OR nurse, and three licensed practical nurses Three OR technicians and three emergency medical technicians
555th[14]	Three general surgeons and one orthopedic surgeon
274th[28]	Two nurse anesthetists, one ICU nurse, one ER nurse, and one OR nurse Three OR technicians and seven medics
102th[21]	Three general surgeons and one orthopedic surgeon Two nurse anesthetists, one ICU nurse, one ER nurse, and one OR nurse Five emergency medical technicians or scrub technicians
FST-OEF-2005[22]	Three general surgeons, two orthopedic surgeons, and one gynecological surgical oncologist Two nurse anesthetists and one ICU nurse Five emergency medical technicians or scrub technicians
541th (-)[24]	Location A: One general surgeon (Commander) and one general surgeon (6-mo rotator) One nurse anesthetist, one ICU nurse, and one licensed practical nurse Two OR technicians and three medics Location B: One general surgeon (6-mo rotator) and one orthopedic surgeon (6-mo rotator) One nurse anesthetist (6-mo rotator), one ER nurse, one OR nurse, and two licensed practical nurse One OR technician and one medic
912th (-)[18]	Two surgeons One nurse anesthetist, two nurse, and one licensed practical nurse One surgical technician and two medics
912th jump[18]	One surgeon, one nurse anesthetist, one licensed practical nurse, and one surgical technician
FRSS[6,8]	Two surgeons and one anesthetist One ICU nurse and two OR technicians One independent duty corpsman or physician's assistant and one basic corpsman
France	
FST-Ivory-2002[9]	One anesthetist, one general surgeon, and one orthopedic surgeon Two nurses anesthetist, one OR nurse, two ward nurses, and three auxiliary nurses
FST-Mali-2013[26]	One anesthesiologist, one general surgeon, and one orthopedic surgeon Two nurse anesthetists, one OR nurse, two ICU nurses, and three auxiliary nurses One radiology technician and one medical equipment technician
7th-Mali and CAR[27]	One anesthesiologist, one general surgeon, and one orthopedic surgeon Two nurse anesthetists, one OR nurse, and two ICU nurses Three emergency medical technicians
14th[10]	One anesthesiologist, one general surgeon, and one orthopedic surgeonTwo nurse anesthetists, one OR nurse, two ICU nurses, and three auxiliary nurses
UK	
FST 1, FST 2, FST 5, FST 6 (Falklands)	One surgeon, one anesthetist, one resuscitation officer, four operating theater technicians, one blood transfusion technician, and one clerk
FST-Telic-2003[13]	One orthopedic and one general surgeon, two anesthetists Eight OR practitioners: One accident and emergency consultant and one ER nurse One radiographer and one laboratory technician Two licensed practical nurse and two combat medical technicians

[a]The administrative officer was not included.

explosives included bombs, landmines, mortars, rocket-propelled grenades, and other types of grenades and improvised explosive devices. Crush and blunt injuries were the least frequently encountered mechanisms of injury followed by burns and stab wounds (SW). The 250th FST and 102th FST experienced higher percentages of GSWs than FEIs, whereas helicopter crashes induced greater numbers of injuries than GSWs in the 274th FST. The 102nd FST experienced relatively higher percentages of motor vehicle accidents/road traffic accidents and SW and the FST-OEF-2005 treated higher percentage of fall injuries compared with other teams.[21,22] Additionally, the French FSTs only treated 185 non-battle injury patients (8%) and 15 battle-related injury patients (0.6%) among whom there were only three SW patients and two GSW patients during the 10-yr humanitarian medical support mission in the Ivory Coast

TABLE III. Distribution of Casualty Source and Gender in Different FSTs.

Team Designation	Casualty Composition					Gender	
	Host-Nation Military	Coalition	Enemy Combatant	Local Friendly Forces	Civilian	Male	Female
FST-Kokoda[12]	362 (100.0)	–	–	–	–	–	–
FST 1, 2, 5, 6[3]	233 (100.0)	–	–	–	–	–	–
555th[14]	79 (51.3)	–	–	52 (33.8)	23 (14.9)	–	–
FRSS-OIF-2003[15]	203 (60.1)	–	135 (39.9)			–	–
250th[16]	60 (61.2)		38 (38.8)			–	–
274th[28]	153 (70.2)	13 (6.0)	20 (9.2)	32 (14.7)	–	–	–
102th[21]	26 (28. 9)	3 (3.3)	–	61 (67.8)		87 (96.7)	3 (3.3)
FST-OEF-2005[22]	106 (12.9)	214 (25.9)	16 (1.9)	212 (25.7)	277 (33.6)	575 (93.7)	39 (6.4)
772th[23]	250 (80.4)				61 (19.6)	–	–
541th[23]	477 (62.7)				284 (37.3)	–	–
7th-Mali and CAR[27]	13 (9.7)	–	2 (1.5)	29 (21.6)	90 (67.2)	114 (85.1)	20 (14.9)
14th[10]	21 (50.0)	–	–	8 (19.1)	13 (31.0)	40 (95.2)	2 (4.8)
Total (%)	967 (49.1)[a]	227 (11.5)[a]	38 (1.9)[a]	333 (16.9)[a]	403 (20.5)[a]	816 (92.7)	64 (7.3)

The numbers in the brackets represent the percentage distributions of casualty source and gender in each group of FSTs.
[a]Data from FRSS-OIF-2003, 250th, 102th, 772th, and 541th FST were not included for calculation.

between September 2002 and August 2012. In contrast, they performed elective surgeries on 1,821 patients (78.7%) and provided non-trauma emergency treatments on 294 patients (12.7%) during that time.[9]

Surgical Procedures Performed

There were a total of 1946 surgical procedures performed by 15 FSTs (Table VI). In general, soft tissue surgeries, specifically, irrigation and debridement (I&D), and wound exploration were the most commonly encountered categories followed by orthopedic surgeries in most teams, but the FST-OEF-2005 and the FRSS teams most frequently performed open reductions under anesthesia. Closed RUA and external fixations were the two most commonly performed procedures by the French FSTs in Mali. Moreover, the overall number of abdomen and pelvis operations was similar to the number of chest surgeries. Laparotomy was the third most common surgical procedure and accounted for over 80% of all abdomen operations among most of the teams with the exception of the French 14th FST and the US 250th FST for which detailed information regarding this category was unavailable (Table VI).

Given that there was no information about the numbers for subdivisions of chest surgeries performed for 10 teams, we can only speculate that closed-tube thoracostomy might have been the most common procedure among all chest surgeries based on the available data. Surprisingly, the overall percentage of head and neck surgeries was relatively low and seemed to be disproportional to the high incidence of observed head and neck injuries. Fasciotomies and amputations accounted for over 5% of all procedures performed by most teams with the exception of the French teams deployed in Africa. Vascular surgeries accounted for approximately 5% of the procedures, but detailed information regarding the subtypes of vascular surgeries was very limited.

Table VII indicates that the average numbers of surgical procedures performed were not different between the small FSTs in Iraq and the full FSTs in Afghanistan, whereas the French small FSTs performed fewer procedures per day in Africa than did the US and UK teams during the War on Terrorism.

DISCUSSION

Medical personnel in FSTs and CSHs faced different medical situations in terms of the mechanisms of injury, injury locations, and surgical procedures. Beitler et al reported that explosions and GSWs were the two most common mechanisms of injury and accounted for over 40% and approximately 20%, respectively, of all injuries encountered by the 48th CSH during a 6-mo period in Afghanistan.[31] Consistently, the US 228th CSH also treated more explosion injuries and GSWs than any other types of injury during an 11.5-mo period in Iraq between December 2004 and November 2005.[32] During OEF in Afghanistan, bomb fragments and landmines were two most frequently observed mechanisms of explosive injuries during the initial invasion phase,[16,19] whereas rocket-propelled grenades and improvised explosive devices became the dominant mechanisms of injury during the latter management period.[22] These data are similar to those from the FSTs analyzed in this article. In contrast, the CSHs treated more burns (8% in the 48th and 9% in 228th) and fewer fall injuries (3.43% in the 48th and 0.8% in the 228th) than the FSTs investigated in this study (burns: 0.5–3.28%, 1.77 on average; falls: 3.72–10.73%, 6.20% on average),[31,32] but the frequency of encounters with burns significantly decreased in the Level III hospitals (1%) during the 12-mo period from January 2010 to December 2010 in Afghanistan.[33] Additionally, although the extremities were the most common injury locations that were treated in the CSHs, MASHs, and FSTs, the percentages of

TABLE IV. Injury Types and Locations Reported in Different FSTs

Team Designation	Injury Type		Injury Locations								
	Battle-Related Injuries	Non-battle Injuries	Head and Neck	Eye, Ear, and Face	Torso	Extremity	Burn	Vascular	Neurology	Urinary	Unknown
555th[14]	–	–	25 (12.3)	–	34 (16.8)	118 (58.1)	6 (3.0)	–	–	–	20 (9.9)
FRSS-OIF-2003[15]	–	–	(16.0)	–	(15.0)	(66.0)	–	–	–	–	–
FRSS-OIF-2004, 2005[17]	–	–	(18.0)	–	(13.0)	(67.0)	–	–	–	–	–
250th-OEF[16]	66 (73.3)	24 (26.7)	–	–	–	–	–	–	–	–	–
320th	–	–	(13.0)	(22.0)	(25.0)	(39.0)	–	–	–	–	–
274th[28]	162 (85.3)	28 (14.7)	14 (5.8)	26 (10.8)	46 (19.1)	141 (58.5)	–	–	–	–	14 (5.8)
102th[21]			12 (20.0)		6 (10.0)	31 (51.7)	–	2 (3.3)	–	–	9 (15.0)
FST-OEF-2005[22]	302 (53.8)	259 (46.2)	75 (11.8)	66 (10.4)	109 (17.2)	385 (60.6)	–	–	–	–	–
772th[23]	–	–	62 (12.7)	–	69 (14.1)	185 (37.8)	16 (3.3)	8 (1.6)	65 (13.3)	8 (1.6)	76 (15.5)
541th[23]	–	–	158 (15.5)	–	167 (16.3)	487 (47.7)	41 (4.0)	16 (1.6)	67 (6.6)	19 (1.9)	67 (6.6)
7th-Mali and CAR[27]	45 (72.8)	16 (26.2)	11 (14.9)	–	20 (27.0)	43 (58.1)	–	–	–	–	–
14th[10]	21 (50.0)	21 (50.0)	4 (21.1)	–	3 (15.8)	12 (63.1)	–	–	–	–	–
Total (%)	595 (63.1)	348 (36.9)	361 (13.2)	92 (3.4)	454 (16.6)	1402 (51.1)	63 (2.3)	26 (1.0)	132 (4.8)	27 (1.0)	186 (6.8)

"–" signifies data unavailable.

The numbers in the brackets represent the percentage distributions of different types and locations of injury in each group of FSTs.

extremity injuries was slightly lower in 48th CSH (42%) than in the 212th MASH (approximately 52%) and the FSTs (37.83–67%, 51.11% on average).[31,34] Moreover, the three most common procedures performed in the FSTs were I&D, open RUA, and external fixation, and these results are similar to those from the 212th MASH (I&D, external fixation, and abdominal procedures were the most common); however, these patterns contrast with those reported by the 48th CSH (I&D, facial procedures, and amputations were most common).[31,34] The frequencies of torso injuries were comparable among these units (48th CSH: 19%; 212th MASH: 16.56%; and FSTs: 16.55% on average), whereas the percentage of injuries to the eyes, ears, and face were remarkably lower in the FSTs (3.35% in average) than in the 48th CSH.[31,34] Because the frequencies of injuries to the head and neck and to the torso were much lower than the frequency of injuries to the extremities, there were relatively few head and neck surgical procedures and thoracic surgical procedures performed in the FSTs. Undoubtedly, the widespread use of body armor and armored vehicles by coalition forces protected against high-velocity GSWs and reduced the severity of injuries sustained to the chest and abdomen. However, recent studies have reported that the incidences of head, face, and neck injuries are disproportionately high in Iraq, Afghanistan, and Israel due to the widespread use of improvised explosive devices, rocket-propelled grenades, and other explosive ordnance.[35] These notions are supported by the fact that US soldiers sustained more head and neck injuries but fewer thoracic and abdominal injuries relative to Iraqi patients who had very limited personnel protective equipment during OIF.[14,15] Given that head/neck injuries and chest injuries are associated with high mortality, the majority of surgeries for these types of injuries would be performed purely for the acute management of hemorrhaging, hemopneumothorax, and the establishment of an emergency surgical airway in the FSTs, whereas the specialist surgeries were supposed to be performed at higher level medical facilities after evacuation.[36]

Rapid and effective evacuation of critically injured patients from a war zone to a military medical facility is believed to be a determining factor of the efficiency of combat medical care. The lethality of war wounds among US soldiers significantly decreased from approximately 30% in World War II to 24% in the Vietnam War due to the wide use of helicopter evacuation. The utilization of FSTs further reduced war wound lethality to 10% during the wars in Iraq and Afghanistan. Nevertheless, the various types of surgical teams have exhibited substantial differences in the killed in action (KIA) and died of wound (DOW) rates during different periods of war. For example, the KIA rates were approximately 7.76% and 2.50% among all casualties presented to the US 274th FST (October 2001 to May 2002) and the 541th FST (November 2006 to December 2007), respectively, during the OEF,[23,28] whereas the KIA rate in the US

TABLE V. Mechanism of Injury in Casualties Treated in Different FSTs

Team Designation	Mechanism of Injury									
	FEI	GSW	MVA/RTA	Fall	Crash	Burn	SW	Crush	Blunt	Others
FST-Kokoda[12]	43 (68.3)	18 (28.6)	2 (3.2)	–	–	–	–	–	–	–
FST 1, 2, 5, 6[3]	105 (45.1)	74 (31.8)	–	–	25 (10.7)	–	–	–	–	29 (12.5)
FRSS-OIF-2003[15]	(48.0)	(43.0)	–	–	–	(3.0)	–	(2.0)	(3.0)	(1.0)
FRSS- OIF-2004, 2005[17]	(62.0)	(33.0)	–	–	–	(0.5)	–	(1.0)	(2.0)	(2.0)
250th-OEF[16]	26 (31.0)	58 (69.0)	–	–	–	–	–	–	–	–
274th[28]	117 (57.1)	29 (14.2)	1 (0.5)	22 (10.7)	34 (16.6)	–	2 (1.0)	–	–	–
102th[21]	12 (21.8)	24 (43.6)	10 (18.2)	5 (9.1)	–	–	4 (7.3)	–	–	–
FST-OEF-2005[22]	198 (36.1)	145 (26.4)	80 (14.6)	74 (13.5)	2 (0.4)	18 (3.3)	11 (2.0)	11 (2.0)	10 (1.8)	
772th[23]	143 (44.7)	69 (21.6)	41 (12.8)	17 (5.3)	7 (2.2)	5 (1.6)	11 (3.4)	–	–	27 (8.4)
541th[23]	374 (49.7)	215 (28.6)	60 (8.0)	28 (3.7)	9 (1.2)	18 (2.4)	2 (0.3)	–	–	46 (6.1)
FST-Ivory-2002[9]	–	2 (40.0)		–	–	–	3 (60.0)	–	–	–
7th-Mali and CAR[27]	22 (41.5)	17 (32.1)	14 (26.4)	–	–	–	–	–	–	–
Total	1040 (44.8)	651 (28.1)	211 (9.1)	146 (6.3)	77 (3.3)	41 (1.8)	30 (1.3)	11 (0.5)	10 (0.4)	102 (4.4)

MVA, motor vehicle accident; RTA, road traffic accident;
"–", data unavailable.
The numbers in the brackets represent the percentage distributions of different types of injury mechanisms in each group of FSTs.

Navy FRSS was approximately 18.27% during OIF, which was even higher than that in the Vietnam War.[5,30] These data might reflect the comprehensive effects of conflict intensity, first aid capability, and evacuation proficiency on combat trauma survival. Additionally, the DOW rates in the split 541th FST (2.36%) and the FRSS (1%) were much lower than those that occurred in the Korean War, the Vietnam War, and the overall DOW rate observed in the War on Terrorism (4.5%).[5,23,24] However, the US Army 555th FST reported that the mortality rate for patients who underwent operations was much higher at approximately 12%, which indicated that a full 20-person FST might not be advantageous compared with a 14-person or smaller team in terms of treatment efficacy. Additionally, although many FSTs were deployed during the Iraq and Afghanistan wars, the majority of all injury mortalities also occurred in the pre-medical treatment facility environment and 24.3% of these deaths were identified as potentially survivable.[36] Thus, the small FSTs that are supposed to be more applicable and flexible than full FSTs might meet the need to provide surgical care closer to the point of injury within a short period of time in the context of large battlefields, especially during the initial phase of war.[14,15,37] The experience of the US split 541th and 912th FSTs also suggested that the organization of small, highly effective teams might be more practical than the preparation and splitting of full FSTs.[18,24] The small teams could be used separately, combined with each other or joined with other surgical and ancillary medical facilities according to the predicted medical care requirements.[18] Because the holding and treatment capacities can be quickly overloaded after deployment, small FSTs might be more dependent on air support for evacuation, resupply, and strategic relocation.

Recently, a large-sample retrospective study demonstrated that the CSHs tended to experience more remarkable increases in the numbers of patients than the FSTs during the stabilization maintenance phase of the Afghanistan conflict.[38] Moreover, the KIA rate was decreased among the critically injured who were transported within 60 min or less, whereas the DOW rate was significantly higher for critically injured casualties who were initially treated by a FST compared with those treated by a CSH.[38] Regarding the limited self-support capacities, a traditional US FST always depends on the adjacent battalion aid station or forward support medical company for sustainable resources, whereas Navy FRSSs are normally combined with a shock trauma platoon that assists with triage and initial resuscitation and provides surgical wards that can hold postoperative patients.[6,15] When the materials and personnel are exhausted, the FST may retreat back for rest and resupply or to support level III hospitals (CSHs, Naval Fleet Hospitals, or Air Force Theater Hospitals).[6] Based on these facts, we propose that the utilization of FSTs must be evaluated with great caution during different phases of a conflict (e.g., invasion, maneuver, or retreat) after judging the battlefield conditions, evacuation efficiency, and medical care requirements.

TABLE VI. Surgical Procedures Performed in Different FSTs

	FST-Telic-2003[13]	FRSS-OIF-2003[5]	FRSS-OIF- 2004, 2005[8,17]	250th-OEF[19]	274th[20]	FST-OEF-2005[22]	FST-Mali-2013[26]	7th-Mali and CAR[27]	14th-CAR[10]	Total[b]
Head and neck	–	21 (14.5)[a]	53 (6.0)[a]	12 (18.5)[a]	4 (2.1)	9 (2.3)	4 (3.2)	6 (8.3)	–	109 (5.6)
Craniotomy	–	–	–	–	2 (1.0)	2 (0.5)	4 (3.2)	1 (1.4)	–	9 (0.5)
Exploration	–	–	–	–	2 (1.0)	3 (0.8)	–	3 (4.2)	–	8 (0.4)
Tracheostomy	–	–	–	–	–	4 (1.0)	–	2 (2.8)	–	6 (0.3)
Chest	–	12 (8.3)[a]	33 (3.7)[a]	11 (16.9)[a]	17 (8.9)	78 (20.3)	3 (2.4)	1 (1.4)	4 (11.1)[a]	159 (8.2)
Closed-tube thoracostomy	–	–	–	–	5 (2.6)	37 (9.6)	–	–	–	42 (2.2)
Airway, intubation	–	–	–	–	–	31 (8.1)	–	–	–	31 (1.6)
Thoracotomy	–	–	–	–	11 (5.7)	6 (1.6)	3 (2.4)	1 (1.4)	–	21 (1.1)
Pericardial window	–	–	–	–	1 (0.5)	2 (0.5)	–	–	–	3 (0.2)
Cardiac massage	–	–	–	–	–	1 (0.3)	–	–	–	1 (0.1)
Exploration	–	–	–	–	–	1 (0.3)	–	–	–	1 (0.1)
Abdomen and pelvis	5 (14.3)	20 (13.8)	76 (8.5)	–	14 (7.3)	40 (10.4)	11 (8.3)	6 (8.3)	1 (2.8)[a]	173 (8.9)
Laparotomy	5 (14.3)	20 (13.8)	76 (8.5)	–	12 (6.3)	32 (8.3)	11 (8.3)	6 (8.3)	–	162 (8.3)
Splenectomy	–	–	–	–	–	3 (0.8)	–	–	–	3 (0.2)
Retropubic exploration	–	–	–	–	–	4 (1.0)	–	–	–	4 (0.2)
Sheeting	–	–	–	–	2 (1.0)	1 (0.3)	–	–	–	3 (0.2)
Soft tissue	17 (48.6)	33 (22.8)	414 (46.5)	32 (49.2)	114 (59.4)	96 (25.0)	50 (39.7)	36 (50.0)	5 (13.9)	797 (41.0)
I&D, wound exploration	17 (48.6)	18 (12.4)	367 (41.2)	24 (36.9)	73 (38.0)	36 (9.4)	13 (10.3)	33 (45.8)	3 (8.3)	584 (30.0)
Abscess drainage	–	–	–	–	12 (6.3)	–	–	–	2 (5.6)	14 (0.7)
Fasciotomy	–	15 (10.3)	47 (5.3)	8 (12.3)	8 (4.2)	27 (7.0)	2 (1.6)	3 (4.2)	–	110 (5.7)
Foreign body removal	–	–	–	–	11 (5.7)	4 (1.0)	32 (25.4)	–	–	47 (2.4)
Burn care	–	–	–	–	–	15 (3.9)	–	–	–	15 (0.8)
Complex laceration closure/ complex repair	–	–	–	–	9 (4.7)	14 (3.7)	–	–	–	23 (1.2)
STSG	–	–	–	–	1 (0.5)	–	3 (2.4)	–	–	4 (0.2)
Orthopedic	12 (34.3)	55 (37.9)	253 (28.4)	7 (10.8)	34 (17.7)	154 (40.1)	55 (43.7)	19 (26.4)	25 (69.4)[a]	614 (31.6)
Open RUA, I&D	–	26 (17.9)	160 (18.0)	–	–	50 (13.0)	–	–	–	236 (12.1)
External fixator	3 (8.6)	6 (4.1)	54 (6.1)	–	10 (5.2)	46 (12.0)	27 (21.4)	13 (18.1)	–	159 (8.2)
Amputation	5 (14.3)	23 (15.9)	39 (4.4)	7 (10.8)	13 (6.8)	29 (7.6)	3 (2.4)	3 (4.2)	–	122 (6.3)
Closed RUA	–	–	–	–	5 (2.6)	24 (6.3)	–	–	–	54 (2.8)
Hand surgery	–	–	–	–	–	–	17 (13.5)	–	–	17 (0.9)
ORIF	4 (11.43)	–	–	–	2 (1.0)	4 (1.0)	6 (4.8)	3 (4.2)	–	19 (1.0)
Dislocation reduction	–	–	–	–	–	–	2 (1.6)	–	–	2 (0.1)
Escharotomy	–	–	–	–	–	1 (0.3)	–	–	–	1 (0.1)
Arthrotomy	–	–	–	–	4 (2.1)	–	–	–	–	4 (0.2)
Vascular	1 (2.9)	4 (2.8)	62 (7.0)	3 (4.6)[a]	9 (4.7)	7 (1.8)	3 (2.4)	4 (5.6)	1 (2.8)[a]	94 (4.8)
Vascular repair	1 (2.86)	–	–	–	2 (1.0)	4 (1.0)	3 (2.4)	4 (5.6)	–	14 (0.7)
Hemorrhage control	–	–	–	–	6 (3.1)	–	–	–	–	6 (0.3)
Others	–	–	–	–	1 (0.5)	3 (0.8)	–	–	–	4 (0.2)

STSG, split-thickness skin grafts; ORIF, open reduction and internal fix.
The numbers in the brackets represent the percentage distributions of different types of surgical procedures.
[a]No detailed information on subdivisions.
[b]The percentage distribution of the subdivisions were calculated based on the data available.
"–", data unavailable.

TABLE VII. Number of Surgical Procedures Performed per Surgical Unit During Deployment

	Number of Procedures (/Unit Day)	Average (/Unit Day)
US and UK small FSTs (Iraq)		
FST-Telic-2003 (12 persons/unit)	1.46	1.27
FRSS-OIF-2003 (10 persons/unit)	0.63	
FRSS-OIF-2004, 2005 (10 persons/unit)	1.37	
US full FSTs (Afghanistan)		
250th-OEF (20 persons/unit)	0.42	1.28
274th (20 persons/unit)	0.86	
FST-OEF-2005 (20 persons/unit)	1.23	
French small FSTs (Africa)		
FST-Mali-2013 (13 persons/unit)	0.22	0.34
7th-Mali (11 persons/unit)	0.54	
7th-CAR (11 persons/unit)	0.25	
14th-CAR (11 persons/unit)	0.35	

Rational organization and effective predeployment training should be upgraded according to the medical experience learned from the battlefield.[39] There is evidence supporting the perspective that FSTs should be staffed primarily by general surgeons. The present review revealed that over 70% of all surgical procedures performed by the FSTs were soft tissue and orthopedic operations, and I&D as well as open reduction and external fixation were especially common. These data echo previous findings that 53% of combat extremity injuries were penetrating soft tissue wounds and 26% were fractures among the casualties in Iraq and Afghanistan. Most of the fractures (82%) were also found to be open fractures.[40] These findings indicate that a traditional FST must employ at least one experienced orthopedic surgeon who should be reinforced by an extra orthopedic surgeon if necessary.[24] Furthermore, the FSTs also performed primary procedures and definitive procedures in addition to lifesaving surgical procedures when an evacuation was delayed.[28] Several studies have reported that selective operations were also performed for the treatment of conditions such as hernia, appendicitis, and tumors in soldiers and civilians during wartime.[13,21,22] Broader operations than "damage control" surgeries were performed when the FSTs were employed in humanitarian and disaster relief actions.[9,41] Because most personnel assigned to a FST had little combat trauma training or experience in disaster rescue before deployment, extensive combat-related operation procedures, especially for the orthopedic skills and definite surgeries, should be included in the FST training courses for all surgeons before deployment if applicable. In addition to standard surgical training and realistic trauma training, new technologies, such as virtual reality, in combination with patient simulators might be used to improve the ability to handle complex multi-organ military trauma in the future.[42]

CONCLUSIONS

Full 20-person FSTs did not exhibit advantages in treatment capacity or effectiveness over small FSTs, which might be more applicable and flexible, especially during the initial phase of war. As orthopedic surgeries were frequently performed by FSTs, more orthopedic surgeons should be included in full FSTs, and at least one orthopedic surgeon is needed per split or small FST. FSTs from different countries had unique medical personnel compositions due to various mission requirements and battlefield situations. Most FSTs depend on other medical facilities for sustainable resources and postoperative holding wards. Compared with level III medical facilities, FSTs exhibited significant differences in terms of the trauma conditions encountered (i.e., mechanisms of injury and injury locations) and surgical procedures performed during wartime. Thus, utilization of FSTs and level III facilities must be evaluated carefully in the context of the battlefield situation, medical care requirements, and evacuation efficiency. Orthopedic skill training should be intensified for all medical personnel before deployment.

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