The U.S. Navy's Forward Resuscitative Surgery System during Operation Iraqi Freedom

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The forward resuscitative surgery system (FRSS) is the Navy's most forward-deployed echelon II medical unit. Between March and August 2003, six FRSS teams were deployed in support of Operation Iraqi Freedom (OIF). During the combat phase of OIF (March 21 to May 1, 2003), a total of 34 Marine Corps and 62 Iraqi patients underwent treatment at a FRSS. FRSS teams were assigned two distinct missions; "forward" FRSS teams operated with combat service support elements in direct support of regimental combat teams, and "jump" FRSS teams served as a forward element of a surgical company. This article presents the experiences of the FRSS teams in OIF, including a discussion of time to presentation from wounding, time to operation, time to evacuation, and lessons learned from the deployment of the FRSS.

Introduction

Since September 11, 2001, the U.S. Marine Corps (USMC) has mounted at least two major combat operations far removed from their usual sea bases. During both Operation Enduring Freedom in Afghanistan and Operation Iraqi Freedom (OIF), the USMC conducted combat operations >400 miles inland. In past sea-based operations, Navy Medicine relied on fleet surgical teams aboard large-deck amphibious assault ships to provide echelon II surgical capabilities in support of USMC combat operations. Because of the distances involved, this was not practical to support operations in either Afghanistan[1] or Iraq. The USMC therefore turned to a new surgical platform, the forward resuscitative surgery system (FRSS), to provide highly mobile and far-forward surgical capabilities. The purpose of this article was to examine how the FRSS was used during OIF, specifically to demonstrate whether the concept of far-forward surgery to care for seriously wounded war casualties was validated.

As time and distance from wounding to surgical intervention increase, so do morbidity and mortality rates.[2] Historically, ~20% of all modern war casualties are killed in action. During the Vietnam War, the Weapons Demonstration Munitions Effectiveness Team study demonstrated that 25% of those killed in action died 10 to 60 minutes after wounding and 3 to 5% of casualties required immediate surgical intervention to survive.[3] Exsanguination was the most common preventable cause of death.

The goal of the FRSS is to save both "life and limb" of those who would be lost because of delayed access to surgical care by decreasing transport times between the point of wounding and echelon II surgical capabilities. To maintain the mobility necessary to move along with a mobile combat services support element, this forward surgical capability has, by necessity, limited resources.

The FRSS was devised to address a specific subset of casualties within the Joint Readiness Clinical Advisory Board patient condition database. The database was developed to represent the range of injuries and disease nonbattle injuries known to occur in a theater of operations.[4] The FRSS subset consists of 59 patient conditions identified as requiring lifesaving surgical intervention before evacuation. A sample of these conditions is listed in Table I.

During the Vietnam conflict, with rapid transport to definitive surgical care, most of these casualties survived. The aim of the FRSS teams during OIF was to salvage these casualties without using fixed medical treatment facilities, which were available in Vietnam but were not available during OIF. To accomplish this mission, the FRSS teams used "damage control" surgical techniques.[5] These surgical procedures restored more normal physiological functioning, often at the expense of anatomic repair, e.g., doing only what is required to keep a patient alive. This concept of damage control surgery is used in many civilian level I trauma centers, where limited supplies and personnel are not the issue but emphasis is placed on early restoration of normal physiological parameters for trauma patients, with later definitive surgery. Definitive treatment of the injuries was accomplished later, at a higher echelon of medical care. This concept of "minimal acceptable care"[6] was necessary because weight and footprint size limits mobility of the FRSS.

The initial table of organization for a FRSS included two general surgeons, an anesthesiologist, a critical care nurse, an independent-duty hospital corpsmen, two operating room technicians, and one field medical technician (Naval Enlisted Classification 8404) (total personnel, eight). An en route care nurse was added to the FRSS for OIF. Three of the six FRSS teams deployed for OIF substituted an orthopedic surgeon for one of the general surgeons.

The table of equipment for the FRSS included two Base-X tents (without their environmental control units), a portable oxygen generator, two 3-kW electrical generators, a portable operating table with lights, an Ohmeda Portable Anesthesia drawover anesthesia vaporizer (Ohmeda, Madison, Wisconsin), three Impact Ultralite model 326 portable ventilators (Impact

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TABLE I

CONDITIONS REQUIRING LIFESAVING SURGERY BEFORE EVACUATION

Patient Condition Description
Cerebral contusion, closed with intracranial hematoma, deteriorating comatose patient
Wound, face and neck with airway obstruction and/or major vessel involvement
Wound, upper arm, penetrating, lacerated, with/without fracture, with nerve and/or vascular injury
Wound, abdomen, open, penetrating, perforating with shattered kidney
Wound, abdomen, open, with pelvic fracture and penetrating perforating wounds to pelvic organs
Wound, thigh, open, penetrating, perforating with fracture and vascular injury, limb salvageable
Wound, lower leg, open, penetrating, with fracture and nerve and vascular injury, limb salvageable
Multiple-injury wound, chest with hemopneumothorax, abdomen with penetrating perforating wound, liver
Multiple-injury wound, abdomen with penetrating perforating wound, colon and spleen

Instrumentation, West Caldwell, New Jersey), and five Propaq 206 monitors (automatic blood pressure, temperature, electrocardiography, and pulse oximetry; Welch-Allyn, Beaverton, Oregon). The FRSS was designed to be able to care for 18 severely injured patients requiring stabilizing surgery. The FRSS can function for 48 hours without resupply or relief of personnel.

All of the FRSS equipment was designed to fit into a high-mobility multipurpose wheeled vehicle M-997 and a high-mobility multipurpose wheeled vehicle M-998, each pulling a M-101 cargo trailer. For OIF, an additional high-mobility multipurpose wheeled vehicle M-1035 or a 7-ton truck was added to carry the resupply blocks for the FRSS and the en route care nurse and supplies. By design, all of the medical equipment and supplies (minus the vehicles) could be transported via C-130 aircraft or CH-53 helicopter.

A shock trauma platoon (STP) is a highly mobile emergency room staffed by two emergency physicians, a physician's assistant, an emergency room nurse, 14 hospital corpsman, and seven Marines. The STPs were originally designed to reinforce a battalion or regimental aid station or to establish a beach or helicopter evacuation station. During the combat phase of OIF, each FRSS was paired with a STP. When working in concert with a FRSS, the STP provided emergency care and supplemented preoperative and postoperative care for patients requiring emergency surgery.

The direct air support center (DASC) colocated with the 1st Marine Division Headquarters directed tactical evacuation using helicopters (casualty evacuation). Later in the conflict, a U.S. Navy flight surgeon was placed in charge of the patient evacuation team (PET) colocated with the DASC. The DASC controlled six designated casualty evacuation CH-46 helicopters, which transported patients from the point of injury to the nearest surgical capability (FRSS, surgical company, fleet hospital, or U.S. Army combat support hospital). The U.S. Army 498th Aeromedical Evacuation Squadron, with 12 UH-60 medical evacuation helicopters, was attached to I Marine Expeditionary Force (MEF) and performed evacuation of casualties from the FRSS or surgical company to a higher echelon of medical care.

TABLE II

USMC CASUALTIES DURING THE COMBAT PHASE OF OIF

Casualty Category	No. of Casualties	%
KIA	55	18.27
DOW	3	1.00
WIA	243	80.73
Total	301	
KIA rate		18.27
DOW rate		1.22

KIA, killed in action; WIA, wounded in action; DOW, died of wounds.

Methods

From March 21 through May 1, 2003, patient data were collected by the officer in charge of each FRSS and were reported to the Chief of Professional Services of the Health Services Battalion. Total USMC casualties, numbers of Marines killed in action, and numbers who died of wounds were obtained from the G-1 section, I MEF. Interviews of key personnel were undertaken and data were recorded in a personal computer by one of the authors (H.R.B.). At the start of OIF, six FRSS teams were deployed. One FRSS lost most of its equipment, because of a vehicle breakdown during a sandstorm, early in the conflict. For the duration of OIF, this FRSS operated in combination with another FRSS. These two teams traveled along with the combat service support element in direct support of the 1st Marine Division and were thus located closest to the point of wounding. Their data were reported as one team, designated a "forward" FRSS team. The other four FRSS teams were deployed in advance of the two surgical companies. They would "jump" to where a surgical company was to set up and would operate until the surgical company was set up at that position and able to accept surgical casualties, usually 2 to 3 days. They would then meld in as a surgical section of the surgical company until they needed to jump forward again. For the purposes of this analysis, the data from these FRSS teams were pooled and reported as "jump" FRSS teams. Two teams functioned in both roles at various times during the combat phase of OIF. Their data were

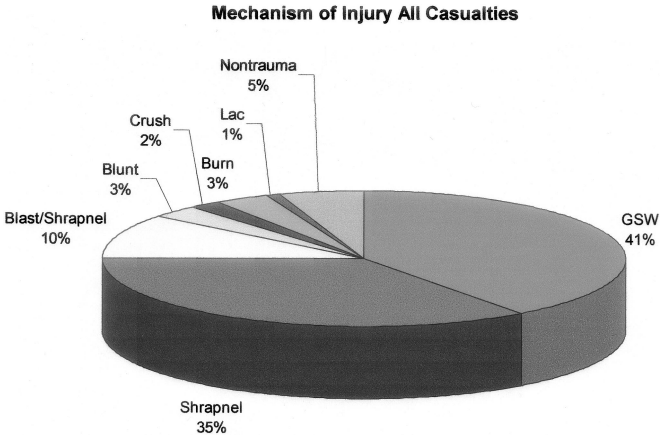


Fig. 1. Mechanisms of injury for all patients treated by FRSS teams. GSW, gunshot wound; Lac, laceration(s).

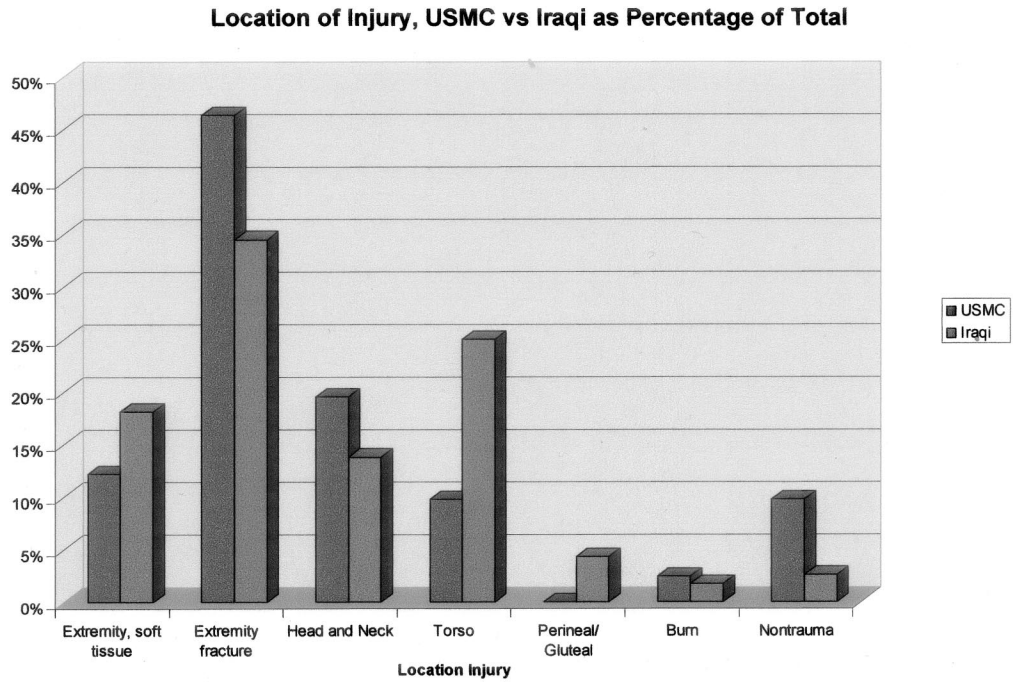
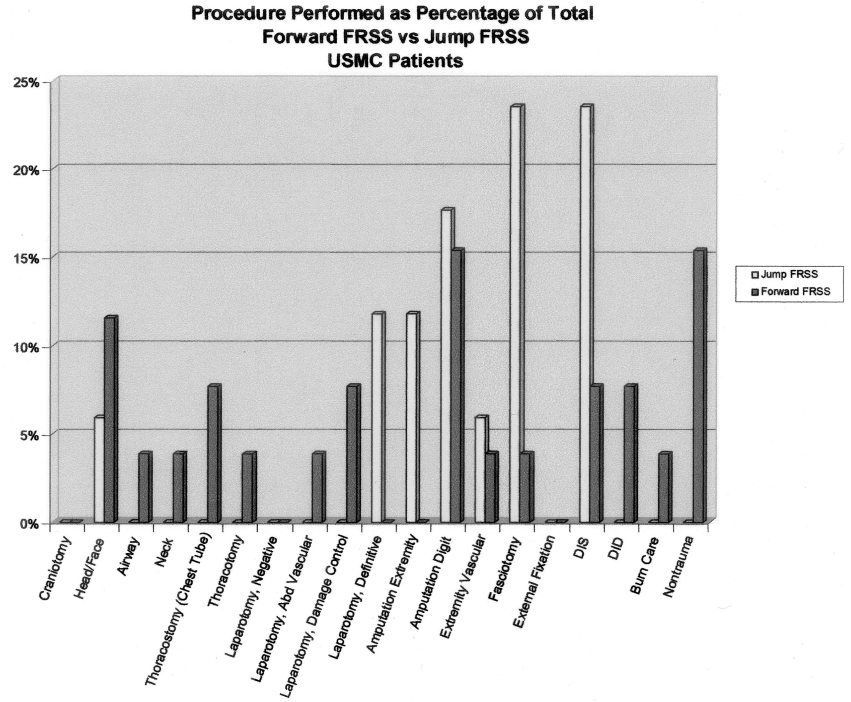


Fig. 2. Locations of injuries for Iraqi patients and U.S. Marines.



Note: DIS = debridement, irrigation, and splinting; DID = debridement, irrigation, and dressing.

Fig. 3. Surgical procedures performed by forward versus jump FRSS teams. DIS, debridement, irrigation, and splinting; DID, debridement, irrigation, and dressing.

allocated depending on the role in which they were functioning at the time casualties were treated. Data are reported as raw numbers or percentages.

Results

During the period of March 22 through May 1, 2003, a total of 34 wounded Marines and 62 wounded Iraqi soldiers and civilians underwent treatment at a FRSS. A total of 108 surgical procedures were performed for Iraqis and 43 procedures were performed for Marines. Total I MEF USMC casualties are presented in Table II. Of 246 Marines wounded in action, 14% underwent surgery at a FRSS. No USMC casualty who underwent treatment at a FRSS died of wounds. The remaining 86% of USMC wounded were treated at a USMC surgical company, at a U.S. Navy fleet hospital, at a U.S. Army combat support hospital, or aboard the U.S. Naval Ship Comfort. Only three of 246 USMC casualties died of wounds (1% of all USMC wounded).

Mechanisms of injury are presented in Figure 1. Gunshot wounds and shrapnel injuries represented >75% of all injuries. Iraqi patients had a higher incidence of thoracic and abdominal injuries than did U.S. Marines. Marines had a higher incidence of extremity injuries than did Iraqi patients. A comparison of the types of injuries between U.S. Marines and Iraqi patients is presented in Figure 2.

Forward FRSS teams performed more urgent surgical procedures that were life- or limb-saving, such as neck and airway procedures, tube thoracostomy, thoracotomy, and damage control laparotomy, than did jump FRSS teams. The jump FRSS teams performed procedures typical of delayed care, such as definitive laparotomy, extremity fasciotomy, and extremity debridement, irrigation, and splinting. A comparison of surgical procedures between forward and jump FRSS teams is presented in Figure 3.

The time to presentation of patients from the time of wounding until arrival at the FRSS, time to surgical procedures, and time to evacuation were shorter for wounded Marines treated by the forward FRSS teams, compared with the jump FRSS teams. For all Marine casualties, the time from wounding until presentation to the forward FRSS was <1 hour. The time from presentation at a FRSS to operation could be a short as 10 minutes, when necessary. Times to evacuation from the FRSS to rearward echelons of medical care were highly variable and largely dependent on weather conditions affecting the ability of helicopters to fly. Long delays in evacuation typically occurred during sandstorms, when helicopters could not fly. Table III presents the times from wounding to presentation at a FRSS, times from presentation to surgery, and times from surgery to evacuation to a higher echelon of medical care for patients treated by forward and jump FRSS teams.

TABLE III

TIME TO PRESENTATION FROM WOUNDING UNTIL ARRIVAL AT A FRSS, TIME TO SURGERY, AND TIME TO EVACUATION TO A HIGHER ECHELON OF MEDICAL CARE FOR U.S. MARINE CASUALTIES TREATED AT FORWARD VERSUS JUMP FRSS TEAMS

Patient No.	Time to Presentation	Time to Operation	Time to Evacuation
1	20 minutes	20 minutes	20 hours
2	20 minutes	2.5 hours	18 hours
3	30 minutes	20 minutes	22 hours
4	15 minutes	10 minutes	1 hour
5	15 minutes	10 minutes	45 minutes
6	1.5 hour	2 hours	2 hours
7	15 minutes	15 minutes	7 hours
8	20 minutes	1.5 hours	6 hours
9	1.5 hours	2 hours	5.5 hours
10	20 minutes	10 minutes	4 hours
11	30 minutes	10 minutes	4 hours
12	10 minutes	15 minutes	4.5 hours
13	10 minutes	10 minutes	7 hours
14	20 minutes	10 minutes	2.5 hours
15	18 hours	10 minutes	8 hours
16	17 hours	2 hours	7 hours
17	23 hours	3 hours	5 hours
18	10 hours	15 minutes	18 hours
19	16 hours	4.5 hours	6 hours
20	6 hours	20 minutes	5 hours
21	5 hours	2 hours	9 hours
22	6 hours	2.5 hours	5 hours
23	18 hours	3.5 hours	5 hours
24	2.5 hours	2 hours	5 hours
25	2.5 hours	4 hours	3 hours
26	3 hours	3 hours	12.5 hours
27	4 hours	10 minutes	37 hours
28	23 hours	10 minutes	10.5 hours
29	15 hours	10 minutes	18 hours
30	10 hours	10 minutes	15 hours

Times are rounded to the nearest 5 minutes (for times of <1 hour) or nearest 0.5 hour (for times of >1 hour). Time to presentation is the time from wounding to presentation of the patient at a FRSS. Time to operation is the time from presentation at a FRSS to the time the patient was brought into the operating tent. Time to evacuation is the time from the completion of a surgical procedure to the time the patient was evacuated (usually by helicopter) to a higher echelon of medical care. Patients 1 to 14 were treated by forward FRSS teams. Patients 15 to 30 were treated by jump FRSS teams.

Discussion

During OIF, the USMC moved echelon II surgical capabilities far forward to provide lifesaving and limbsaving surgical treatment for wounded U.S. Marines, as well as for Iraqi patients. A majority of the projected surgical conditions described in the Joint Readiness Clinical Advisory Board database that the FRSS was designed to treat indeed presented for treatment at a FRSS during OIF. A high percentage of USMC injuries were extremity injuries. Iraqi patients, both civilians and soldiers, had a higher incidence of torso injuries than did USMC patients presenting to a FRSS. This situation was very likely attributable to the wearing of Kevlar helmets and body armor by Marines[6] and an almost-complete lack of protective equipment for Iraqi patients. Because of the high incidence of extremity injuries and subsequent orthopedic surgical procedures, the substitution of an orthopedic surgeon for one of the general surgeons on some of the FRSS teams was considered to be beneficial by the teams with an orthopedist.

Patients treated by a forward FRSS team tended to have a higher acuity of injury than did patients treated by a jump FRSS team. More damage control laparotomies were performed by the forward teams, whereas the jump teams, operating more to the rear, performed more definitive laparotomies and fasciotomies.

One obvious advantage of locating the forward FRSS teams closer (5–15 km) to the point of wounding was that the time from wounding to surgery was usually <1 hour, typically 30 minutes. In comparison, the patients who presented to jump FRSS teams, which were typically located >50 km from the point of wounding, presented 2 to 20 hours (or longer) after injury. Therefore, the time to first surgical care was clearly shortened by positioning mobile surgical care closer to the combat units of the 1st Marine Division.

In this experience, the actual period of combat lasted 5 weeks. Only 34 Marines were treated at a FRSS, whereas 212 Marines were treated at other coalition medical facilities. Because of the short duration of conflict and small numbers of casualties, care should be exercised in drawing far-reaching conclusions about the future of naval medical support of the USMC. However, several conclusions can be drawn. One is that a forward FRSS can markedly reduce the time from injury to surgery. Colocation of a FRSS with a STP was very helpful, given the high acuity of the surgical patients treated. A FRSS has only eight staff members and can care for only five patients at one time. The STP personnel provided preoperative and postoperative care, allowing the surgeons and anesthesiologists to focus on surgery.

Because of the high acuity of injuries treated by the FRSS teams, rapid evacuation of postsurgical patients to a higher echelon of medical care was essential; otherwise, resources would be very rapidly depleted. Rapid air evacuation to a higher echelon of medical care necessitates an en route care nurse, equipment, good communications, and dedicated aeromedical evacuation capability (which assumes control of air space and good weather).

The addition of an en route care nurse to the FRSS was essential during OIF. Because of the acuity of their injuries (need for mechanical ventilation, hypotension, coagulopathy, and acidosis), the patients required a critical care nurse to accompany them during helicopter transport to a higher echelon of medical care. Communications were poor throughout the combat phase of OIF. Satellite telephones and electronic mail were the only reliable methods of communication. Electronic mail was available only later, at fixed locations. Without adequate communications with the DASC/PET, which controlled dedicated medical evacuation helicopters, the advantages of forward FRSS teams would be lost.

What does this experience teach us about the future of naval surgical support for USMC operations? FRSS/STP combinations will likely be used in future conflicts. These teams are much more mobile than a USMC surgical company, which does not have organic lift and typically requires 2 to 4 days to be fully set up. Naval medicine must train for this certain change. The table of organization of USMC medical battalions, both active and reserve, will change to reflect future use of FRSS/STP combinations. Improved communication capability must be provided to each FRSS to maximize the advantages of a forward echelon II surgical capability. Without good secure communications between the DASC/PET and FRSS/STP, the risks of placing surgical personnel and equipment far forward would outweigh the benefits to the patients.

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U.S. Air Force attendees relax during a break-out session