# Trauma System Development in a Theater of War: Experiences From Operation Iraqi Freedom and Operation Enduring Freedom

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**Background:** Medical lessons learned from Vietnam and previous military conflicts led to the development of civilian trauma systems in the United States. Operation Iraqi Freedom represents the first protracted, large-scale, armed conflict since the advent of civilian trauma systems in which to evaluate a similar paradigm on the battlefield.

**Methods:** Collaborative efforts between the joint military forces of the United States initiated development of a theater trauma system in May 2004. Formal implementation of the system occurred in November 2004, the collaborative effort of the three Surgeons General of the U.S. military, the United States Army Institute of Surgical Research, and the American College of Surgeons Committee on Trauma. One trauma surgeon (Trauma System Director) and a team of six trauma nurse coordinators were deployed to theater to evaluate trauma system component issues. Demographic, mechanistic, physiologic, diagnostic, therapeutic, and outcome data were gathered for 4,700 injured patients using the Joint Theater Trauma Registry. Interview and survey methods were utilized to evaluate logistic aspects of the system.

**Results:** System implementation identified more than 30 systemic issues requiring policy development, research, education, evaluation of medical resource allocation, and alterations in clinical care. Among the issues were transfer of casualties from point of injury to the most appropriate level of care, trauma clinical practice guidelines, standard forms, prophylactic antibiotic regimens, morbidity/mortality reporting, on-line medical evacuation regulation, improved data capture for the trauma registry, and implementation of a performance improvement program.

**Conclusions:** The implementation of a theater trauma system demonstrated numerous opportunities to improve the outcome of soldiers wounded on the battlefield.

**Key Words:** Battlefield, Combat, System, Trauma, Quality improvement, War.

*J Trauma.* 2006;61:1366–1373.

The development of trauma care has been a synergistic relationship between the military and civilian medical environments for the past two centuries.[1–3] During the Civil War, military physicians realized the utility of prompt attention to the wounded, early debridement, and amputation to mitigate the effects of tissue injury and infection and evacuation of the casualty from the battlefield. World War I saw further advances in the concept of evacuation and the development of echelons of medical care. With World War II, blood transfusion and resuscitative fluids were widely introduced into the combat environment and surgical practice was improved to care for wounded soldiers. From his World War II experiences, Dr. Michael Debakey noted that wars have always promoted advances in trauma care because of the concentrated exposure of military hospitals to large numbers of injured people during a relatively short span of time. Furthermore, this wartime medical experience has fostered a fundamental desire to improve outcomes by improving practice.[4] In Vietnam, more highly trained medics at the point of wounding and prompt aeromedical evacuation decreased the battlefield mortality rate even further.[5]

In 1966, the National Academy of Sciences published "Accidental Death and Disability: The Neglected Disease of Modern Society," noting trauma to be one of the most significant public health problems faced by the nation. Concomitant with advances on the battlefield and the conclusions of the National Academy of Sciences was the formal development of civilian trauma centers. In 1976, the American College of Surgeons produced the first iteration of injury care guidelines, the "Optimal Resources for the Care of the Injured Patient." This concept rapidly evolved into the development of formal, integrated trauma systems. Trauma centers and trauma systems in the United States have had a remarkable impact on improving outcomes of injured patients,[2,5–18] reducing mortality by up to 15% in mature systems.

However, despite the evolving successes of civilian trauma systems, Operations Desert Shield and Desert Storm in 1992 highlighted a number of issues in which the U.S. military had fallen behind the successful construct fostered by

Submitted for publication April 6, 2006.

Accepted for publication September 5, 2006.

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Presented at the 64th Annual Meeting of the American Association for the Surgery of Trauma, September 22–24, 2005, Atlanta, Georgia.

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DOI: 10.1097/01.ta.0000245894.78941.90



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civilian systems of injury care. Inadequacies were formally noted in both preparation and delivery of trauma care in the combat environment.[3,19–21] Shortly after the terrorist attacks of September 11, 2001, the United States once again had vast numbers of soldiers committed to armed conflict. At this juncture, the medical leadership of the joint forces enacted a plan to emplace a formal system of trauma care in theater to improve the care of the battlefield wounded. The goal was to develop and implement a true trauma system, modeled after the successes of civilian systems but modified to account for the realities of combat. The stated vision of the joint theater trauma system was to ensure that every soldier, marine, sailor, or airman injured on the battlefield has the optimal chance for survival and maximal potential for functional recovery. In other words, to get the right patient to the right place at the right time.

## METHODS

The joint military forces of the United States initiated the development of a theater trauma system in May 2004. Initial groundwork included military surgical consultant visits to theater followed by the identification of a trauma surgeon (Trauma System Director) to be placed at the theater's medical command headquarters to introduce the concept and importance of establishing a trauma system in the theater of operations. After this preparatory phase, a collaborative effort of the Surgeons General of the U.S. military, United States Central Command, the United States Army Institute of Surgical Research, and the American College of Surgeons Committee on Trauma formally implemented the system in November 2004. A trauma system director and a team of six trauma nurse coordinators were deployed to the theater to address trauma system components and to organize the medical assets and identify discrete deficiencies within the existing medical infrastructure. A formal system performance improvement process was initiated. Injury data, including demographic, mechanistic, physiologic, diagnostic, therapeutic, and outcome data, were gathered using a Joint Theater Trauma Registry (JTTR). Interview and survey methods were utilized to evaluate logistic aspects of the system.

## RESULTS

The initial charges of the system were identified as follows:

1. Recommend improvements to the trauma system to:
   a. optimize placement of surgical assets within theater.
   b. decrease the number of surgical sites within the theater.
   c. develop triage criteria for casualty evacuation to get "the right patient to the right place at the right time."
   d. develop and implement trauma practice guidelines.
2. Review and maintain the following:
   a. JTTR
   b. Morbidity and mortality reports shared between institutions
   c. Operative case reports
3. Develop clinical information management scheme.
4. Implement a system of continuous performance improvement.
5. Develop/write a resource for optimal care of combat casualties, "green book" utilizing the Optimal Resources Gold Book[22] as a template.

Derived from the Resources for Optimal Care handbook,[22] component elements of the trauma system included prevention, point of wounding/battlefield care, and acute care facilities. To be complete and successful, the system implementation also mandated placement and evaluation of infrastructure elements including trauma leadership (impact of education on medical and tactical planning, etc.; path to leaders who make the decisions); professional resources; performance improvement; morbidity and mortality information management; research and education; and advocacy.

### Prevention

Since the implementation of the military trauma system, the effect of new prevention measures has been most marked in the reduced number of soldiers killed from combat wounds, with current case fatality rates of 8.8% compared with 16.5% during Vietnam[23,24] (Tables 1and 2). The two primary modes of prevention are realistic and relevant predeployment training and personal protective equipment.

Numerous trauma training programs, including the Army, Air Force, and Navy Trauma Training Centers associated with nationally renowned Level I trauma centers, have evolved to train providers to treat combat injury and prepare them for the realities of medical care on the battlefield. Others courses, such as Tactical Combat Casualty Care, Emergency War Surgery, and the Joint Forces Combat Trauma Management Course, have revolutionized the way medical providers are trained for wartime deployment.

Data gathered about injury patterns has driven force protection changes in combatant training and equipment. The impact of the personal protective equipment (body armor) fielded during this conflict has been substantial. In an early interim analysis of casualties from January to July 2004, the rate of thoracic injury was 18% in patients without body armor and <5% in soldiers wearing armor. As the conflict transitioned from a maneuver war, in which most injuries were the result of gunshot wounds, to an insurgency characterized by ambushes and improvised explosive devices, wounding patterns changed from mainly small arms injuries

**Table 1** Comparative US Combat Casualty Statistics

| | World War II | Vietnam War | Iraq/Afghanistan |
|---|---|---|---|
| KIA (%) | 23.7 | 21.3 | 12.5 |
| DOW (%) | 3.4 | 3.5 | 4.1 |
| Total mortality (%) | 22.8 | 16.5 | 8.8 |

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



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**Table 2** Iraq/Afghanistan US Combat Casualty Statistics

| | WIA | RTD | Evacuated | DOW | KIA | Total Mortality |
|---|---|---|---|---|---|---|
| Total | 13,383 | 6,482 | 6,618 | 283 | 986 | 8.8% |

KIA, killed in action; DOW, died of wounds; WIA, wounded in action; RTD, return to duty.

to multiple fragment injuries. Rapid fielding initiatives led to the up armoring of military vehicles with anecdotal concomitant reports of a decrease in the number and severity of these types of injuries.[25]

## Battlefield Care

Most deaths on the battlefield are caused by total body disruption, severe brain injury, or hemorrhage. Little can be done on the battlefield for primary injury from total body disruption or severe brain injury. However, attention to hemorrhage control at the point of wounding is the focus of ongoing efforts. Responding to feedback from medics and corpsman on the battlefield, a number of products and therapeutic devices have been fielded to the battlefield for hemorrhage control, including new hemostatic dressings and newly tested and selected tourniquets.[26,27] Reports from the battlefield thus far have documented efficacy of both dressings and tourniquets in the tactical environment similar to those in the literature.[28]

## Acute Care Facilities

The onset of Operation Iraqi Freedom was marked by a rapid ground influx of combat elements that required attached medical/surgical capability to support the fast-paced tempo of the conflict. Surgical support was initially ascribed to small surgical units such as the Army forward surgical team and the Navy forward resuscitative surgical system. Subsequently, more robust hospital elements with more operating room and intensive care unit capability were established throughout Iraq. With the increased capability came an increased capacity to render higher level care to soldiers injured on the battlefield. The larger hospital units were capable of operations 24 hours a day, 7 days a week, and could provide trauma care at a standard that would be expected of a major trauma center in the United States (Table 3).

## Leadership

With the backing of the Central Command Surgeon and the three Surgeons General, the position of trauma system director was rapidly incorporated as a general staff position within the theater medical command. This leadership position enabled the trauma system director to rapidly implement actionable items such as data collection, implementation of standard practice guidelines, and performance improvement. A number of trauma clinical practice guidelines have now been instituted as standards of care within the theater trauma system, including deep vein thrombosis prophylaxis, prophylactic antibiotics, hypothermia prevention, and the management of specific battlefield injury patterns such as burn, vascular injury, and penetrating traumatic brain injury. To illustrate the efficacy of clinical practice guidelines in theater, the rate of hypothermia upon presentation has been decreased from 7% to <1% since inception. The leadership and administration of the combat trauma system is roughly analogous to the leadership hierarchy of the U.S. civilian trauma community (Table 4). These intrinsic leadership entities within the medical system drive advances within the trauma system by direct oversight of the medical processes and advocacy, which ultimately leads to better patient care.

**Table 3** Comparison of Civilian and Military Trauma Center Levels

| Military Designation* | Description | US Civilian Designation |
|---|---|---|
| V | Major trauma center with teaching and research | I |
| IV | Large trauma center | II |
| III | Regional trauma center, limited capability, 30-day ICU holding capability | III |
| IIB | Community hospital with limited emergency surgery capability | IV |
| IIA | Battalion aid station outpatient clinic | — |
| I | EMS/Corpsman/Medic | — |

* Military trauma center levels are as follows: V, major US-based military hospital; IV, large, nontheater hospital (e.g., Landstuhl, Germany); III, e.g., theater hospitals in Iraq; IIB, e.g., Army Forward Surgical Team.

## Professional Resources

Professional resources are a finite and precious commodity, not only for the maintenance of the trauma system, but also for the medical care of injured warriors. Evaluation of the surgical assets in theater by the trauma system made a strong case for redeploying home many of the smaller surgical units after the larger combat support hospitals were established to conserve vital surgical resources, especially in light of the ongoing nature of the conflict and the likelihood of subsequent deployments for these individuals, approximately 65% of whom are Reserve soldiers.

In the context of the trauma system, it was rapidly determined that one trauma coordinator was needed for oversight at each combat support hospital to guarantee compliance with guidelines, improve information management, and enable data collection. Predeployment training for these individuals was performed under the guidance of the trauma coordinator and staff at the Brooke Army Medical Center and Wilford Hall Medical Center, the two Level I trauma centers in the Department of Defense. These trauma site coordinators have proven invaluable to the function of the combat trauma system.



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**Table 4** Trauma System Organization

| | Civilian Trauma System Components | Military Trauma System Components |
|---|---|---|
| National/federal level | American College of Surgeons, Committee on Trauma<br>- Registry (NTDB)<br>- AAST/EAST/WEST (academic organizations influencing trauma care) | Department of Defense, Health Affairs, Joint Surgeon's Office<br>- Joint Theater Trauma Registry<br>- Defense Medical Readiness Training Institute/ Combat Trauma Surgery Committee/Committee on Tactical Combat Casualty Care |
| State/command level | State Trauma System<br>- State Director (Texas: Governor's EMS and Trauma Advisory Committee Chair)<br>- State registry<br>- State Trauma System Plan | Combatant Command (CENTCOM)<br>- JTTR-derived data<br>- Joint Theater Trauma System (JTTS) |
| Regional level | Regional Trauma Areas<br>- registry Area of Responsibility (Operation Iraqi Freedom, Operation Enduring Freedom [Afghanistan])<br>- JTTR-derived AOR data | |
| Local level | Lead Trauma Center<br>- trauma registry JTTS Leadership<br>- local trauma database, begin capture JTTR data | |
| Local/regional components | Regional Advisory Council<br>- RAC Chair<br>- Rural/Urban Organizations<br>- EMS (ground/air)<br>- Hospital reps, all Levels<br>- PI/Comm/Rehab/Prev | MEDCOM/CENTAF/MEF Surgeon<br>- JTTS director<br>- Level II/III facilities<br>- Level I/Medevac Battalion<br>- Level II/III facilities<br>- PI/Comm/Prev |

## Information Management

Multiple deficiencies were noted in all aspects of the information management and casualty information flow of injured patients. This immediate concern was one of the primary issues addressed by the system. One basic problem noted early in the evaluation was the relative paucity of clinical patient information, which was transferred to the next higher level of care. In many instances, for lack of a better method, surgeons wrote brief narratives in marker directly on patients' dressings to convey clinically relevant information (Figs. 1 and 2).

The reason for this lack of information flow was multifactorial, but included communication failures, operational tempo, casualty acuity, casualty load, etc. The goals at the system level were to improve clinical information flow, thereby minimizing the number of duplicate procedures at multiple levels of care and streamlining the continuity of care for soldiers being evacuated from the battlefield. Several strategies are currently being implemented to correct this problem, including universal serial bus memory devices and Internet-accessible electronic medical records. One particular instrument was developed

**Fig. 1.** *Improvised patient information communication strategy.*

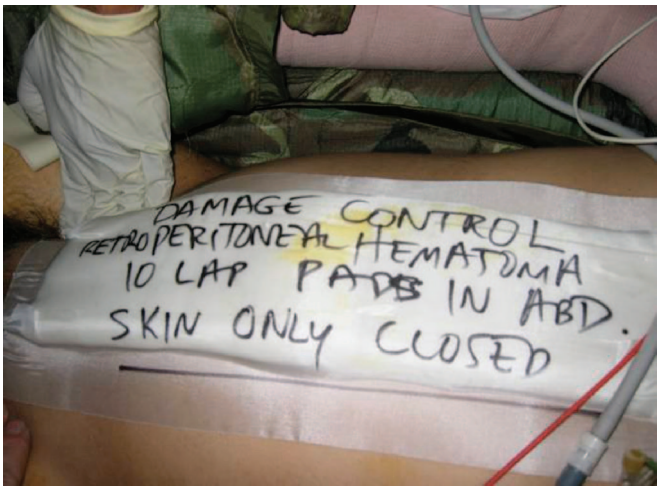


**Fig. 2.** *Improvised patient information communication strategy.*



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in response to the trauma system demand. This tool known as the Joint Patient Tracking Application is a Web-based application that allows users to get real-time information about the status of injured troops as they make their way through the medical system.

The other aspects of information flow essential to the improved care of injured soldiers were the performance improvement project and registry data management currency. The performance improvement process was adopted at all combat support hospital sites and is being utilized to identify inadequacies in the evolving system. Registry data that was being completed at a 10% rate before the system is now being collected on >80% of casualties within the current theater of operations.

## Research

Before the current conflict, much of the data on combat injury was derived from the Vietnam conflict and the Wound Data and Munitions Effectiveness Team database.[29–31] Before the development of the formal combat trauma system, little data were being published about the conflict, and the data being published was largely small series and case reports.[32–43] With the thought that research drives doctrine, a concerted effort was put forth to field the JTTR. This registry is a concise form developed to capture demographic, mechanistic, physiologic, diagnostic, therapeutic, and outcome data along with a brief physical examination (Fig. 3). To date, with improved registry capture as a direct result of the trauma system, the JTTR database contains >7,500 soldier injury

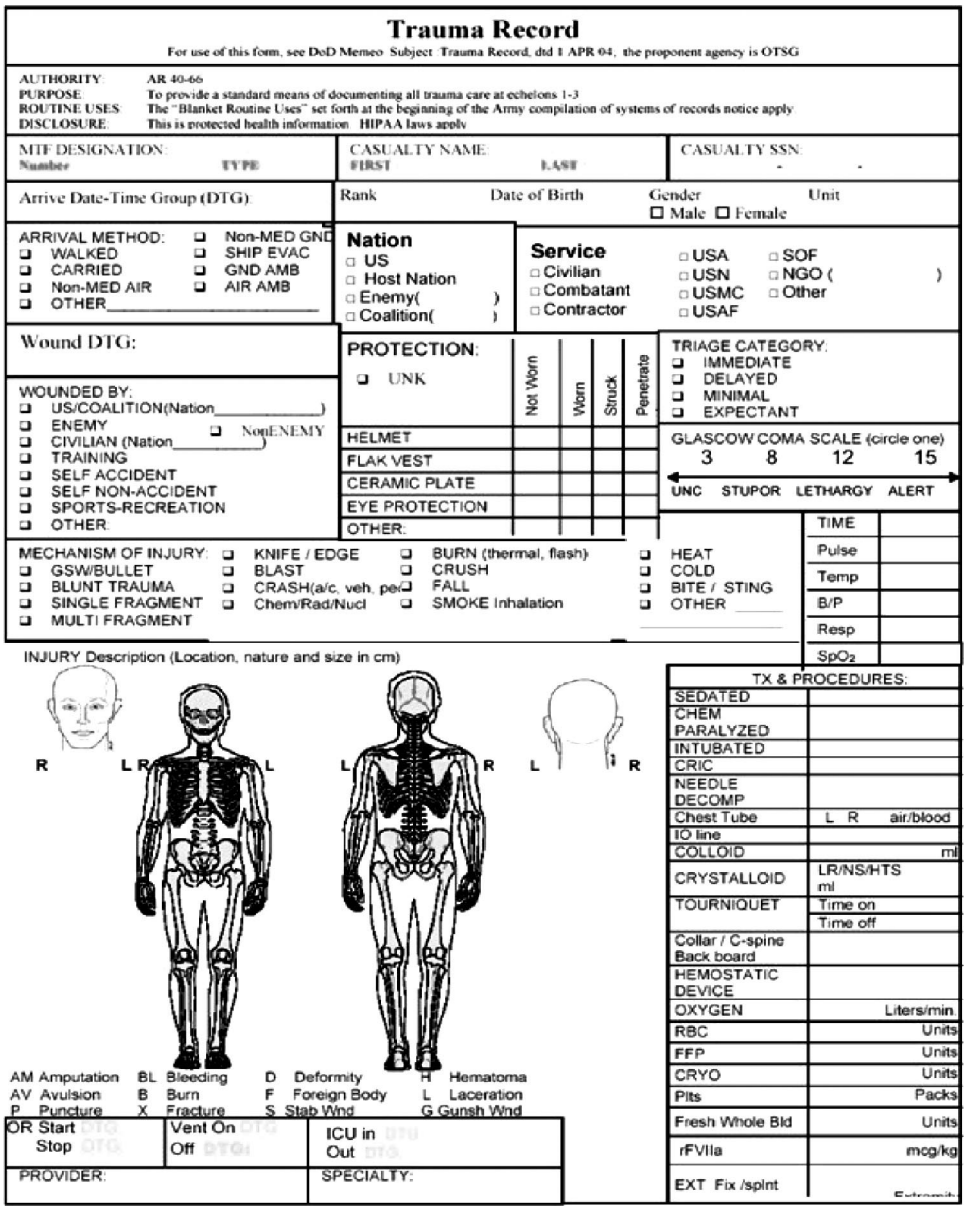


**Fig. 3.** *Joint theater trauma registry record.*



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records as well as data on other individuals injured and cared for at US theater medical assets. The results being derived from this data will likely drive the course of combat trauma care for decades to come.

Ongoing joint military research efforts include the following:

- Personal protective gear
- Body armor extensions
- Kevlar helmet revisions
- Hemostasis
- Battlefield tourniquets
- Hemostatic dressings
- Recombinant factor VIIa
- Resuscitation
- Hypotensive resuscitation
- Hemostatic resuscitation
- $O_2$ therapeutics/hemoglobin-based oxygen carriers

### Education and Advocacy

Combat injury is the most substantial healthcare issue in theater. Two-thirds of all evaluations at combat support hospitals are for injury. One goal of this system has been to educate soldiers, leaders, and medical providers and commanders with respect to the importance of maintaining the system that has been built. Coalition partners, including the British, have expressed sincere interest in broadening the system into a multinational coalition venture. The combat trauma system has become the standard of care on the battlefield.

## CONCLUSIONS

The combat trauma system has improved combat casualty care to a level never seen before. However, a less tangible but nonetheless very real and practical impact of the combat trauma system is the effect it has on soldiers and families and morale. They can read in the newspaper or see on the television that combat soldiers injured on the battlefield have a greater chance than ever before of surviving their injuries and returning home. Although this marked improvement in outcomes is multifactorial, the continued evolution and development of a deployed trauma system will certainly have a lasting impact on the delivery of healthcare on the battlefield of today and the future. Full implementation of the joint theater trauma system will insure that the credo, "Right Patient, Right Place, Right Time", will be met and lives will continue to be saved as a consequence.

## ACKNOWLEDGMENTS

All coauthors of the article have extensive contemporary battlefield experience and mutually participated in the conceptualization, development, and implementation of the joint theater trauma system.

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## DISCUSSION

**Dr. Donald D. Trunkey** (Portland, Oregon): I think this article is very encouraging, because I think there has been a major change since Desert Storm. I believe, though, there are still some unsolved problems. I would like to have your comments. Has the military looked at how effective the civilian trauma training is for those who are in the active military?

My sense is it has been very positive. However, there may be another problem. At least a majority of the surgeons and anesthesiologists that come into the military from the reserve are not getting the same type of training, and their skills may not be equal to what you're being able to maintain in the active duty.

This becomes a further problem if you look at the other needs within the United States. Not only do we have to provide training for the reserves but then we have the DMAT (Disaster Medical Assistance Teams) and we have Homeland Security needs.

It seems to me that if we had the vision, we could put together a system that integrates all of these needs. I think we should have a pool of highly trained surgeons, anesthesiologists, and nurses who could solve all of these needs. By increasing by one-third the manpower in Level I trauma centers, we would create a "reserve pool".

Who pays for this? Well, I would argue that the military is already wasting some money with Specialized Training and Assistance Program (STRAP) programs in order to attract people into the military. If you pooled these dollars and you got Health and Human Services and Homeland Security to put in some dollars, we could then have this reserve pool. It would be very similar to what the airline pilots do. They can get called back into active duty at any time. The airlines cooperate with this program. Similarly, if you had surgeons and anesthesiologists and nurses working in civilian trauma centers, you could pull out maybe up to a third at any given time to solve some of these needs.

The other thing that I identified, at least after Desert Storm, is that in military hospitals, critical care was being done by nonsurgeons. Maybe that's the model we should adopt; I, personally, don't think so, but I'd like your opinion about that, as well.

I was very encouraged by some of the things that you're doing from a system standpoint, and it is so logical to use the American College of Surgeons system's approach in the military.

Finally, I'm going to ask you a question you won't probably want to answer, but is this now the time that we should reconsider the purple suit? It seems to me the Surgeons General are now cooperating, and should we have a pool of surgeons who belong to really no branch but could be dispatched or placed anywhere in the world and fulfill what the military sees as their role.

**Dr. Donald Jenkins:** I think that the judgment would be that the civilian trauma center experience has been effective. Certainly, the opinion polls taken of those surgeons who have been through that site, the nurses and the medics, have gained tremendous amounts of hands-on experience they didn't otherwise get the opportunity to have.

They felt much more confident. I think that there is some clinical success that you see there in the first engagements that we have data for. As far as critical care, that's what we see as being the difference. I wasn't in Vietnam, but I judge that the ward that we have in that field hospital doesn't look a lot different. The difference in lives saved, I think, is over in the critical care end of that.

What can't be overlooked is the Air Force role in critical care air transport, where you could take a fellow with a damage control operation, triple amputation arriving with a blood pressure of 60, have a lifesaving damage control operation, three times in less than 40 hours: once in Iraq, once in Germany, and once in Walter Reed, and that kid then, 6 months later, is getting married, and walking without assistance on his prostheses. It is a tremendous success story.



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So, I think critical care is definitely the way to go. As far as the purple suit idea goes, that would sort of be a Department of Defense level question that you know I'm not going to answer. But I will tell you this, I worked side-by-side with my Army colleagues at this hospital. That team up there was made of Australian neurosurgeons and Air Force general surgeons and Army nurses and British nurses, and we were about as close to a purple suit operation, I think, as you can get there in some of those facilities. So, I think there is merit to that, Sir.

**Dr. Sheldon Brotman** (Pittsfield, Massachusetts): You say that you have a PI program. I'd like to know how you're closing loops. Let's say you've got a triage problem with a certain unit. How do you get back to these people and how are you able to effectively monitor your problems?

**Dr. Donald Jenkins:** That is a 24/7 endeavor. We have one trauma nurse at each one of those Level III facilities. Their responsibility is to provide feedback down to those Level II institutions, as well as forward to the Level IV institutions.

We just held, for the first time, a three-continent performance improvement conference out of Iraq last week via the telephone with folks in San Antonio, folks in Germany, folks in Washington, DC, and folks down in Iraq, all on the phone together talking about some of those patients. So, it's old-fashioned hard work, stubby pencil, see the problem, come up with a solution set for that problem, call those folks forward. It's done on a regular basis. Lowell Chambers, down at Level II, I think, would be the first to say that it's in evolution, but it does work. Captain DeNobile (USN) and Colonel Flaherty are in Iraq actually working on this today.

**Dr. David G. Burris** (Bethesda, Maryland): For Don Trunkey's question, it was very interesting a year and a half ago, when a Tri-Service trauma surgeon group sat down and said, "What we need in theater is this kind of a guy" (a Theater Trauma Consultant). For that group to suggest that a "blue guy" (Air Force) suddenly go into a "green slot" (Army) in theater to make this happen shows that we are functioning as a purple suit, but maybe are not wearing a purple suit.

Don, some people ask me, "What does purple suit mean." So, if you would define that, and second, you mentioned the levels of care, and you mentioned "The Gold Book". Please discuss that a little bit because there is not a one-to-one correlation between Gold Book levels of care and military levels of care. I think that might be confusing for people, so I appreciate your discussion of that.

**Dr. Donald Jenkins** (San Antonio, Texas): The purple suit idea is that instead of each of the services having their own medical corps (with the Navy serving not only the Navy but also the Marine Corps), you had one medical service that was joint, you could tap into that pool and they would go to any kind of engagement regardless of the troops that would be involved. I'm currently wearing pretty close to a purple suit. I've got this little Army medical department badge up here that was put on me by the Army Surgeon General; I speak a lot of Army now.

To answer the Army levels of care question, those ordinals are inverse from what we would consider in the United States. A Level I trauma center in the United States is a Level V facility for the US military. That's the burn center in San Antonio or Walter Reed Army Medical Center. These Level III facilities that we're talking about are more robust than Level III facilities, I think, that you would find here in the US system of things. It's somewhere between a II and a III with, again, 6 or 8 operating beds, 40 to 100 ward beds, half a dozen to 25 ICU beds at those places, with all the surgical capabilities.

**Dr. Gregory Beilman** (Minneapolis, Minnesota): Just a quick question. I noticed in my experience there that 70% to 80% of the patients we're caring for are Iraqis, Iraqi soldiers, MOI, and so on. How are you tracking outcomes with those patients compared to our soldiers?

**Dr. Donald Jenkins:** Yes, the local Iraqi population is a difficult endeavor to track down those outcomes. Things change over time, and we had the great luxury of being able to keep our patients for as long as they needed to be kept and see them back in follow up.

Some of that is changing today, so it does represent a significant challenge for us. If those patients are transferred out of that hospital today, you lose that follow-up on those individuals. The JTTR has the charts and will be entering the data of these Iraqi patients. Across the theater, 60% or more of all admitted casualties are non-US casualties; these patients will all eventually be captured in the JTTR.

**Dr. Erwin F. Hirsch** (Boston, Massachusetts): After the debriefings that occurred in the aftermath of Operation Desert Shield/Desert Storm, many questioned the ability of the Armed Forces to prepare its Medical Services in the care of combat casualties. I stand here to congratulate the authors of this article plus everybody else involved since the beginning of this operation, not only for the excellence in patient care, but in addition for the development of this system, which we in the civilian community should look at very seriously. I think very soon the paradigm that the civilians are training the military is going to change and that military lessons learned will apply to the care of nonmilitary patients.



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