Since the beginning of recorded history, wars have forced military medical systems to revamp practices proven in prior conflicts. The war on terrorism is no different. The large number of casualties produced as a result of Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) has stimulated the military medical community to retrain and rethink traditional battlefield trauma management. Because of changing weapons systems and numbers of personnel engaged, everyone from the combat medic to surgeons at combat support hospitals (CSH) to stateside fixed medical centers are exposed to types of injuries and casualty numbers that are uncommon in nondeployed daily practices. Surgeons located at small community hospitals, who rarely see trauma, may find themselves in the middle of a mass-casualty situation with multiple critical patients. Damage-control techniques or various subspecialty procedures such as vascular repairs that have not been practiced since the surgeon was a resident may first appear as daunting tasks. After working in a motor pool for most of their careers, medics may find themselves as the first line of treatment for patients who have complex injuries including mutilating amputations. As a result, military medical departments provide refresher courses to medics before deployment. A greater effort is made to ensure that medical teams such as Forward Surgical Teams train in civilian trauma centers before deploying. This training allows them to hone trauma skills and management algorithms. In an effort to improve outcomes, the function and use of all medical units is evaluated and redefined continually in the combat theater. Data collection is now a priority and is performed for each casualty. The data are placed in the Theater Trauma Registry (TTR) to study injury patterns, treatment practices, and outcomes. Data from the TTR can be used by research teams,
such as the 31st CSH research group, to establish practice guidelines and change policy for types and numbers of personnel. Communication between combat zones and the higher-echelon rear-area treatment facilities in Germany and the United States has improved dramatically, allowing trends to be identified rapidly, addressed, and corrected at the forward area and along the medical evacuation route The following discussion outlines some of the lessons learned in OIF and OEF.

The 31st CSH deployed in support of OIF from January 2003 to January 2004. The hospital was divided between two sites, Balad and Baghdad. Located within the International Zone, the Baghdad portion of the 31st CSH operated out of the Ibna Sina hospital and was staffed with approximately 300 active-duty and reserve soldiers. This hospital was a three-story building that provided a fixed hardened structure perfect for continued operations in the combat theater. The hospital was connected to a five-story dormitory-like building used to house the staff. A separate area of the hospital that once served as Saddam Hussein family’s private hospital was converted into a 10-bed emergency department and triage area. The hospital was renovated and provided approximately 60 inpatient ward beds for coalition troops, Iraqi nationals, and insurgents. Three operating suites provided five operating tables. A 20-bed ICU, CT and MRI scanners, and a basic radiology suite were available. During the yearlong deployment, approximately 3600 trauma patients and 700 medical patients were treated. Sixty percent of trauma patients were American (Fig. 1). The average patient age was 28 years (range, 9 months to 77 years). There were more than 100 pediatric patients and 29 patients over the age of 60 years (Fig. 2). Penetrating injuries from blasts or gunshot wounds were the most common mechanism of injury (Table 1). The CSH treated patients who were evacuated directly from the site of injury and also acted as higher level of care for forward surgical units. The CSH performed definitive treatment and coordinated evacuation out of theater. United States and Coalition troops treated at the CSH were evacuated to higher echelons of care in Germany and stateside locations when stable. Iraqi patients stayed until they were near ready for discharge and were transferred to an Iraqi facility to arrange follow-up care. In addition to the care of patients injured as a result of the ongoing

![Admission Nationality](image)

**Fig. 1.** Admission to 31st Combat Support Hospital by nationality.
conflict, the 31st CSH provided medical treatment for new or existing medical conditions in Coalition troops, embassy personnel, contract company employees, Iraqi detainees, and some Iraqi nationals. There was also a focused humanitarian mission for children who had medical conditions that could not be cared for in the Iraqi medical system.

Prehospital care

A review of the causes of death at the CSH showed findings similar to those of prior conflicts. Non-survivable injuries were present in 49% of the deaths. The remaining 51% had potentially survivable injuries; the most common mechanisms were penetrating injuries from small arms fire and fragmentary devices. The most common cause of death was hemorrhage, which accounted for 76%. In this group, 68% had torso injuries, 13% had axillary/groin or neck injuries, and 19% had extremity injuries;

Table 1
Causes of injury

<table>
<thead>
<tr>
<th>Primary mechanism</th>
<th>No, if injuries (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>IED/blast</td>
<td>1246 (36.7)</td>
</tr>
<tr>
<td>Gunshot wound</td>
<td>997 (29.4)</td>
</tr>
<tr>
<td>Indirect fire</td>
<td>443 (13.0)</td>
</tr>
<tr>
<td>Motor vehicle crash</td>
<td>329 (9.7)</td>
</tr>
<tr>
<td>Fall</td>
<td>126 (3.7)</td>
</tr>
<tr>
<td>Crush</td>
<td>76 (2.2)</td>
</tr>
<tr>
<td>Stab wounds</td>
<td>47 (1.4)</td>
</tr>
<tr>
<td>Burns</td>
<td>42 (1.3)</td>
</tr>
<tr>
<td>Assault</td>
<td>35 (1.1)</td>
</tr>
<tr>
<td>Aircraft crash</td>
<td>12 (&lt;1)</td>
</tr>
<tr>
<td>Electrical injuries</td>
<td>8 (&lt;1)</td>
</tr>
<tr>
<td>Other</td>
<td>7 (&lt;1)</td>
</tr>
<tr>
<td>Unknown</td>
<td>26 (&lt;1)</td>
</tr>
</tbody>
</table>

Abbreviation: IED, improvised explosive device.
68% had noncompressible hemorrhage, whereas 32% had hemorrhage that could be compressed or controlled with a tourniquet (Cuaddrado D, et al. Cause of death analysis from Operation Iraqi Freedom. Abstract submitted for presentation). The knowledge of the distribution of the injuries and especially that soldiers die from hemorrhage that could be stopped with simple pressure applied to the wound pointed out the need to improve battlefield treatment techniques, especially in the area of hemorrhage control.

This information has changed the training of medics and other medical staff at the first level of care. Combat medics are sent to courses such as the Tactical Combat Casualty Care course conducted at Ft. Lewis, Washington. This course includes short didactic sessions, case-based scenarios, team-building exercises, medical simulation, and live tissue training combined into a hybrid, weeklong review of treatment and triage principals specific to battlefield trauma. This course provides needed refreshment of training and skills that may not be used in the medic’s day-to-day function while stationed in the United States. Courses now are being added to unit training schedules as a skill that is as important as firing a weapon. Commanders understand that these skills must be practiced and the knowledge refreshed in a periodic fashion.

In most cases combat medics do not have the skills or equipment to perform intubations in the field, and they are not afforded the luxury of being able to participate in anesthesia rotations as are doctors, physician’s assistants, and paramedics. Only a small portion of salvageable patients die from airway injuries, and the loss of airway in the field carries a poor prognosis. Airway issues were found to be the cause of death in 10% of the patients who reached the CSH, although it is not clear how many patients who had airway issues died and were never transferred to the CSH (Cuaddrado D, et al. Cause of death analysis from Operation Iraqi Freedom. Abstract submitted for presentation). Medics have a very short time to address airway issues before death, and doing so may be impossible if the tactical environment prevents rapid extraction and treatment. The largest group of potentially salvageable patients is those who have compressible hemorrhage. After the shooting stops, medics are to use the mnemonic MARCH (Box 1) to direct treatment priorities [1].

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**Box 1. MARCH mnemonic for directing treatment priorities**

M Massive hemorrhage  
A Airway  
R Respiration  
C Circulation  
H Head injury/hypothermia
There is now an emphasis on treating life-threatening compressible hemorrhage first. Treatment includes the use of direct pressure, pressure dressings, tourniquets, and hemostatic dressings, including HemCon, QUIKCLOT, and dry fibrin sealant. The MARCH mnemonic also is used in mass-casualty situations to prioritize the treatment of patients. Tourniquets are taught as a first-line treatment to control bleeding, which then allows the time to identify other injuries in that patient and to triage other patients in the area. After the hemorrhage is controlled, airway issues are addressed. Medics are given instructions on the use of a Combitube, although it was more common for a patient to arrive at the 31st CSH after a cricothyroidotomy than with a Combitube in place. Medics are instructed in performing cricothyroidotomy and practice this skill using simulators and live-tissue models. This training is followed by the identification and treatment of tension pneumothorax and sucking chest wounds. Medics learn to perform needle decompression of tension pneumothorax, the use of an occlusive dressing or Asherman chest seal valves for sucking chest wounds, and chest tube insertion. Circulation is evaluated, and the idea of permissive hypotension is now emphasized. In patients who have a radial pulse and normal mentation, intravenous fluids are not given. Intravenous access is obtained but not used unless the radial pulse is lost or mental status changes are present. Intravenous fluids are then given but in small, controlled volumes, and the patient’s response is monitored closely. This protocol is a change from prior resuscitation practices in which all patients received fluids that may lead to continued losses because of higher blood pressure, dilution of the remaining red cells and coagulation proteins, and increased hypothermia. The final treatment involves preventing additional injuries and loss of body temperature.

**Tourniquets**

Tourniquet use was restricted primarily to military prehospital prevention of exsanguination from extremity wounds. Opinions about tourniquets range from it being an “instrument of the devil that sometimes saves a life” [2] to the current teaching of the military. Some believe that the tourniquet should be prohibited except to allow extraction of the patients and placement of a long compression dressing out of fear that additional ischemic injury occurs to the tourniqueted extremity and reperfusion injuries to the limb and other vital organs occur upon removing the device. Some of these concerns are based on experience with improvised tourniquets that were applied improperly [3]. Tourniquets are almost never used in civilian trauma systems. Dorlac and colleagues [4] reviewed deaths from isolated extremity injuries in a civilian trauma system and found that there was a small number of patients who potentially could benefit from early hemorrhage control of extremity injuries. Approximately 10% of all combat deaths are caused by
extremity injuries that are potentially preventable with proper tourniquet use. Lakstein and colleagues [5] reported a 4-year review of tourniquet use in the prehospital setting by the Israeli defense forces. Of 550 soldiers treated in the prehospital setting, 91 had tourniquets applied. Of these tourniquets, 78% were effective in controlling hemorrhage, but 47% of the applied tourniquets were not medically indicated. Five patients experienced neurologic complications in seven limbs, ranging from paralysis to paresthesias and weakness, that were thought to be related to the tourniquet use. The authors concluded that use of a tourniquet in the prehospital setting is technically easy, cheap, and effective for the control of extremity hemorrhage.

Tourniquets are an essential therapy based on recent experience in Iraq. The 31st CSH saw 67 patients with documented tourniquets between January 2003 and January 2004 [6]. The average tourniquet time was 70 minutes. For the patients for whom tourniquet effectiveness was documented, 83% of the tourniquets were effective. Tourniquets at the thigh level were much more likely to be ineffective than those applied to the lower leg or arm. The tourniquet was not indicated in 20.9% of cases, and only one tourniquet was improperly placed. There were no known complications associated with tourniquet use. A review of patients who died at the CSH with extremity injuries without tourniquets found that four of seven patients were potentially salvageable if a tourniquet had been used. The data point that is missing in the 31st CSH tourniquet database is the number of patients who had extremity injuries and who died from compressible extremity exsanguination before evacuation to a treatment facility. This information would provide the denominator to show a difference in the tourniquet versus no-tourniquet outcome. It is hoped that reducing the number of deaths caused by extremity hemorrhage now that every soldier has a tourniquet as part of the first aid pack will show the true effectiveness of tourniquets.

The use of a tourniquet at the CSH was universal. Patients arrived hypotensive with multiple fragmentation wounds distributed throughout their bodies. It was common for these patients to start bleeding from multiple extremity injuries as the resuscitation ensued. If the patient arrived with a tourniquet, it was rapidly converted to a pneumatic tourniquet for better control. A tourniquet was placed on any patient who had multiple-level fragmentation wounds and hypotension. The evaluation of the head, chest, and abdomen then was performed without concern of further blood loss from an extremity injury. The extremity evaluation and removal of tourniquets occurred after the completion of this evaluation. In patients who had life-threatening abdominal or thoracic injuries, the tourniquets remained in place until the completion of the damage-control procedure for these injuries.

Tourniquets should be used in all patients who have extremity hemorrhage or penetrating injuries to facilitate rapid control that allows extrication or triage and treatment of other patients. When the patient reaches a medical treatment facility, the need for the tourniquet can be reassessed, and it can be left in place or replaced with a pressure dressing.
Triage at the combat support hospital

Rapid effective triage of multiple patients is a skill that is vital to the success of a CSH. In his article reviewing his experience as the Chief of Surgery at the 67th evacuation hospital in Vietnam, Sebesta [7] writes that the skill of triage cannot be taught. The basic principals of triage can be taught in residency programs, but the implementation of those principals and the ability to identify injury patterns is a skill that is developed and polished in the combat environment. To triage a patient effectively, a simple and rapid evaluation without the use of additional instrumentation is required. McManus and colleagues [8] showed that the character of a trauma patient’s radial pulse is prognostic. Patients who had a strong radial pulse had a mortality of 3% compared with 29% if the pulse was weak. Holcomb and colleagues [9] reported that the character of the radial pulse, combined with the motor and verbal components of the Glasgow Coma Scale, is effective at predicting the need for prehospital life-saving interventions in patients who do not have head injuries. Checking a radial pulse and making a quick assessment of the motor and verbal components of the Glasgow Coma Scale by asking patients to raise two fingers and state their names provided a rapid triage tool that differentiated urgent from delayed patients. This assessment could be made in a few seconds as the patient was rolled through the door. Patients who had weak radial pulses or who were unable to comply with the directions were taken into more urgent treatment areas for closer assessment and triage.

Triage for the CSH involved stratifying patient needs at multiple levels. The triage officer had the ominous task of directing patient evaluations and use of hospital assets in the chaos of a mass-casualty event. In the emergency department, triage of the patients was done first to determine their place in the line for evaluation. Within the emergency department, patients were again triaged for the use of the CT scanner, ultrasound, and emergency department–level treatments including the use of emergency-release blood products. As patients reached the operating theater, the use of blood products again was triaged because of the limited capacity to thaw products or draw and prepare whole blood. The use of hospital beds and the need for evacuation of stable, treated patients to the next echelon of care was assessed continually. All of this coordination required accurate, timely communication and retriage at all levels to optimize the care of the injured.

Evaluation of the patient who has multiple fragmentation injuries

The introduction of the improvised explosive device has created injury patterns not seen before. These weapons create casualties with multiple, in some cases hundreds, of fragmentation injuries from head to toe (Fig. 3). In addition, blast injuries, burns, and inhalation injuries commonly are seen in the same patient. The evaluation of these patients who have literally
hundreds of penetrating injuries is complex, and frequently there are several patients from the same event. The depth of penetration depends on the size of the weapon, the type of material that was fragmented, and the patient’s distance from the explosion. The sensitivity and specificity of physical examinations, focused abdominal sonography for trauma (FAST), and the CT scan for identifying fascial penetration and the need for laparotomy were reviewed retrospectively at the 31st CSH. The first lesson learned was that physical examination and estimation of penetration based on the entrance wound was not effective, with a sensitivity of 28% and specificity of 94%. Patients would present with a tiny, scratchlike injury to the head, and CT evaluation would reveal intracranial fragments. Abdominal examinations and palpation often were misleading because of the diffuse nature of the injuries and because small fragments may create localized perforations that are not evident clinically for hours. The use of FAST examination was found to be useful only in the quick evaluation of the abdomen in the unstable patient who had multilevel injuries. A positive FAST scan confirmed that the probable source of instability was in the abdomen, and the patient was taken directly to the operating theater. With a sensitivity of 12% and a specificity of 100%, FAST was not effective at identifying fascial penetrating injuries in stable patients. The most effective tool for the rapid assessment of multiple fragmentation injuries was the CT scanner, which demonstrated a sensitivity of 96% and a specificity of 85%. It provided rapid, accurate assessment of the depth of penetration of fragments and the need for operative exploration of the head, chest, and abdomen. The use of the CT scanner prevented the unnecessary exploratory laparotomy that would waste precious operating theater time and hospital assets. The
CT scanner also was extremely effective in determining which patients required a neck exploration for penetrating neck injuries.

**Damage-control surgery**

Pringle [10] championed the technique of damage-control surgery for the treatment of hepatic hemorrhage for trauma in 1908. These techniques had been used through World War II but fell out of favor because of poor outcomes. The techniques were reintroduced in 1981 by Feliciano and colleagues [11] and were described in detail by Stone and colleagues [12] in 1983. Since then, the use of damage-control surgery has gained widespread support in the treatment of trauma patients. Eiseman and colleagues [13] expressed concerns about the use of damage-control techniques in a combat environment, especially in highly mobile forward surgical units. They believed that these techniques were resource intensive and limited unit mobility. Recent experiences in OIF and OEF have mirrored the results found in the urban trauma centers and re-emphasized the importance of damage-control surgery in combat. In the current combat theater, most medical assets are in fixed positions, and evacuation channels are well established. Even in the absence of these factors, damage-control surgery allows rapid stabilization and transfer to higher echelons of care for definitive treatment. The constellation of injuries, evacuation times, and limited resources in the face of multiple casualties made damage-control techniques essential to avoid physiologic burnout in severely injured patients. Data from the 31st CSH showed that 18% of casualties were hypothermic (temperature < 36°C) at presentation and that these patients had lower pHs and hematocrits, higher base deficits, required more blood products, and had a higher mortality. Temperatures below 34°C were associated with nearly 100% mortality, a finding consistent with the data reported by Jurkovich [14].

From January 2003 to January 2004, the 31st CSH performed 333 primary laparotomies for penetrating trauma. Damage-control techniques were performed on 92 (27.6%) of the initial laparotomies. The overall survival rate was 72.8%. For the most part, the use of damage control was the default operative plan, and the surgical team had to decide during the case to change to a definitive-treatment procedure. In the forward surgical facilities, damage control allowed stabilization of the patient for transportation. The patient could then be transferred to a CSH with more robust resources for the evaluation and definitive treatment. In the author’s experience, patients transferred from forward surgical units after properly applied damage-control techniques had outcomes similar to those of patients who had their primary procedure performed at the CSH, 66.6% versus 72.8%.

The decision to perform damage-control surgery was based primarily on the status of the patient. The initial point considered was the type and
severity of injuries. In patients who had injury complexes such as penetrating head and abdominal injuries or major extremity vascular and complex abdominal injuries, damage-control procedures allowed rapid assessment and temporization of the abdominal wounds, making possible treatment or damage control of the other injuries. Temperature, pH, and base deficit then were used to help direct the operative plan. The deadly triad of hypothermia, acidosis, and coagulopathy was avoided at all costs. The final factor was the current backlog of surgical cases, the severity of their wounds, and the current number of inbound casualties. During extremely busy times, damage-control procedures were performed in a relatively stable patient to limit operative times to allow the operative management of a more severely injured patient who had arrived after the case had started. The planned second-look and definitive repairs could occur within 1 to 2 hours or be delayed for as long as 36 hours. The patient was returned to the operating theater as soon as the patient’s physiologic status improved and time was available.

The basic damage-control procedure was based on the principals of controlling bleeding, limiting contamination, and preventing additional injuries or worsening of the physiologic status. The initial step was incision, packing, and allowing anesthesia to “catch up” with the resuscitation. Proper packing of the abdomen temporarily controlled most injuries and allowed time for resuscitation and for the operative team to prepare for the procedure by obtaining staplers, packs, and other equipment. After the patient was resuscitated, the abdomen was explored. Depending on the injuries, vascular injuries were treated first, as they were identified. Injuries to minor veins were treated with ligation. Major venous structures including the inferior vena cava and portal vein can be ligated, but the goal was repair or shunting. Most venous injuries can be treated initially by packing or by shunting. Bowel injuries were controlled by using a stapler or umbilical tape to prevent further contamination. Mesenteric defects required the isolation and control of the individual vessels and then a running suture to over-sew the free edge of the mesentery. Duodenum and pancreatic injuries were drained. Spleen and kidney injuries that were complex or had arterial bleeding usually required rapid removal. Liver injuries generally could be controlled with packing. Rarely, hepatic injuries had to be explored to control bleeding from a hepatic artery branch. Ureter injuries could be treated with ligation or simple drainage. Bladder injuries were over-sewn and drained. If a rectal injury was present, the distal sigmoid colon was divided with a stapler, and drains were placed, including a presacral drain. After these injuries were treated, the abdomen was irrigated with warm fluids to remove gross contamination and repacked. A radiograph cassette cover was fenestrated and then placed between the bowel and the fascia. A Kerlix (The Kendall Company, Mansfield, Massachusetts) roll was unrolled in the defect, and two 10-mm Jackson-Pratt (JP) drains were placed in the layers of the Kerlix. The skin on the abdomen was dried, and Mastisol (Ferndale Laboratories, Ferndale, Michigan) was placed in a wide swath around the wound. An
Ioban (3M, St. Paul, Minnesota) was then placed to create a seal, and the drain tubes were enclosed in a mesentery of the Ioban. The drains were placed quickly on suction. This dressing configuration allowed continued swelling of the abdominal contents without forming an abdominal compartment syndrome. The fenestrations and the JP’s allowed fluid loss and ongoing hemorrhage to be monitored. This dressing was inexpensive, durable, and allowed patient movement and other treatments without losing its integrity. It also prevented injury to the surrounding skin or fascia that can occur with other closures.

The importance of damage-control techniques was demonstrated again in the complex set of injuries created by a high-velocity, trans-pelvis penetrating injury. Casualties who had this injury were some of the most challenging to treat. These patients had a complex injury including pelvic fracture and major vascular, ureter, bladder, and colorectal injuries. Often the exit wound would contain aerosolized stool in the extensive soft tissue injury. These patients generally presented with hypothermia and acidosis and were hypotensive. Any attempt at anything other than damage control resulted in sliding down the slippery slope of huge blood losses and physiologic burnout. Major pelvic veins can be controlled with packing. Internal iliac arteries were ligated, and common and external iliac arteries were stented or were repaired very rapidly with an abdominal aortic cross-clamp and femoral vessel clamps in place. Vessel loops were left in place at the closing to facilitate future dissections and rapid control if arterial bleeding restarted. The distal sigmoid colon was stapled, and a distal washout was performed because of the degree of destruction of the rectum and associated structures. Ureters were ligated, and bladder injuries were over-sewn. Most of the bleeding from the pelvic fractures was controlled with packing and rarely required internal iliac artery ligation on the side of the fracture. The packing of the pelvis required forceful packing of sponges into the pelvis. Additional packs were placed in the lower abdomen, and the skin of the lower abdomen was closed to help with the tamponade affect. Standard damage-control closure was performed in the upper abdomen.

The second-look procedure was performed as soon as the patient was resuscitated and rewarmed. In several cases, the patient was so unstable that the resuscitation and rewarming occurred in the OR. After several hours, a second-look damage-control procedure was performed before taking the patient to the ICU. In general, second-look procedures occurred between 12 and 24 hours after damage control. The average number of procedures was 3.4 for each patient, and 77% of patients who survived had definitive treatment of their injuries and closure of the abdomen. Average time to closure was 3.3 days [15].

Damage-control techniques often were used outside the abdomen. Vascular injuries of the extremities often were treated with shunting in forward surgical units. Tourniquets are a variation of vascular damage control that allows the patient to be stabilized and transported for definitive
treatment. Thoracic damage control included tractotomy and packing of the thoracic cavity for diffuse soft tissue injuries.

Knowledge of damage-control surgery techniques in the management of complex trauma patients is essential for the surgeon in the combat environment. The use of damage-control techniques can avoid the lethal triad and allows rapid treatment of larger numbers of casualties in mass-casualty situations. The author’s experience shows outcomes similar to that of urban trauma centers in both the forward surgical units and at the CSH.

**Transfusion services**

One of the most precious resources at the CSH was blood products. Within the combat theater, adequate stores of blood products, including packed red blood cells, cryoprecipitate, and frozen fresh plasma (FFP) were available. During times of high-intensity combat, stores of blood products at the CSH could be limited. Part of the issue with availability of blood products at the CSH was the limited staff and equipment to prepare blood products for transfusion. Thawing of FFP and cryoprecipitate was particularly difficult. During the 31st CSH deployment, platelets rarely were available. Blood product use commonly was triaged to the most severely injured until the blood bank could process enough units for all patients. A review of all the patients who received blood products during the first 24 hours at the CSH revealed that the average number of units administered per patient was 5.5, less than half the units required for patients undergoing damage control (Fig. 4). The use of whole blood in this figure is slightly skewed because very little whole blood was used until the second half of the year.

The use of fresh whole blood is not a new concept. It has been used in almost every military conflict since World War I. The modern practice of blood transfusions was started in the 1930s when a Canadian surgeon, Norman Bethune, transported blood from donors to recipients on the front lines.

![Initial 24 Hour Transfusion](image)

Fig. 4. Initial 24-hour transfusion (in units). FFP, fresh-frozen plasma; PRBCs, packed red blood cells.
Component therapy is the standard for transfusion of blood products, but the process of separating these products results in the loss of half the platelets, and erythrocytes and clotting factors are diluted by 36%. The mixing of the components in a one-to-one ratio creates a unit of whole blood with a hematocrit of 29%, a platelet count of 88k, and 62% of the clotting activity. The use of fresh whole blood has been described multiple times in situations where blood product components are limited or not available. During the battle of Mogadishu, 120 units of fresh whole blood were drawn, and 80 units were administered. These units were not tested and were transfused based on dog-tag information. The surgeons commented on the ability of the fresh whole blood to stop diffuse coagulopathy. There were no known transfusion reactions or viral transmissions.

During the yearlong deployment, difficulty in obtaining adequate blood products in the correct distribution led to the development of a massive transfusion protocol. Massive transfusion commonly is defined as transfusions of 10 or more units of blood or the replacement of one blood volume in a patient. The massive transfusion protocol standardized the release of blood products including packed red blood cells, FFP, cryoprecipitate, and factor VIIa when initiated. At the same time, a call was made to the prescreened walking donor pool within the hospital, the United States embassy, and the surrounding units for whole-blood donations. As the whole-blood donation was started, continued preparation of these standardized amounts of blood products was performed in an attempt to avoid delays in blood product administration and to prevent the onset of coagulopathy. Identified donors were screened before donation for anemia with a copper sulfate test, and posttransfusion hematocrits were checked. One unit of whole blood was collected in a citrate phosphate dextrose adenine bag, and the sample was tested for HIV and hepatitis B and C, using ELISA if available. The entire process produced a steady supply of whole blood in 1 to 2 hours.

Although some believe that the extinction of whole blood use is imminent, the 31st CSH found it to be a vital part of its massive transfusion protocol. Although the retrospective evaluation of the use of whole blood is still ongoing, the surgical staff of the 31st CSH believed that fresh whole blood was the “magic bullet” that could help prevent physiologic exhaustion and also reverse it. Whole blood provided hemoglobin, clotting factors, and platelets in a prewarmed resuscitative fluid. The 31st CSH transfused 545 units of fresh whole blood to 86 severely injured trauma patients. There was one febrile nonhemolytic transfusion reaction; three were positive for hepatitis C virus, and one was indeterminate for HIV and human T-cell leukemia virus by Western blot. The use of fresh whole blood was a vital part of the prevention or treatment of physiologic burnout in the severely injured trauma patient. The military is well suited for whole blood transfusions because of the presence of a large, prescreened walking donor pool that is at low risk for infectious transmission.
Factor VIIa

The use of activated blood coagulation factor VII in the treatment of OIF and OEF injured has increased steadily. Since its introduction for the treatment of hemorrhage in hemophilia patients who have antibodies to factor VIII, the use of activated factor VII has been described for prostatectomy, cardiac surgery, aortic aneurysm repair, polypectomy, postpartum bleeding, and bleeding complications in cirrhotic patients [20–23]. The first report of use for trauma injuries was from an Israeli group, and this report has been followed by several reports of success using activated factor VII for hemorrhage. In a retrospective review, Harrison and colleagues [24] compared the use of activated factor VII in 29 trauma patients with well-matched controls. He showed that there was no difference in mortality, but there were fewer packed red blood cell transfusions in the factor VIIA group (2.4 ± 6.2 versus 8.5 ± 9.6 units). This difference in transfusion requirements also held true with platelets and cryoprecipitate. There was no difference in FFP use. Patients who were given factor VIIa and survived had lower pHs than controls. Boffard and colleagues [25] reported similar results with a reduction in packed red blood cell transfusions after administration of factor VIIa. He also showed a 63% reduction in the need for massive transfusion. Thus, factor VIIa may play a role in the avoidance in the complications, including multiple organ failure, acute respiratory distress syndrome, and infectious complications, that are associated with massive transfusions [26–28].

The use of factor VIIa by the 31st CSH still is being reviewed. Approximately 600 doses of factor VIIa have been administered to 300 patients in Iraq. The protocol used calls for 90 μg/kg given immediately in the emergency room followed by an additional dose when the patient becomes normothermic. The use of factor VIIa in the acidotic patient is still a matter of controversy. Several studies have shown a decrease in the effectiveness of factor VIIA in the acidotic patient. The staff of the CSH found that in combination with massive resuscitation including crystalloid, bicarbonate, and other blood products, factor VIIa played a role in decreasing ongoing losses and reducing transfusion requirements. Additional research is required in this area to define further the effectiveness and possible strategies to reverse this effect, if present, and to allow the use of this product in the patients who may gain the most from it.

Future directions

The future may hold exciting changes in the use and position of blood products. Soldiers soon may carry units of their own freeze-dried blood or FFP on the same chain as the dog tags. If the soldier is injured, the blood and FFP may be reconstituted and given back to him. This technique would eliminate the need for blood typing, reduce preparation time, and prevent viral transmissions. FFP could be used as an initial resuscitative fluid
administered by medics in the field. This technique would provide the casualty with volume and coagulation factors that might help to decrease additional bleeding. Blood stores may have the surface antigens removed by surface decoration to create a unit of universal blood that could be given to any patient without the delay of blood typing and prevent some transfusion reactions.

References


