Prehospital Blood Product Transfusion by U.S. Army MEDEVAC During Combat Operations in Afghanistan: A Process Improvement Initiative

LTC Robert F. Malsby III, MC USA; MAJ Jose Quesada, MS USA†; MAJ Nicole Powell-Dunford, MC USA‡; CPT Ren Kinoshita, MC USA‡; CPT John Kurtz, APA-C USA‡; CPT William Gehlen, MS USA‡; CPT Colleen Adams, NC USA§; MAJ Dustin Martin, APA-C USA‖; Col Stacy Shackelford, USAF MC¶*

ABSTRACT U.S. Army flight medics performed a process improvement initiative of 15 blood product transfusions on select Category A (Urgent) helicopter evacuation casualties meeting approved clinical indications for transfusion. These transfusions were initiated from point of injury locations aboard MEDEVAC aircraft originating from one of two locations in southern Afghanistan. All flight medics executing the transfusions were qualified through a standardized and approved program of instruction, which included day and night skills validation, and a 90% or higher written examination score. There was no adverse reaction or out-of-standard blood product temperature despite hazardous conditions and elevated cabin temperatures. All casualties within a 10-minute flight time who met clinical indications were transfused. Utilization of a standard operating procedure with strict handling and administration parameters, a rigorous training and qualification program, an elaborate cold chain system, and redundant documentation of blood product units ensured that flight medic initiated transfusions were safe and effective. Research study is needed to refine the indications for prehospital blood transfusion and to determine the effect on outcomes in severely injured trauma patients.

INTRODUCTION

Combat wounded on today's battlefield experience the highest survival rate in history.[1] Advances in battlefield medicine during the conflicts in Iraq and Afghanistan have included universal availability of effective tourniquets,[2] damage control resuscitation,[3–5] trauma system development,[6,7] en route care,[8,9] use of tranexamic acid,[10] and advanced topical hemostatic dressings.[11,12] In addition, a Secretary of Defense memorandum in 2009 resulted in medical evacuation times of unprecedented speed in Afghanistan. Currently, 97% of casualties who reach a Role III theater hospital alive will survive until discharge, with 76% to 92% of deaths occurring before the casualty arrived at a medical treatment facility.[13–15]

Five separate analyses of combat deaths from 2007 to 2011[13–17] have consistently shown that the primary cause of potentially preventable death on the battlefield is hemorrhage, with the prevailing sources of hemorrhage attributed to noncompressible torso hemorrhage (48%–67%) and junctional/nontourniquetable hemorrhage (19%–31%).[13,16,17] These sources of hemorrhage cannot typically be controlled through standard means available in the prehospital environment; this has led to an increased interest in prehospital blood transfusion, which potentially could improve survival for the casualty in profound hemorrhagic shock.

Although not of proven survival benefit, prehospital blood transfusion has been available on select U.S. medical evacuation (MEDEVAC) platforms since 2010. This capability was expanded to the U.S. Army through a process improvement initiative; two DUSTOFF units were selected to conduct a series of prehospital blood product transfusion by flight medics in Afghanistan beginning in May 2012.

METHODS

Following determination by the Joint Casualty Care Research Team that this initiative met criteria to be performed as a process improvement project, U.S. Army flight medics performed a case series of 15 blood product transfusions in select Category A (Urgent) helicopter evacuation patients meeting approved clinical criteria for transfusion. These transfusions occurred on MEDEVAC flights from point of injury originating from two sites in southern Afghanistan. Each transfusion mission culminated in an after action review with the assigned flight crew, local and/or regional medical director, Blood Support Detachment Commander, and the Joint Theatre Trauma System Director.

A standard operating procedure (SOP) was developed to guide the handling of blood products, indications for transfusion, and procedure of transfusion by flight medics. The SOP,

*Womack Army Medical Center, 2817 Reilly Road, Stop A, Fort Bragg, NC 28310.

†440th Blood Support Detachment, Fort Sam Houston, TX 78234.

‡25th Combat Aviation Brigade, 1343 Wright Avenue, Wheeler AAF, Schofield Barracks, HI 96857.

§TF-Med Afghanistan Joint Enroute Critical Care Nurse, Walter Reed National Military Medical Center, Bethesda, MD 20307.

‖Deputy Surgeon, 82nd Airborne Division, 2817 Reilly Road, Stop A, Fort Bragg, NC 28310.

¶USAF Center for Sustainment of Trauma and Readiness Skills, R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, 22 South Greene Street, Baltimore, MD 21201.

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approved by the Command Surgeon General, was certified for use during military emergency contingencies and wartime for both ground and in-flight operations. Patient consent for transfusion was implied by military status. All transfusions were performed with physician oversight.

Blood products were stored in a Desert Thermal Transport Golden Hour Container (GHC) (Minnesota Thermal Science, Plymouth, Minnesota; NSN 6530-01-505-5306), a reusable iceless thermal container. Each GHC can hold a maximum of four units of blood product for up to 72 hours. The MEDEVAC blood transfusion SOP initially specified that each mission would carry one unit of thawed group AB plasma and one unit of group O type Rh negative packed red blood cells (PRBC). After the first five transfusions, during a scheduled evaluation, the SOP was modified to allow carrying either two units of group O (Rh positive or negative) PRBC or the original complement of one unit thawed plasma and one unit PRBC. Blood products stored in the GHC were exchanged at the blood bank of the adjacent surgical hospital every 24 hours.

Indications for transfusion in trauma patients with apparent blood loss were established. The transfusion indicators were initially selected as systolic blood pressure (SBP) <90 mmHg or heart rate (HR) >120 bpm or arterial oxygen saturation (SaO_2) < 90%. After the first five transfusions, the transfusion indicators were modified to exclude SaO_2 as an indication for transfusion and to include the injury pattern of double, triple, and quadruple amputation (with at least one amputation being proximal) as an indication for transfusion regardless of vital signs.

The procedure for transfusion specified that intravenous (IV) or intraosseous (IO) access would be obtained. Two personnel were required to verify the blood products were the correct group and were not expired. Unit numbers were confirmed and documented on the Emergency Release of Blood Products form, and the units were inspected to ensure safety criteria were met. A Safe-T-Vue indicator (Discovery Diagnostics, Ontario, Canada; NSN 6515-01-267-4669) was attached to each unit; this indicator would permanently change color if storage temperature exceeded 50°F (10°C). All blood products were infused through a dedicated IV line flushed with normal saline using Y-tubing with a blood filter. An approved blood warming system was used for all transfusions ([En Flow, Enginivity LLC, Lexington, Massachusetts; NSN 6515-01-553-0107] or [Thermal Angel, Estill Medical Technologies, Dallas, Texas; NSN 6515-01-500-3521]). Transfusions were performed as rapidly as possible using a pressure bag, manual compression, or a 60-cc syringe with 3-way stopcock.

To avoid overresuscitation, a second unit of blood product was transfused only if clinical transfusion indicators were still met. Crystalloid infusion was minimized.

All medical personnel executing the transfusions were certified through a standardized and approved program of instruction, that included day and night validation of skills and a 90% or higher written examination score. Training strongly emphasized that maximal hemorrhage control was required before initiation of blood product transfusion using tourniquets, topical hemostatic dressings, manual compression, and pressure dressings as needed. In addition, the airway was confirmed patent or secured and hypothermia prevention measures were instituted before blood product transfusion.

Lab and air crew were trained in GHC exchange procedures, which included radio transmission indicating the requirement for resupply of blood products.

RESULTS

The series of blood product transfusion to 15 casualties was completed between May 28 and July 18, 2012. In total, seven units of thawed plasma and 12 units of PRBC were transfused to 15 patients. In one of 15 cases, the flight medic performed additional airway control measures before initiation of the transfusion, whereas in eight of 15 cases, additional measures for bleeding control were conducted before transfusion. The average time from decision to initiation of blood products was 6.7 minutes. On two missions, two complete units of blood products were transfused before arrival at the surgical hospital; on three missions, one and a half units were administered; during five missions, one complete unit was administered; and in five missions, less than one unit was administered. The amount of blood product transfused was proportional to the length of the transport times.

The mechanism of injury was improvised explosive device in 13 cases and gunshot wound in two cases. Specific injuries are listed in Table I.

SOP-guided indications for blood product transfusion by the flight medic included traumatic injury with SBP < 90 mmHg in five cases, HR > 120 bpm in 13 cases, SaO_2 < 90% in one case, and multiple extremity amputations in five cases. Pre- and posttransfusion vital sign and outcome indicators are listed in Table II.

Of the 15 casualties, four were U.S. military, five were Afghan Security Forces, and six were Afghan civilians. Five casualties were delivered to U.S. forward surgical hospitals (Role II); four to North Atlantic Treaty Organization theater hospitals (Role III); and six to the Kandahar Regional Medical Center, Afghanistan. Two casualties did not survive their injuries. In seven cases, the patient required over 10 units of blood products during the first 24 hours after injury. In one case, the casualty was diagnosed with a simple pneumothorax and did not require any further blood product transfusion.

Fourteen of the 15 transfusions were performed with two medical providers on the MEDEVAC aircraft. In five cases, a medic was paired with an en route critical care nurse (ECCN); in nine cases, the team included two flight medics; and in one case, a ground medic was paired with a flight medic. Crew chiefs were trained to assist with oxygen administration and to ensure the casualty was placed on a monitor.

TABLE I. Injuries and Prehospital Interventions

Transfusion Mission	Mechanism of Injury	Injuries Sustained	Pre-MEDEVAC Procedures	MEDEVAC Procedures
Vampire 1	IED	Right Foot Amputation Left Leg Open Fracture	Pressure Dressing Tourniquet × 4	O_2 NRB IV
Vampire 2	IED	Penetrating Wound to Neck, Chest, Thigh	Nasal Airway Needle Decompression Chest Pressure Dressing	O_2 NRB Passive Warming IV × 2
Vampire 3	IED	Facial trauma Penetrating Neck Injury	Cricothyroidotomy Hemostatic dressing	O_2 BVM Passive Warming IV
Vampire 4	IED	Right Below Knee Amputation Left Above Knee Amputation	Pressure Dressing IV IO Intubation	O_2 BVM Active Warming
Vampire 5	GSW	Penetrating Abdominal Trauma	Hemostatic Dressing IV Intubation Foley	O_2 BVM
Vampire 6	GSW	Right Thigh Gunshot Wound With Vascular Injury Femur Fracture	Tourniquet Splint IV	O_2 NRB
Vampire 7	IED	Bilateral Below Knee Amputations	Tourniquet × 2	Tighten Tourniquets Pressure Dressing C-Collar O_2 NRB IV IO
Vampire 8	IED	Penetrating Injury to Face and Neck Right Lower Extremity Soft Tissue Injury	Tourniquet IO	Tighten Tourniquet Pressure Dressing IO
Vampire 9	IED	Right Above Knee Amputation Left Below Knee Amputation	Tourniquet × 2	Tighten Tourniquets Pressure Dressing O_2 NRB IV
Vampire 10	IED	Bilateral Below Knee Amputations	Tourniquet × 2 IV	Tourniquet × 2 Pressure Dressing Splint IV
Vampire 11	IED	Right Above Knee Amputation Soft Tissue Injuries Left Leg And Right Arm	Tourniquet	Tighten Tourniquet O_2 NRB C-Collar IV
Vampire 12	IED	Left Below Knee Amputation Right Lower Extremity Soft Tissue Injury	Tourniquet × 2	Tourniquet Pressure Dressing O_2 NRB Splint IO
Vampire 13	IED	Bilateral Below Knee Amputations Right Upper Extremity Fracture Left Lower Extremity Soft Tissue Injury	Tourniquet × 2	Pressure Dressing O_2 NRB IV
Vampire 14	IED	Facial Trauma Bilateral Upper Extremity Soft Tissue Injury	None	Tourniquet × 2 Attempted King Tube Cricothyroidotomy Splint IO × 2 CPR
Vampire 15	IED	Right Below Knee Amputation Left Lower Extremity Soft Tissue Injury	Tourniquet × 2 IV Pressure dressing	O_2 NRB IO

IED, improved explosive device; GSW, gunshot wound; NRB, non-rebreather mask; BVM, bag valve mask; CPR, cardiopulmonary resuscitation.

TABLE II. Pre- and Post-Transfusion Vital Signs and Outcome Indicators

Transfusion Mission	Indication for Transfusion	Pretransfusion Vital Signs	Posttransfusion Vital Signs	Base Deficit (BD) + Hemoglobin on Arrival	Additional Blood Products First 24 Hours	Patient Survival at 24 Hours
Vampire 1	Injuries + Tachycardia > 120	BP 145/83 HR 128 RR 20 SaO_2 97%	BP 136/68 HR 117 SaO_2 100%	BD - 2 Hg 12.9	3 PRBC 2 FFP	Survived
Vampire 2	Injuries + Decreased Mental Status	BP 124/71 HR 77 RR 18 SaO_2 100%	†	†	2 PRBC 4 FFP 1 Plt	†
Vampire 3	Injuries + Tachycardia > 120, SaO_2 < 90%	BP 92/52 HR 128 RR Agonal SaO_2 66%	†	†	†	†
Vampire 4	Injuries + Tachycardia > 120	BP 92/36 HR 136 RR 14 SaO_2 96%	BP 127/47 HR 124 RR 14 SaO_2 99%	BD - 14 Hg 9.2	10 PRBC 6 FFP	Died
Vampire 5	Injuries + Hypotension < 90 + Tachycardia > 120	BP 68/54 HR 128 RR 22 SaO_2 100%	BP 114/68 HR 122	†	4 PRBC 2 FFP	†
Vampire 6	Injuries + Hypotension < 90 + Tachycardia > 120	BP 63/47 HR 138 RR 22 SaO_2 95%	BP 88/52 HR 141 SaO_2 100%	†	†	†
Vampire 7	Injuries + Tachycardia > 120	BP 108/51 HR 129 RR 18 SaO_2 87%	BP 65/37 HR 82 RR 18 SaO_2 98%	†	†	†
Vampire 8	Injuries + Tachycardia > 120	BP 80/p HR 122 RR 22 SaO_2 88%	BP 102/52 HR 100 RR 18 SaO_2 95%	†	†	†
Vampire 9	Injuries + Tachycardia > 120	BP 146/86 HR 132 SaO_2 95%	BP 151/66 HR 138 RR 10 SaO_2 100%	BD - 4 Hg 10.6	17 PRBC 13 FFP 4 Plt 10 Cryo	Survived
Vampire 10	Injuries + Tachycardia > 120	BP 104/78 HR 144 RR 22 SaO_2 94%	BP 130/69 HR 111 RR 24 SaO_2 100%	BD - 7 Hg 14.2	12 PRBC 6 FFP 9 Cryo 1 Plt	Survived
Vampire 11	Injuries + Hypotension < 90 + Tachycardia > 120	BP 71/45 P 138 RR 20 SaO_2 98%	BP 143/83 HR 138 RR 18 SaO_2 100%	†	†	†
Vampire 12	Injuries + Tachycardia > 120	BP 104/68 P 134 RR 18 SaO_2 77%	†	†	†	†
Vampire 13	Injuries + Tachycardia > 120	BP 99/41 P 156 RR 24 SaO_2 71%	BP 110/71 P 139 RR 22 SaO_2 100%	BD - 7 Hg 14.5	24 PRBC 20 FFP 3 Plt 20 Cryo	Survived
Vampire 14	Injuries + Hypotension < 90	BP 80/P P 55 RR BVM SaO_2 82%	†	†	†	Died
Vampire 15	Injuries + Tachycardia > 120	BP 137/70 P 137 RR 10 SaO_2 100%	†	†	†	†

RR, respiratory rate; P, pulse; Plt, apheresis platelets; Cryo, cryoprecipitate. †Unable to obtain data from patients delivered directly to Afghan hospital.

In no instance was there an out-of-standard temperature condition for any of the MEDEVAC blood products. There were only minor issues in the storage container or exchange process, all of which were identified and rectified during the after action review process. There were no instances of adverse clinical reactions associated with any transfusion. All casualties with a MEDEVAC flight time over 10 minutes who met clinical indications received a transfusion.

DISCUSSION

The use of blood product transfusion on U.S. military MEDEVAC flights has occurred on a limited basis in Afghanistan since 2010; however, to our knowledge, this is the first time the procedure has been subjected to a thorough documentation and review process. Lessons learned from the implementation of this program will prove valuable as this program expands to the remaining MEDEVAC units in Afghanistan and for future conflicts and contingency operations.

Golden Hour Containers

One GHC was maintained at each MEDEVAC site and carried in the lead aircraft for all Urgent missions. Additional refrigerated containers were maintained in the blood bank to allow MEDEVAC teams to rapidly exchange blood products every 24 hours.

A tracking system was developed to monitor the expiration date and time for the GHC; temperature indicators afforded extra reassurance. There were no out-of-standard temperature conditions for any blood products in spite of ambient weather conditions frequently exceeding 100°F (37.8°C).

Packed Red Blood Cells Versus Fresh Frozen Plasma

The first version of the SOP specified one unit group AB plasma and one unit O negative PRBC as the universal donor blood products carried in each GHC. Medics were instructed to initiate transfusion with plasma followed by PRBC. During the trial period, several logistic barriers were encountered with thawed plasma supply. First, resupply of thawed plasma at forward surgical hospitals was difficult when a critically injured patient was delivered to the hospital, since blood bank resources were diverted to care of the very same patient. Second, additional resources to maintain a supply of thawed plasma were a barrier to expansion of these missions to additional sites. Given the logistical challenges to carrying thawed plasma, the SOP was changed to allow use of either one unit thawed plasma/one unit PRBC or two units PRBC in the GHCs.

Criteria for Initiating Blood Product Transfusion

Presence of SaO_2 < 90% is not a Valid Indication for Blood Product Transfusion

This indication was initially included based on a preexisting SOP; however, review of current and past cases confirmed that hypoxia alone is more likely to indicate a respiratory derangement than a need for blood transfusion. From these observations, SaO_2 < 90% was removed as an indication for blood transfusion and training was modified to further emphasize the need to search for respiratory problems (airway obstruction, pneumothorax, pulmonary contusion) as the cause for hypoxia. Additional emphasis was placed on the observation that massive hemorrhage and pneumothorax may coexist, particularly after a gunshot wound to the torso or blast injury with amputations.

Infusion of Hextend or Crystalloid Fluids

In seven cases, hextend or crystalloid infusion was initiated by the ground medic before arrival of MEDEVAC. The initial SOP and training did not provide enough clarity for the medics on what to do with IV fluids when blood products become available.

The SOP was modified to specify minimization of all hextend and crystalloid infusions when blood product transfusion was initiated.

Patient Assessment

Patient assessment skills by flight medics were uniformly excellent, and the SOP was followed closely. However, interpretation of decreased mental status in the hemodynamically normal patient was an area of potential confusion. According to Tactical Combat Care Committee guidelines,[18] if a patient's blood pressure is low or borderline, a decrease in mental status (in the absence of head injury) can help confirm that the patient is in shock. Flight medic training was refined to emphasize that mental status change alone, without abnormal vital signs, was not an indication for blood transfusion.

Valuable time may be lost by obtaining a complete set of vital signs in an unstable patient. A palpable radial pulse is roughly equivalent to SBP ≥ 90 mmHg; therefore, absent radial pulse may be substituted for the actual blood pressure measurement to expedite initiation of blood transfusion in the hypotensive trauma patient.

Initiation of a Second Unit of Blood Product

Military prehospital standards defined by the Tactical Combat Care Committee guidelines[17] specify the use of hypotensive resuscitation to avoid disruption of formed clot. Since some types of bleeding may not be controllable before arrival in an operating room, particularly noncompressible torso bleeding or extensive junctional bleeding, hypotensive resuscitation should be maintained with a target SBP of approximately 90 mmHg. To avoid overresuscitation, the SOP was modified to specify that vital signs would be reassessed after one unit transfused, whereas at the same time instituting pain control measures as needed. A second unit was initiated if the transfusion indications (SBP < 90 mmHg or HR > 120) were still present.

Presence of Multiple Amputations

This was added to the SOP as an indication for blood product transfusion. It was emphasized in training that at least one of the amputations should be a proximal amputation. In such a case, transfusion was initiated even if the vital sign indicators were not present. This indication was added to the SOP because of the frequency that this injury pattern occurred, as well as the difficulty achieving complete hemostasis in this patient population, frequent profound shock on arrival to the hospital, and nearly universal requirement for massive transfusion within the first 24 hours of injury.

IVAccess

Over the course of the project, flight medics transitioned from peripheral IV to humeral head IO as the preferred access site for blood product transfusion. The rate of infusion through IO sites was improved by use of a 60-cc syringe and 3-way stopcock. Sternal IO devices proved to have a slow infusion rate for blood products, and this site was avoided whenever possible.

Lack of Checklist Utilization During Transfusion Procedures

During the trial period, all 15 transfusions were completed safely and accurately without the use of the prepared transfusion checklist. It was noted that the use of checklists is not a routine process for flight medics, and the checklist was impossible to read at night. Although the flight medics were instructed to use the transfusion checklist during training, the above challenges prevented use of the checklist on real-world missions. In fact, flight medics are the only aircraft crew members with a highly detailed skill set who lack checklists for emergency procedures. In addition, checklists have been shown to improve patient safety in hospital-based surgical environments.[19,20] Incorporation of universal flight medic protocols and institutionalization of a checklist mentality may improve overall patient safety during MEDEVAC.

MEDEVAC Teams

Traditional Army DUSTOFF crews have only included one flight medic in addition to one crew chief. During the initial blood transfusion program, the presence of a second dedicated medical care provider in the MEDEVAC helicopter, as well as a crew chief trained in the use of a monitor, was identified by the flight medic as extremely helpful to improve transfusion speed and overall casualty care. It is our strong recommendation that MEDEVAC units be adequately manned to allow placement of two medics on the lead aircraft for all Urgent missions and to train the crew chief in emergency medical technician skills such as cardiopulmonary resuscitation and the use of a monitor.

En Route Critical Care Nurses

Nursing professionals have extensive experience with in-hospital and en route blood transfusion and contributed valuable expertise for training flight medics. ECCNs with previous en route transfusion experience served as ideal "train the trainers" for MEDEVAC physicians and physician assistants who do not routinely transfuse blood products in their normal scope of practice. ECCNs served as subject matter experts on the technical procedure of blood product transfusion. It is our recommendation that ECCNs remain closely involved with flight medic training and are incorporated on point-of-injury missions when appropriate.

Physician Oversight

One hundred percent physician review is required for all blood products administered by noncredentialed MEDEVAC providers. Ideally, this supervision would be performed by a fulltime Prehospital Medical Director qualified in emergency medical services who is also a flight surgeon. A theater Prehospital Medical Director could provide oversight and assist in identifying and standardizing the best practices and equipment throughout the military and improve the direct infusion of lessons learned back into training institutions.

CONCLUSION

This case series of 15 blood product transfusions during MEDEVAC showed the safe administration of blood products by U.S. Army flight medics onboard MEDEVAC aircraft. MEDEVAC training and practice must continue to emphasize that the most consistent factors in survival are to stop bleeding, control airway, and transport rapidly to a surgical facility. Further emphasis on checklist utilization during training may improve overall safety during MEDEVAC. Research study of prehospital blood transfusion is needed to refine the indications for blood product transfusion and to determine the impact on survival of the combat wounded.

REFERENCES

1. Holcomb JB, Stansbury LG, Champion HR, Wade C, Bellamy RF: Understanding combat casualty care statistics. J Trauma 2006; 60: 397–401.
2. Kragh JF Jr., Walters TJ, Baer DG, et al: Practical use of emergency tourniquets to stop bleeding in major limb trauma. J Trauma 2008; 64: S38–50.
3. Holcomb JB, Jenkins D, Rhee P, et al: Damage control resuscitation: directly addressing the early coagulopathy of trauma. J Trauma 2007; 62: 307–10.
4. Beekley AC: Damage control resuscitation: a sensible approach to the exsanguinating surgical patient. Crit Care Med 2008; 36: S267–74.
5. Borgman MA, Spinella PC, Perkins JG, et al: The ratio of blood products transfused affects mortality in patients receiving massive transfusions at a combat support hospital. J Trauma 2007; 63: 805–13.
6. Eastridge BJ, Jenkins D, Flaherty S, Schiller H, Holcomb JB: Trauma system development in a theater of war: experiences from Operation Iraqi Freedom and Operation Enduring Freedom. J Trauma 2006; 61: 1366–72.
7. Eastridge BJ, Costanzo G, Jenkins D, et al: Impact of joint theater trauma system initiatives on battlefield injury outcomes. Am J Surg 2009; 198: 852–7.
8. Carlton PK, Jenkins DH: The mobile patient. Crit Care Med 2008; 36: S255–7.
9. Beninati W, Meyer MT, Carter TE: The critical care air transport program. Crit Care Med 2008; 36: S370–6.

10. Morrison JJ, Dubose JJ, Rasmussen TE, Midwinter MJ: Military Application of Tranexamic Acid in Trauma Emergency Resuscitation (MATTERs) Study. Arch Surg 2012; 147: 113–9.
11. King DR: Thirty consecutive uses of a hemostatic bandage at a US Army combat support hospital and forward surgical team in Operation Iraqi Freedom. J Trauma 2011; 71: 1775–8.
12. Cox ED, Schreiber MA, McManus J, Wade CE, Holcomb JB: New hemostatic agents in the combat setting. Transfusion 2009; 49: 248S–55S.
13. Kelly JF, Ritenour AE, McLaughlin DF: Injury severity and causes of death from Operation Iraqi Freedom and Operation Enduring Freedom: 2003–2004 versus 2006. J Trauma 2008; 64: S21–6.
14. Holcomb JB, McMullin NR, Pearse L: Causes of death in U.S. Special Operations Forces in the global war on terrorism: 2001–2004. Ann Surg 2007; 245: 986–91.
15. Pannell D, Brisebois R, Talbot M, et al: Causes of death in Canadian Forces members deployed to Afghanistan and implications on tactical combat casualty care provision. J Trauma 2011; 71: S401–7.
16. Eastridge BJ, Hardin M, Cantrell J, et al: Died of wounds on the battlefield: causation and implications for improving combat casualty care. J Trauma 2011; 71: S4–8.
17. Eastridge BJ, Mabry RL, Seguin P, et al: Death on the battlefield (2001–2011): implications for the future of combat casualty care. J Trauma Acute Care Surg 2012; 73: S431–7.
18. National Association of Emergency Medical Technicians, American College of Surgeons Committee on Traume. PHTLS Prehospital Trauma Life Support, Military, Ed 7. St. Louis, MO, Mosby Jems Elsevier, 2011.
19. Hales B, Terblanche M, Fowler R, Sibbald W: Development of medical checklists for improved quality of care. Int J Qual Health Care 2008; 20: 22–30.
20. Weiser TG, Haynes AB, Dziekan G, Berry WR, Lipsitz SR, Gawande AA Safe Surgery Saves Lives Investigators and Study Group: Effect of a 19-item surgical safety checklist during urgent operations in a global patient population. Ann Surg 2010; 251: 976–80.