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Tactical Damage Control Resuscitation

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ABSTRACT Recently the Committee on Tactical Combat Casualty Care changed the guidelines on fluid use in hemorrhagic shock. The current strategy for treating hemorrhagic shock is based on early use of components: Packed Red Blood Cells (PRBCs), Fresh Frozen Plasma (FFP) and platelets in a 1:1:1 ratio. We suggest that lack of components to mimic whole blood functionality favors the use of Fresh Whole Blood in managing hemorrhagic shock on the battlefield. We present a safe and practical approach for its use at the point of injury in the combat environment called Tactical Damage Control Resuscitation. We describe pre-deployment preparation, assessment of hemorrhagic shock, and collection and transfusion of fresh whole blood at the point of injury. By approaching shock with goal-directed therapy, it is possible to extend the period of survivability in combat casualties.

INTRODUCTION

The Tactical Combat Casualty Care (TCCC) guidelines are structured to accomplish three primary goals: 1) treat the casualty, 2) prevent additional casualties, and 3) complete the mission.¹ The treatment aspects of the TCCC guidelines are constantly being revised based on operational experiences and medical evidence that have been gained through the years of protracted conflict in Afghanistan and Iraq. The in-hospital resuscitation strategy for shock attributable to traumatic hemorrhage has changed significantly and now emphasizes use of blood products in a 1:1:1 (platelets : plasma : red blood cells) ratio over use of crystalloid.² This is reflected in the revised TCCC guidelines which suggest use of blood first, rather than crystalloid or colloid.³ These changes represent an adaptation of Damage Control Resuscitation (DCR) strategies in the pre-hospital arena. Implementing DCR principles in the TCCC guidelines will require significant modification because of obvious differences in the prehospital and in-hospital environments, which include most prominently the tactical situation, limitations in resources and capabilities, weather and environmental conditions. What is generally accepted as optimal management

inside a hospital might not be accomplished in the combat environment. To distinguish between in-hospital DCR principles and DCR principles implemented in the tactical environment under the auspices of TCCC guidelines we propose to call the latter, Tactical Damage Control Resuscitation (TDCR).

TDCR is the active medical management of a patient in hemorrhagic shock in the combat environment. TDCR focuses on counteracting the lethal triad (coagulopathy, acidosis, and hypothermia), primarily through the use of blood products and hypothermia prevention with the ultimate goal of extending the period of survivability. Current TCCC guidelines recommend the use of fresh whole blood (FWB) as the first line resuscitation fluid for hemorrhagic shock.³ Strandenes et al. recently published guidelines and training for the Norwegian Naval Special Operations Commando.^{4,5} However, there are no current guidelines or training that adequately describe how to do this safely and efficiently in the tactical environment by the nonmedic and by U.S. Forces. Through implementation of the protocol that we describe below, combat units can possibly maximize the use of a lifesaving fluid already present in each assault force.

We consider TCCC a spectrum of care that starts at the point of injury and concludes with delivering a viable patient to a surgeon in a medical treatment facility.⁶ We also propose Prolonged Field Care to be a fourth phase in the spectrum of TCCC. Prolonged Field Care is not based on arbitrary times, rather it begins when the tactical provider has completed all primary and secondary assessments and has addressed all life-threatening conditions with appropriate interventions. The tactical provider now can begin goal-directed resuscitation with the intent of delivering a patient to a definitive care facility in the best condition possible.

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NEED FOR TDCR

Over the last 14 years, U.S. Forces made several improvements in prehospital care that reduced death on the battlefield, most notably the reintroduction of tourniquets. Nevertheless, prehospital mortality has remained stubbornly high, except in the 75th Ranger Regiment where it has dropped to zero.^{1,7} According to a recent autopsy study, 89% of U.S. Military combat deaths occurred prehospital, of which 26% were potentially survivable.⁷ Defining potentially survivable is a challenge, but Eastridge et al. have provided a useful definition of nonsurvivable injuries:

“physical dismemberment, catastrophic brain injury (brain evisceration, transcranial penetrating brain injury involving deep nuclei or critical vasculature, and brain stem injury), cervical cord transection (above cervical level 3), airway transection within thorax, cardiac injury, thoracic aorta injury, pulmonary artery, hepatic avulsion, and catastrophic abdominopelvic injury characterized by lower-extremity amputations with open pelvis and large soft tissue loss/traumatic hemipelvectomy.”⁷

It can be said that all other casualties must be considered potentially survivable.⁷ Aggressive TDCR in the prehospital setting represents the “gap” in care that could lead to improved survival.⁸ This is a major challenge to the point-of-injury tactical provider as these injuries can be extremely difficult to manage in a medical facility and we are challenging them to do it in a remote, combat environment. The operational focus should be on evacuating the casualties to surgical care, as without surgery the majority of critical casualties will succumb to their wounds no matter how excellent the prehospital care is. It is our opinion that the application of TDCR best practices will increase the patient’s period of survival and increase the time we have to get the casualty to definitive surgical care.

Blood and blood products are potentially available on board most rotary-wing evacuation platforms, and at Role II and Role III facilities. It is the time from point of injury to Tactical/Medical Evacuation platform (TACEVAC/MEDEVAC) arrival that represents the challenge to be solved. The requirement for refrigerated storage places logistic restraints on carrying fresh blood products forward on the battlefield. Currently, U.S. Army Special Operations forces carry freeze-dried plasma in an attempt to bring blood products as far forward as possible.

To assist in TDCR, the 75th Ranger Regiment will employ a specially selected and trained nonmedic, the Advanced Ranger First Responder. The Advanced Ranger First Responder will replace the current Emergency Medical Technician–Basics and will emphasize advanced skills and not clinical decision-making. Their training course is 10 days in length and teaches the following: anatomy and physiology, trauma survey, advanced hemorrhage control, assisting in cricothyroidotomy and tube thoracostomy, supraglottic airway placement, medication administration, traumatic brain injury evaluation/management, tourniquet conversion, and FWB collection and administration.

HISTORICAL PERSPECTIVES

Medical providers improvising and attempting new techniques during wartime have produced many great advances in medicine and surgery. Hemorrhagic shock has always been a major cause of death in war. The treatment of shock in combat is well documented since World War I. In 1918, Cannon noted that cold, critically wounded casualties have a drop in blood pressure.⁹ Cannon also found that the administration of saline worsens acidosis and is harmful to the critically wounded.⁹ Fraser concluded that the use of saline is unsatisfactory.¹⁰ In 1918, Robertson and Watson also noted that many casualties who were deemed inoperable made it to surgery because of FWB transfusions.¹¹ They concluded:

“Transfusion of blood after primary hemorrhage is a life-saving intervention of the greatest value and enables urgent operations to be successfully performed under conditions otherwise hopeless.”¹¹

In 2014 the Committee on Tactical Combat Casualty Care dropped saline from the recommended fluid list for hemorrhagic shock resuscitation.³

During World War II (WWII), H.K. Beecher conducted several studies regarding shock and resuscitation. He summed up his research in 1949 when he published “Resuscitation and Anesthesia for Wounded Men: The Management of Traumatic Shock.” In this book, he noted the uselessness and potentially dangerous effects of saline and glucose solutions as “blood substitutes.”¹² Throughout WWII plasma was used when whole blood was not available, and became recognized as a means of temporizing until adequate resuscitation could be given: “Plasma gives more time to get whole blood into the patient.”¹²

Furthermore, when it came to whole blood transfusions, Beecher observed that a patient could easily receive 3 units of group O blood before receiving group specific blood.¹² Beecher did caution about the mistake of delaying surgery in order to transfuse blood, which stresses the importance of obtaining definitive surgical care as rapidly as possible.¹² Therefore, TDCR must be performed in conjunction with a plan for efficient TACEVAC. It is also important to note that as therapeutic as blood can be, historical evidence as well as recent research suggests that FWB use must be goal directed. The authors do not advocate for unrestrained whole blood transfusion, but resuscitation using endpoints more based on physiologic parameters that will be discussed later.

In Vietnam, the use of crystalloid fluids became increasingly widespread. Reasons for the preferential use of crystalloids included the medic carrying more prepackaged fluids to treat heat related injuries, and shorter evacuation times that reduced the need for extensive fluid replacement.¹³ Nevertheless, blood was still considered superior in the treatment of hemorrhagic shock. In 1968 during the height of the Vietnam War, Shires and Moore warned against the excessive use of isotonic solutions, and emphasized that saline was not a substitute for blood.¹⁴ However, a gradual switch to

component therapy and isotonic fluids occurred in the decade following Vietnam because of the ease of providing these fluids together with the reduction of transfusion related risks. In addition, there was a belief that coagulation functional reserves in most patients were sufficient and plasma and platelet transfusions would not be required.

During more recent warfare, specifically the conflict in Somalia and the early phases of the wars in Afghanistan and Iraq, the standard civilian model of Advanced Trauma Life Support was heavily relied upon for the management of hemorrhagic shock.^{15,16} The differences between combat casualty care and civilian trauma management became painfully apparent during combat operations in Somalia in 1993.¹⁷ After the loss of men in Somalia, CAPT Frank Butler et al. released their findings for a new approach to tactical medicine. These findings defined Tactical Combat Casualty Care, as we know it today.¹⁸ And in 2001, the Committee on Tactical Combat Casualty Care was formed.

In 2009, a FWB transfusion was performed at Role I in in Afghanistan, where a severely wounded casualty received 5 units of group A FWB from 5 different group A donors.¹⁹ His injuries included penetrating shrapnel wounds to the left lower quadrant of the abdomen and left upper thigh, a gunshot wound to the right upper arm, and open fractures of the left tibia and fibula. He presented in shock with only a palpable carotid pulse, a heart rate of 150 beats per minute, and altered mental status.¹⁹ The casualty responded well to FWB resuscitation and survived 16 hours post injury, though he eventually died after reaching surgical care.¹⁹ This case demonstrates the ability to significantly prolong the period of survivability in a critically wounded casualty through the use of FWB. Far forward transfusion of FWB also proved efficacious to an injured service-member who received a total of 3 units of group specific blood with positive effects on blood pressure, mentation, and hemorrhage (personal communication, October 2014). These cases demonstrate the feasibility of FWB transfusion in the prehospital setting.

CURRENT APPROACH TO HEMORRHAGIC SHOCK

According to the United States Army Institute of Surgical Research (USAISR), the current approach to Damage Control Resuscitation in Level II/III Treatment Facilities is:

“The goal in transfusion of the patient with need for massive transfusion is to deliver a ratio of PRBCs to plasma to platelets of 1:1:1. Therefore, the goal of 1:1:1 resuscitation should be 6 units PRBCs: 6 units FFP: 1 unit apheresis platelets”.²

However, the USAISR guidelines also recognize and endorse the utility of FWB use:

“Two retrospective analyses in combat casualties comparing FWB to component therapy (which included platelets) have been published. One study showed a potential survival benefit to the use of FWB during resuscitation of

severe combat injuries, and the other showed FWB to be equivalent to component therapy”.^{2,20}

There is further evidence from retrospective studies in Role III facilities and U.S. trauma centers that administering Packed Red Blood Cells (PRBCs), FFP, and platelets in a 1:1:1 ratio in the hemorrhagic shock patient improves patient outcomes.^{21–27} The Pragmatic Randomized Optimal Platelet and Plasma Ratios study, a randomized trial of 680 patients, recently documented the utility of the 1:1:1 strategy in establishing hemostasis and reducing early deaths because of exsanguination.²⁸ Although, this approach may be achievable in a Role III or a civilian trauma center, it is logistically impossible for the medic who must work out of his aid bag. According to Repine et al. and Spinella et al., FWB is at least as beneficial as 1:1:1 component therapy in the hemorrhagic shocked patient.^{21,23} This might be expected given that a 1:1:1 mix of components yields an anemic, thrombocytopenic, and coagulopathic product compared with whole blood.²⁹ We suggest that in the absence of component therapy, which mimics whole blood functionality, a feasible option is to use FWB in managing hemorrhagic shock on the battlefield.

BLOOD PRODUCTS

Blood products and components available to some U.S. Forces at the point of injury include FWB, PRBCs, and Freeze-Dried Plasma (FDP). Although, the use of PRBCs is relatively safe and effective in correcting anemia, there are significant logistical issues, which hinder their use by the combat medic. Although, the 75th Ranger Regiment has used PRBCs twice in Afghanistan at the point of injury with success and survival of both patients, the practice is logistically burdensome. The French Military has used FDP extensively since 1994 and recently demonstrated the effectiveness of FDP for the prevention or correction of coagulopathy and hemorrhage in combat casualties.³⁰ French FDP is currently being fielded by U.S. Army Special Operations in the prehospital setting under an Investigational New Drug protocol and has been used successfully once within the 75th Ranger Regiment.

There is one single product available on target which contains all the clotting factors, has fully functioning red blood cells and platelets, costs less than \$100 per unit to collect, and is maintained indefinitely at 98.6 degrees Fahrenheit. Critics of FWB use in the prehospital setting cite the potential for transfusion reactions and Transfusion Transmitted Disease (TTD); however these risks are often over-inflated compared to the risk of not transfusing (immediate death because of exsanguination). Major transfusion reactions occur as a result of the recipient's naturally occurring antibodies to alternate blood groups. Thus, there is a serious risk of transfusion reaction with FWB if ABO incompatible units are transfused. There are two types of hemolytic transfusion reactions: immediate intravascular hemolytic transfusion reaction (IHTR) and delayed hemolytic transfusion reaction (DHTR). A DHTR is the result of an immune response and takes 2-3 weeks to

manifest, which is unlikely to be seen in the pre-hospital setting. Intravascular hemolytic transfusion reaction, on the other hand, is caused by pre-existing antibodies and will cause lysis of red blood cells through complement fixation. The preferred method of FWB transfusion is to administer group specific whole blood; however, there are studies, which show giving group O with low anti-A or -B antibody titers, regardless of the recipient's blood group, is safe. This has been performed successfully in thousands of patients since WW II.³¹ Over 10,000 FWB transfusions in Iraq and Afghanistan have occurred with an excellent safety record.^{20,32} The safest way to administer FWB in the prehospital setting, where the risk of error in matching donor and recipient blood types is highest, is to draw from group O donors identified as "universal" – those producing only low titers of anti-A and anti-B antibodies. Though correlation between antibody levels and risk of hemolysis is imprecise, these antibodies can be measured in the lab setting in order to identify low risk FWB donors.³³

Use of untested FWB entails a small, but significant risk of transfusion transmitted diseases.³² Risk can be mitigated through routine predeployment testing for diseases of concern. The target population for FWB donation is already tested for HIV and many are tested for syphilis because of certain U.S. Army school requirements. It is recommended that additional testing for HCV be added to the lab tests. The military population is vaccinated for HBV and HAV, further increasing the safety of FWB. Technologic advancements are in development to facilitate both point-of-care testing and rapid leukoreduction using a platelet-sparing leukoreduction filter. Furthermore, in identifying specific universal donors, it is feasible to perform increased Transfusion Transmitted Disease screening on select individuals before deployment.

Low titer group O FWB transfusion is not only safe; it is available throughout the battlefield. According to the Red Cross, 45% of the U.S. population is group O.³⁴ Low titer group O is defined by low levels of anti-A and anti-B occurring in immunoglobulin G (IgG) and immunoglobulin M (IgM). The primary concern is IgM levels as these are most closely associated with hemolysis. There is no universally accepted definition of "low titer"; however, many experts suggest an IgM level of less than 1:128. According to Berséus et al. a "universal donor" has IgM and IgG titers of 1:100 and 1:400 respectively.³¹ The Norwegian Naval Special Operations Commando uses similar values for their "universal donor" program.³⁵ Acceptable levels for this protocol will be < 256 for IgM. By identifying universal donors, the medic can eliminate several steps in the blood transfusion process as well as eliminate a significant amount of equipment, allowing for a transfusion on target to start within 15 minutes of the call for blood.

PROTOCOL

In order to make TDCR with FWB practical and safe at the point of injury, the process must become a battle drill that is

adopted by the entire unit. The following sections lay out a practical approach.

The United States Army Institute of Surgical Research (USAISR) current Clinical Practice Guidelines state the following for predicting massive transfusion

"A number of predictors for massive transfusion upon hospital admission have been identified. In a patient with serious injuries, these include:

- (1) Systolic blood pressure < 110 mm Hg
- (2) Heart rate > 105 bpm
- (3) Hematocrit < 32%
- (4) pH < 7.25
- (5) Other risk factors for massive transfusion include: INR level > 1.4, NIR-derived StO₂ < 75%³²

Unfortunately, at the point of injury the ability to carry the equipment necessary to properly evaluate the above parameters is currently limited. However, there are other parameters that can adequately predict physiological decompensation and the need for FWB transfusion. Foremost is type of injury. Proximal traumatic amputation of lower extremities and obvious penetrating injuries of the chest, abdomen or pelvis are always associated with significant blood loss and need for transfusion. The physiologic parameters most practically monitored are heart rate (HR), blood pressure (BP) and lactate. The critical values for initiating goal-directed TDCR are systolic blood pressure between 80 and 100 mmHg or lower, lactate \geq 5mmol/l, HR > 100 beat per minute, and StO₂ \leq 70% (Fig. 1).^{2,36-38}

Tissue perfusion as measured by StO₂ and SmO₂ presents significant advantages for measuring oxygen delivery at the tissue level, thereby giving a reflection of shock. These monitors represent valuable tools in triage of multiple casualties. However, as of now they are relatively large and difficult to carry. A drop in StO₂ below 75% signals evolving shock, often well before pulse or mental status change.³⁶ This is an early indicator to the medic that he should press forward with FWB administration.

Currently, lactate is very simple to check in the field environment. The tests are small, reliable, easy to purchase, and require little training and function comparably to current glucose monitors. Lactate has been shown to be a reliable indicator of shock in severely injured patients in trauma.^{38,39} Lactate levels can vary based on the fitness of the individual and the amount of exercise performed. The highest observed levels are typically 3 to 8 minutes after maximal exercise, with some abnormal levels present for up to 60 minutes.⁴⁰ Therefore, we propose measuring lactate upon assumption of care and 15 to 20 minutes later in order to establish a trend line, particularly since significant pre-injury exertion, as is typical in combat scenarios, can produce lactate elevations that are unrelated to shock. If lactate is less than 5mmol/l and stable or falling, this generally suggests an acceptable perfusion state. If the lactate rises above 5mmol/l

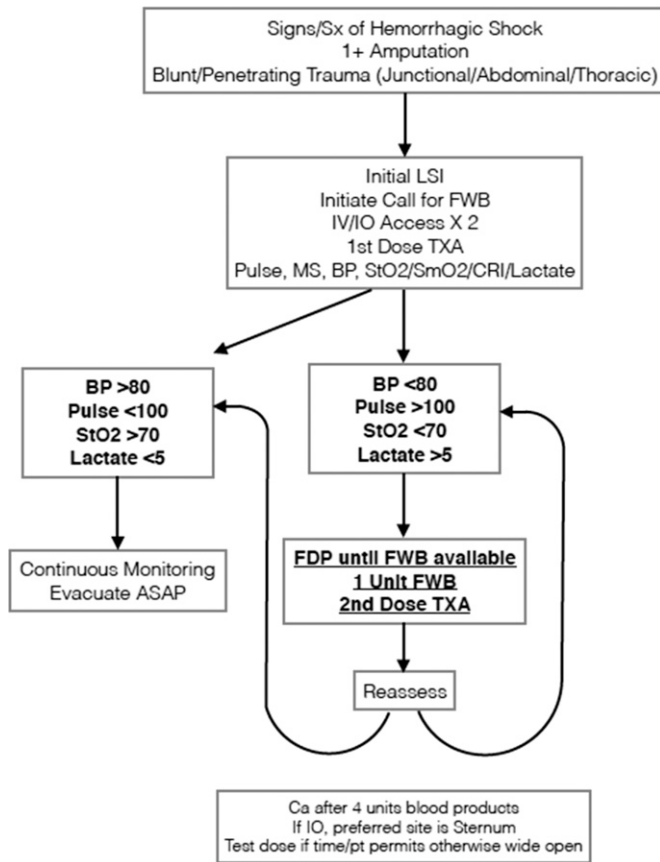


FIGURE 1. 75th Hemorrhagic shock.

after 15 to 20 minutes this is most likely because of shock. This rising lactate level should serve to signal the medic to increase resuscitation with FWB. Monitors are currently in development that can accurately and noninvasively give both a SmO₂ and a pH, potentially replacing the lactate and StO₂ monitors. Compensatory Reserve Index is a new technology that evaluates arterial waveforms obtained from a pulse-ox monitor to estimate cardiac stroke volume and central blood volume to evaluate evolving shock.^{41,42} This technology is currently being evaluated in clinical trials, but appears promising.⁴¹

Blood typing is performed on every new Ranger upon their arrival to the unit. Rangers with group O blood will be sent for additional antibody titer testing. Titers for IgM anti-A and anti-B are drawn. Two confirmed lab results of the same blood group give the medical staff very high confidence of blood group accuracy.⁴³ Each platoon medic maintains a roster of all personnel in his platoon. The roster will have each member's blood group, low titer status, and date of communicable disease testing. The average platoon has 35 to 40 men, and it is estimated that 5 to 30% of group O donors will have high titers. Therefore 45% of 38 men (group O %) or 17 will have group O, and at least 70% of these 17 men (% low titer) or 12 will have group O low titer per Assault Force (Fig. 2). These Rangers with low titer levels

Quick evaluation of potential low titer group O within a group
 $\# \text{ Soldiers} \times 0.45 (\% \text{ group O}) = \# \text{ Group O Soldiers.}$
 $\# \text{ Group O Soldiers} \times 0.7 (\% \text{ low titer of O blood group}) = \# \text{ number if low titer Soldiers within a group.}$

FIGURE 2. Evaluation for low titer group O.

(<128) will be identified and will be the “universal donors.” It is noted that all “universal donors” will be voluntary.

Once someone sustains a serious injury (presence of hemorrhagic shock, one or more major amputations, penetrating torso trauma, evidence of severe bleeding), which has the potential to require TDCR, the medic will obtain intravenous (IV) access (or intraosseous [IO] if unable to gain IV) at two separate sites and give the patient one gram of Tranexamic Acid.⁴⁴

Once TDCR has begun, the medic will need to titrate the use of blood products (specifically FWB) to an achievable goal (hypotensive resuscitation, targeting SBP 90-100mmHg). If no monitoring is available, pulse and MS should be used to guide resuscitation. The advantage of using a radial pulse and mental status (current standards) is that they are relatively simple to measure without any additional tools. The difficulty with using a pulse to guide hypotensive resuscitation is that while it does an adequate job of providing a lower limit for BP, it does not give accurate information about how high the casualty's BP may rise. The major difficulty with monitoring mental status is that many casualties will have altered mental status either from traumatic brain injury or from pain medication administration. Administration of blood should be by gravity; lack of observable flow via an IO route should prompt choice of alternate vascular access point rather than attempts at squeezing blood through the IO (this will likely not improve flow and only result in mechanical hemolysis).

If there is no significant change in the TDCR parameters 10 minutes after initiating the FWB transfusion, the medic will call for more blood and the process will repeat. It is not recommended that a blood transfusion be stopped unless there is a transfusion reaction that will end in a fatality. In order to not delay TACEVAC to surgical care, it is feasible to evacuate a donor with the casualty and perform the WBT on the evacuation platform.

CONCLUSION

The goal of TDCR is to deliver a live, warm, and non-coagulopathic patient to definitive surgical care as fast as possible. TDCR and FWB transfusion offer an approach to not only decrease oxygen deficit, but also to mitigate the development of coagulopathy.⁴⁵ Since World War I, whole blood transfusions have been saving lives in combat. As the conflict in Afghanistan winds down and the tyranny of distance reasserts itself in small unit counterinsurgency and counterterrorism missions, the difficulty in getting injured

soldiers to definitive care will be increased. With the recent changes in the TCCC guidelines advocating blood products for hemorrhagic shock, a safe and effective TDCR protocol is needed. The described TDCR approach is simple and fast; it also has the potential to be safe. The TDCR protocol uses the same approaches that have been used in the past, along with current guidelines and the newest technology available. TDCR remains an evolving field of art and science; our job is to practically apply the best-known science to the point of injury in a way that makes tactical sense. The evacuation of the severely wounded to definitive surgical care should not be delayed for fresh whole blood transfusion; rather TDCR should be performed in conjunction with an efficient casualty response system. By applying the concepts described in this article, we can be better armed to improve survival in hemorrhagic shock.

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