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Enduring Combat to Develop New Trauma Protocols

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In the waning days of World War II, Michael DeBakey was quoted as saying, "the only winner in war is medicine". Revolutionary innovations and technical advances in the disciplines of medicine, surgery, and anesthesia of medicine and nursing are inextricably connected to military conflict. The last decade of war has likewise produced evolution of long accepted concepts, including pre-hospital trauma care, acute resuscitation, and forward deployed surgical care teams. The demonstrated life-saving value of these novel approaches in high acuity trauma has provided the impetus for translation of these elements into injury care in the civilian environment.

One element of this battlefield medical revolution is the implementation and refinement of forward surgical care. All of the US military services have unique configurations of this surgical team to match their expeditionary capacity. The US Army Forward Surgical Team (FST) is a small, mobile surgical unit fielded since the 1990s, but not ubiquitously utilized until the current contingency operations in southwest Asia. The FST has been utilized in a variety of ways during the current conflict with or without augmentation by a forward support medical company (FSMC), Area Support Medical Company (ASMC), Brigade Medical Company also known as C-Med. Far forward stand-alone FST have often been emplaced to provide a surgical capability for patients in austere operational environments in order to optimize casualty survival in situations of high risk operations and/or with potential for protracted evacuation. In the FST model, the surgical team performs lifesaving interventions, specifically surgical hemorrhage control for battlefield casualties within the "golden hour" of injury. After initial resuscitation, casualties are then packaged for medical evacuation to a higher level of care. The FST by doctrine includes 20 staff members including 3 registered nurses (RN), 3 licensed practical nurses (LPN), 2 surgical techs and 4 medics, 1 detachment sergeant, 1 administrative officer ,4 surgeons (3 general and 1 orthopedic), 2 certified registered nurse anesthetists (CRNAs),. By doctrine of Field Manual (FM) 4-02-25 (March 2003) and Army Training and Evaluation Program (ARTEP) 8-518-10, the team is capable of continuous operations with a divisional or non-divisional medical company for up to 72 hours with a planned caseload of 30 critical patients.. A functional operating room can be established within one hour of being on scene and break down to move to a new location within two hours of ceasing operations. The FST can sustain surgery for 24 total operating table hours and has the ability to separate into two component teams that function independently at disparate locations. In these split operations circumstances, the team must be split to maintain functionality by maintaining logistic, operational, surgical, and anesthesia support with CRNA coverage [1].

Nurses first provided anesthesia to wounded soldiers during the Civil War. Nurse anesthetists have been the main providers of anesthesia care to U.S. military personnel on the front lines during the history of modern warfare. In 1914, Dr. George Crile, a pioneer in American surgery, and his Nurse Anesthetist, Agatha Hodgins, who became the founder of the American Association of Nurse Anesthetists (AANA), went to France with the American Ambulance Group to assist in the establishment of hospitals that would provide care for the sick and wounded of the Allied Forces. Nurse Ellan Orkin was a prime example of the courage, dedication and leadership exhibited by nurse anesthetists in support of our troops during World War 2. In a field in its infancy, she received rudimentary training, became a nurse anesthetist in three days, and landed with the 164th General Hospital supporting the main body of the invasion of Normandy on D-Day armed only with vials of sodium pentothal. She continued to serve troops with honor during world WWII as did her sister. The commitment and sacrifice of the CRNA community in combat surgical support has been maintained through current operations of Iraqi Freedom and Enduring Freedom. In 2003 Steve Hendrix, CRNA, LTC participated in rescue mission of PFC Jessica Lynch. Colonel Gale Pollock, CRNA was promoted to Major General and became 22nd Chief of Army Nurse Corps, the third CRNA to serve in that position. Later, she was appointed acting Surgeon General of the US Army [2-4]

Illustrating the vital importance of the CRNA in contemporary combat operations, the following case is presented. In the predawn hours of September 9, 2014, our tactical operations command center received a nine-line aeromedical evacuation (MEDEVAC) report of two incoming Afghan National Army (ANA) casualties injured in an encounter with enemy forces. The first was hemodynamically unstable with active hemorrhage from the lower extremity and the second was reported as stable with no life-threatening injuries. Initial report stated both were victims of fragment injury from a grenade attack. The surgical team initially mobilized and reported to pre-determined and rehearsed stations.

We received a quick brief of the little information we had and prepared for contingencies with the incoming patients. Within minutes, the Blackhawk MEDEVAC helicopter landed, and our patients were unloaded. Per our standard operating procedures, the normal process for casualty intake included stripping the patient down to so called "trauma naked" in a shielded metal container just outside the medical treatment facility. This step is performed for two main reasons: one was to visualize all wounds and the second to inspect for explosives and other agents potentially injurious to the casualty and medical personnel.

0639 Unidentified 40 ish Afghan National Security Forces (ANSF) soldier injured in special operations by a 7.62mm round which entered to the left posterior thigh wound, shattered his left femur, and exited leaving a large soft tissue wound of the left anterior thigh. His initial presentation to advanced trauma life support (ATLS), he was hypotensive with BP of 70/38, tachycardia at135 and hypothermic at 93.6. He had a Combat Application Tourniquet (CAT) applied to high left thigh. Visualizing continued hemorrhage, a second tourniquet was applied in ATLS to control arterial and venous hemorrhage as well as Combat Gauze which was tightly packed into the left lower extremity wound cavity. Studies by Walters in 2004 found that this Combat Application Tourniquet® (C-A-T®) was effective 100% of the time in quickly and effectively occluding arterial blood flow in both the upper and lower extremities in all trials [5]. The tremendous life-saving potential of the tourniquet in this and subsequent analyses lead the military services to require tourniquet fielding to service members deployed to the battlefield. In the acute resuscitation area, large bore intravenous lines were placed including a femoral introducer and right Internal jugular line .We then initiated our massive transfusion protocol which consisted of a balanced ratio of packed red blood cells and plasma to restore volume, oxygen carrying capacity and correct the inherent coagulopathy of trauma elicited by most high acuity combat casualties.

The patient was groaning but responsive, and his Glasgow coma scale (GCS) was 11. Breathing regular and mildly labored. Patient was intermittently phonating with multiple screams and speaking in Pashtun, his native dialect. Chest symmetry equal with bilateral breath sounds. Trachea mid-line. Heart tones, S1 and S2 no clicks murmurs, or gallops noted. Initial Labs: WBC 24.6; Hgb 12.8 g/dl; Hct 39.1%; Plt 297; Venous Ph 7.3; Base excess -7; K 3.3; Na 141; Cl 106; Ica 1.10; Glucose 188; Bun 11; Crea 1.2;. Medics administered 2 grams Ancef IV- and 0.5-ml IM Tdap. Anticipating emergency surgery for hemorrhage control, the casualty's airway was secured by rapid sequence induction (RSI) by administering 120 mg succincholine IV, 200 mg ketamine IV, 0.4 mg scopolamine IV with cricoid pressure. The Miller 2 blade in the kneeling position was utilized due to low rickshaw height and a 7.5 endotracheal tube was placed atraumatically with bilateral lung sounds verified and cricoid removed. Post intubation 100 mg Rocuronium given, 1000 mg of trans emic acid (TXA) and patient quickly moved to operating room for emergency surgery at 0730. ER course included 5 units PRBC's and 3 FFP. With limited reserves of component therapy at our forward deployed station, we transitioned our resuscitative therapy to fresh whole blood in the operating room [6]. To institute this therapy, a walking blood bank alert was issued over the FOB (forward operation base) "big voice" loudspeaker communication system by calling for "all American soldiers with type B+ blood report to the forward surgical team at once".

Trauma resuscitation protocols have changed drastically within the past decade secondary to the analyses of lessons learned in the conflicts in both Iraq and Afghanistan and subsequent changes in clinical practice have occurred. The fourth United States Revision on Emergency published in 2013, US Army Surgeon general Trauma Consultant Colonel Brian Eastridge noted "the antiquated system of prehospital care espoused by Pre-Hospital Trauma Life Support (PHTLS) has been ubiquitously supplanted by the paradigm of Tactical Combat Casualty Care (TCCC) divided into phases depending on the tactical scenario. In each phase, the greatest potential threat to life is managed as a priority in the context of mission capability and mission completion. Embedded within the overarching concept of TCCC are major care tenets of HEMORRHAGE control and airway management. Tourniquet utilization has become a fundamental pillar of hemostasis in the TCCC and has been shown to be associated with an attributable survival advantage" [6].

One of the legacy medical achievements of this war, was the development of a new resuscitation paradigm coined Damage Control Resuscitation. The focus of this novel strategy is developed upon the concept of early management of the coagulopathy of trauma by utilizing a balanced resuscitation of plasma to augment red cell transfusion. We utilized this new approach to balanced resuscitation of battlefield trauma resuscitate this patient. Our approach focused on the thought pattern that we would be willing to sacrifice the limb to save the life. Further anesthesia management included adjuncts to this therapeutic regimen to include an aggressive emphasis on thermoregulation. ATLS and the operating room temperature were increased to a setting of "hot" on the environmental control unit (ECT). The patient presented with an initial temperature of 93.6 and upon discharge from the recovery unit to the medevac transport he was reconstituted to a temp of 98.4 degrees. We also focused on minimizing crystalloid solution and made an effort to transfuse the patient sooner with a mixture of PRBC's and FFP until whole blood could be prepared for us. We also focused on early administration of hemostatic agents and used coagulopathy testing modalities to facilitate resuscitation. We infused tranexamic acid (TXA) 1000 mg prior to the start of surgery with a goal administration of getting the TXA on board within 3 hours of the initial injury after which is shown to be detrimental. We also concluded the surgical portion of the resuscitation with an additional dose of 1000 mg of TXA [6, 7].

TXA in trauma is a novel therapeutic agent with a well-developed safety profile in elective surgery to minimize blood loss around the globe. There is current evidence in elective surgery that TXA has a benefit of decreasing periprocedural blood loss. The CRASH 2 Trial (citation) and the US military Matters trials (citation) both demonstrated a survival advantage of the drug in injured patients, especially those who received transfusion and even more profound survival advantage was noted in casualties after massive transfusion. One intangible benefit of this paper was well as in the new guidelines in trauma anesthesia management is the principle of prevention of problems and being proactive instead of being reactive [6, 7].

Calcium should also have a continued place in trauma management, although not all would agree on this topic. We should continue to have a weight-based risk benefit profile for the use of calcium. We know we need calcium to continue the coagulation cascade and it is the only factor that is derived from our diet as factor 4 and is critical in the cascade. The interesting theoretical question that arises from doing trauma care on local nationals is the difference in a balance and unbalanced diet. We pose the bigger question on that topic and do we need to consider the use of calcium sooner in this patient populations due to the increased risk of malnutrition in third and fourth world countries. The authors recommend the use of 1 gram of Calcium with every 2-4 units of PRBC's and if available monitoring ionized calcium levels to maintain the level of at least 1 mmol/l [6, 7].

Incumbent in the new philosophy of resuscitation is the central focus on the management of the lethal triad of acidosis, coagulopathy, hypothermia after injury [8]. We will focus on each piece of the triad and discuss our intervention for them. Temperature control has assumed a new perspective in the last several years. We have always understood that hypothermia has global impacts on the patient as enzymatic and physiologic processes have optimal kinetics in a fairly tight range of temperature and pH. New Data has forced us to finally embrace warm operating rooms. This is a cultural shift that will take years to break. Hypothermia is one of the most preventable surgical and anesthesia complications.

Temperature is controlled by 4 variables: convection, conduction, evaporation, and radiation. Depending on the phase of the surgery some of them change the percentage of surgical heat loss.

Conduction

(10% of heat loss) Heat energy is transmitted through a substance by the transfer of the energy of motion of the molecules to adjacent molecules. Air is a poor conductor of heat, so air trapped in clothing protects against this form of heat loss. DIRECT CONTACT: Laying on a cold bed. We increased the ambient room temp, and this had a secondary effect on warming the bed although very minor [9-12].

Radiation

(50%-60% of heat loss) a hot object emits radiation over a wide range of wavelengths predominantly infrared; a bar of steel when heated will glow red then orange then blue then white. This radiation carries away heat and the object cools. An important form of heat loss normally and in the OR. It may account for up to 50-60% of the heat loss at room temperature in an unclothed patient. Radiant heat loss is increased when body is surrounded by cool objects and decreased by radiation from warm objects near it. For example, space blankets (silvered Mylar film) passively reflect the body's radiated heat energy back to it. The Alaska tent and environmental control unit was placed on the heat setting. There was no thermostat in the tent to gauge the actual temperature. The ATLS and Operating room temperatures were kept on hot and judging by the final patient temperature, we were able to maximize this route of temperature control [9-12].

Convection

(30% of heat loss) the air layer adjacent to the body surface is warmed by conduction and expands and rises, since heated air is less dense. The resultant convection current carries heat away, like the "heat waves" one can see above the highway on a hot day. We applied warm blankets and use the Bair hugger to provide what protection we could to the patient on this avenue. The final portion of the paper will focus heat control for transport [9-12].

Surface Evaporative Heat Loss

(20% of heat loss) the loss of latent heat of vaporization of moisture on the body surface. Accounts for around 20% of heat loss at room temperature, can be more in extremely warm environments or when greater areas of moist skin are exposed (e.g., larger incisions). Amount of heat lost is proportional to the water vapor pressure gradient between body and air, and to the total amount of skin exposed. We used a humidified moister exchanger. The patient was not sweating at this point appeared to be vasoconstriction which helped with this mechanism [9-12].

Additional options for heat protection: Irrigation fluids were warmed in a microwave in the tent. The warming time is 4 minutes per liter with a mixing performed as to not have hot pockets created. IV fluids were not warmed as the only device to warm was a microwave and we believe this is not a safe avenue to warm IV fluids. The whole blood was at the live donor temperature and bought to us warm. We used a Belmont for rapid transfusion. The head was covered with a military issue, thermoflect heat reflective technology heat cover. Temperature was monitored throughout the case with a final temperature achieved of 98.0 degrees and monitored via nasopharyngeal. Wide fluctuations can be noted with this route, unless intubated, in which case it reflects brain temperature (blood flow past the cribiform plate).

Acidosis

Normal pH is defined as a healthy individual maintaining a physiologically normal pH of 7.35–7.45. This is accomplished through a complex balance of hydrogen ions (acids) and buffers predominately controlled by the pulmonary and renal systems. In acute trauma this system often has great trouble maintaining a normal pH secondary to the metabolic derangements of shock [8]. Acidosis is defined as an arterial pH < 7.35 in trauma patients and the major contributor is poor perfusion of tissue. Anemia from acute blood loss, peripheral vasoconstriction in response to hypothermia and continued blood loss, and an overall decrease in cardiac output severely impair oxygen delivery to the tissues. The resulting tissue oxygen demand far exceeds oxygen delivery. The body needs energy and is forced to make functional energy. This is accomplished by the body's cells being forced to utilize anaerobic metabolism instead of the normal aerobic metabolism, resulting in the production of lactic acid as a byproduct [13]. When a trauma patient's perfusion worsens, lactic acid rapidly accumulates in the tissues. This causes the body's pH to drop, resulting in a severe metabolic acidosis. This process frequently occurs in the presence of normal or only slightly abnormal vital signs. Additional causes of acidosis in the trauma patient is the practice of excessive resuscitation using unbalanced crystalloid solutions [14]. Normal Saline has a pH of 5.5 and is far more acidic than the desired normal blood pH. In large-volume resuscitations, normal saline predictably causes its own metabolic acidosis as a result of the high chloride content.15 this hyperchloremic metabolic acidosis only serves to compound the existing lactic acidosis of trauma. There is evidence that excessive use of normal saline with its high chloride content may increase systemic tissue inflammation and can contribute to the coagulopathy of trauma [15]. Lactated Ringers (LRs) is not a substitution for normal saline. Lactate Ringers pH is 6.5 and contains lactate and is incompatible with many medications and blood products [8]. Finally, a trauma patient may also have respiratory acidosis as a result of hypoventilation due to respiratory depression or obstruction resulting in hypercapnia (increased CO_2 levels). This respiratory acidosis in trauma can have multiple causes and a good investigation can help with additional treatments as needed. With severe acidemia (pH < 7.20), disastrous consequences in numerous metabolic processes can occur [16]. For the trauma patient, the most harmful effect is that their coagulation system can become severely impaired. In one study, the function of part of the coagulation system was reduced by 55–70% when the pH dropped from 7.4 to 7.0 [17,18]. In such circumstances, agents such as THAM can be utilized for recovery. THAM has several advantages in trauma related acidosis: Nahas et al found that THAM supplements the buffering capacity of the blood bicarbonate system, accepting a proton, generating bicarbonate, and decreasing the partial pressure of carbon dioxide in arterial blood ($paCO_2$). It rapidly distributes through the extracellular space and slowly penetrates the intracellular space, except for erythrocytes and hepatocytes, and it is excreted by the kidney in its protonated form at a rate that slightly exceeds creatinine clearance. Unlike bicarbonate, which requires an open system for carbon dioxide elimination in order to exert its buffering effect, THAM is effective in a closed or semi closed system and maintains its buffering power in the presence of hypothermia. THAM rapidly restores pH and acid-base regulation in acidosis caused by carbon dioxide retention or metabolic acid accumulation, which have the potential to impair organ function [19].

Trauma Calculations for THAM
Dosage: Loading dose of THAM acetate 0.3 mol/l in the treatment of acidaemia:

Example: ml of 0.3mol/L soln = KG x base deficit
Max dose is 15 mmol/kg or 3.5L of a 0.3mol/l soln in a 70 kg patient 70kg X -9.1 = 637cc

An alternative to using THAM in trauma is the traditional method of using Sodium Bicarbonate. This system is dependent on keeping the patient normothermic. The evidence to support the use of bicarbonate is limited at best and a calculated risk benefit should be undertaken prior to using it. The administration of bicarbonate does produce carbon dioxide that requires the anesthesia provider to monitor labs closely and the need to change minute volume may be required to clear this additional carbon dioxide. The additional risk of using bicarbonate is you can see a reduction in the ionized calcium levels related to the use of sodium bicarbonate. This may have added effects on your coagulation status for which we are trying to treat as well. Careful and controlled consideration must be taken before using sodium bicarbonate. Until the civilian world embraces the benefit of THAM we may only have sodium bicarbonate to use or be willing to use. The mathematical calculation for the use of bicarbonate is as follows:

Trauma bicarbonate Dose Calculation
Normal bicarbonate level minus base deficit times patient weight in kg times 0.3
25 (normal) – 10 (base deficit) times 70 kg x 0.3
Example: 15 x 70 kg = 1050 x 0.3 = 315 meq
In practice we only give half the dose for 167 meq or 3 amps of sodium bicarbonate

Blood administration ratio in trauma has become a controversial topic. Questions of how much crystalloid first (if any), how much blood, when to start, ratio of blood components, end goals have all been debated. In the military, the debate has shifted to accept early use of blood, minimal crystalloid, a 1:1:1 ratio of packed red blood cells (PRBC) to Fresh frozen plasma (FFP) and platelets based upon several studies which demonstrated survival advantage using this resuscitation strategy [20, 21]. The most important part of this paradigm may not be the specific ratio of red cells to plasma, but rather the principle of intervening to manage coagulopathy with a proactive approach. Traditional trauma or massive transfusion protocol paradigms have relied upon INR values with elevations in the INR prompting the administration of FFP. This technique ultimately require reacting to resuscitative difficulties instead of preventing them. This type of "damage control" trauma resuscitation has improved outcomes on US soldiers requiring a massive transfusion (> 10 PRBC in 24 hrs.)21 In the FST, there is a limited supply of blood available, per Army doctrine the FST has the capacity to receive 50 units of type O+ and O- PRBC's although the components available can vary depending on many logistical factors. In an established theater of operation type, A or AB FFP is also available in varying amounts, as well as cryoprecipitate. However, due to storage logistics, the FST is not currently fielded with platelets [1]. This limited blood product availability along with the potential to encounter several catastrophically injured individuals simultaneously requiring massive transfusion can quickly exhaust blood stores and place patients at risk. This risk is mitigated by using fresh whole blood (FWB) during massive resuscitative efforts.

Fresh whole blood has been used in the resuscitation of soldiers since WWI. The use of FWB is not FDA approved and is unique to the military for several reasons. First, the supply of packed red blood cells and other blood components is typically readily available in the modern trauma center. Typically, massive transfusion protocols in these hospitals are capable of delivering several units of type specific blood products to the trauma team for their resuscitative efforts in the ER and OR. Second the potential for blood borne disease transmission, although the rate of blood borne diseases using current blood banking techniques is incredibly low. It would be difficult to persuade any health care practitioner to stray from what has proven to be a very safe blood banking and administration program to use FWB during traumatic resuscitation. Finally, the ability to get fresh whole blood would mean having individuals within the community be on call to have blood taken from them for use 24 hours a day. Not to mention the periodic testing for blood borne diseases. In the military, nearly everyone knows their blood type, it is on their dog tags (although it is WRONG about 4-10% of the time), all service members are tested for blood borne diseases, in fact a soldier restricted from deploying if HIV positive, in part because of the use of FWB in theater. Troops are immunized by regulation, for hepatitis A and B. The FWB donation program takes advantage of these facts as well as the fact that all these soldiers are in immediate proximity to the blood donation site. To initiate the process an announcement brings these selfless soldiers to give their blood to help save a life, they do not know if it is an American or a foreign national fighting alongside Americans, or an enemy combatant, but they come to donate. The process of getting the first unit of blood to the patient often begins long before the causality hits the FST doors. The process of organizing the "walking blood bank" is often the responsibility of the laboratory personnel assigned to the medical support entities co-located with the FST or the FST itself when functioning independently. Along with the task of organizing the blood bank when blood is needed, these responsible individuals coordinate the prescreening of a pool of donors. These individuals have blood drawn and sent for testing. These samples are first used to establish ABO type. Because the FWB contains all components it needs to be type specific, no universal donor is available for whole blood. Potential donors are tested for H/H, HIV, Hep B, Hep C, malaria, and RPR for syphilis. They are also questioned about personal activities that potentially place them at risk. These individuals are then entered into a database along with test results. In an event of blood bank activation, these individuals are used first to reduce the risk to the recipient. When these individuals are exhausted un-screened soldiers are put through the process of screening on site and blood is drawn and tested using rapid-result type testing. The same labs are sent out to FDA approved laboratories for testing, results of these tests are obviously not used in the emergent determination of donor eligibility but are used to verify rapid tests and if a positive result is found then appropriate testing and treatment are conducted on the donor. The pre-screed donors are also re-tested using the rapid result tests to verify safety. Unless the patient is in extremis, the results of communicable diseases are usually verified before the blood is used. The plan is rehearsed to minimize the potential for clerical errors well known to be the most common cause of ABO incompatibility. If two different blood types are being drawn, if possible, two completely separate teams should be used to minimize contamination. Assuming all has gone well, a 450-milliliter bag of fresh whole blood is delivered to the resuscitation area. These units can be kept at room temperature for 8 hours and refrigerated for 24 hours [22].

In battlefield medicine patient movement using available aeromedical assets plays significantly in the life saving capabilities of every level of care within the battle space. Conforming to NATO nomenclature, these levels of care are referred to as roles. Role I is the most basic of care, point of injury care or care at a battalion aid station where limited treatment and triage of patients can occur. These aid stations are manned by physicians and/or physician assistants and combat medics. The role II medical company can provide basic and advanced emergency treatment, they have blood, lab support, X-ray and other medical assets including dental, PT, OT, combat stress: depending on configuration. They also have some patient holding capacity with or without critical care support. In the modern battlefield setting these units are frequently "pulsed up" with a forward surgical team making them role II+. They are co-located in the same area [1].This adds the element of damage control surgery. These groups have a very synergistic effect on each other and together these teams are the foundation of far forward surgical care for those too unstable to transport further. Role III care is everything role II+ and more. An example is a combat support hospital. These are 248 bed field hospitals with most of the amenities of a modern hospital. These hospitals can provide damage control surgery and definitive surgical treatment. They typically have an array of surgical specialties including neuro, vascular and thoracic surgery along with orthopedic and general/trauma surgical services. Role VI hospitals are a full spectrum hospital, providing all services of a modern hospital. These facilities are fixed hospitals typically located outside of the area of active conflict. Between every level of care, there is a necessary aeromedical asset. Nearly the same time the call comes in reporting casualties are enroute to any role 1-3 facility, the simultaneous plan is concurrently being developed to get the patient moved to the next level. This movement almost always involves air movement. Exceptions to this would are typically a result of poor visibility, dangerous tactical conditions, or inadequate availability of air assets. In these situations, ground vehicles are sometimes used, some are specialized patient moving vehicles and sometimes they are the fighting vehicles with a medic on board. Like the escalating rolls of care described earlier, there are escalating rolls of care in aeromedical evacuation. These are described as Causality evacuation (CASEVAC) where a non-medical aircraft or vehicle is used. Typically, minimal, or no medical care is given with this type of evacuation. Next is medical evacuation (MEDEVAC) where specially trained medics and nurses can provide minimal emergency resuscitative care, typically in specially equipped helicopters. Finally, the highest level of care within the battle space is Aeromedical Evacuation (AE). At this level specialty teams of technicians, medics, nurses, and physicians can provide critical care transportation in highly modified aircraft. These are usually specially equipped fixed wing airplanes. Before transporting patients by any means, the patient must be appropriately prepared for the trip. Transport of patients out of the theater is done by strategic evacuation and in the cases of high acuity patients, are accompanied by a US Air Force Critical Care Air Transport team (CCATT). There are of course circumstances where the ability to stabilize the patient requires that the patient be taken to the next level of care. However, typically the patient must be in a stable state prior to transfer; this luxury of a relatively stable patient frequently happens at the roll II or II+ facility and higher. Stabilization from the battlefield many times is nothing but a tourniquet providing life sustaining hemostasis until the patient can reach surgical treatment. That said, preparing a patient for transfer from a role II or higher has to consider several aspects of patient injury and treatment. Once in a role II+ hospital (or higher) the team resuscitates the patient, provides damage control surgical intervention as necessary and will hold the patient in the intensive care area to continue the resuscitative efforts until the patient is stable enough for transfer. There are recommended clinical parameters that should be met prior to arranging for transfer out. These parameters include stable vital signs, and laboratory values. HR <120, SBP >90 HCT >24, pH >7.3 and temperature of >35C are some of the goals that should be reached before moving patients. Once the patient achieves a relatively stable state the patient can be prepared for air travel. When thinking about transferring a patient by air we must think about a few gas laws (do not worry, no calculators needed, just concepts) [23].

As we know, according to Boyle's law, in when the pressure of a gas decreases the volume of that gas increases [24]. Per Dalton's law when atmospheric pressure decreases the partial pressure of oxygen also decreases; these concepts are important when transferring a patient via air [25]. A gas bubble in liquid will double in size at 18,000 feet above sea level; so, things like a small pneumothorax that could be "observed" on land needs to have a chest tube placed in it before taking a patient to altitude or it may turn into a catastrophic event in the air. Endotracheal tube cuffs are filled with saline, and air is removed from IV bags. Patients stable on room air may need oxygen support because of a decrease in the partial pressure of oxygen. These are of a few of the considerations that have to be taken simply because of the reduction in atmospheric pressure. Additionally, there is a reduced threshold for intubating and sedating and even paralyzing patients for safety of the crew and the patient. Conventional observation and evaluation of the patient is impossible in an aircraft because of noise, vibration, and the confined space of the aircraft. The patient will experience wide swings in temperature. Part of the lethal triad of trauma is hypothermia, so the patients are always wrapped. Specialized blankets that wrap around the patient with chemical heating devices in them are available and frequently used in transport. These devices are designed to make access to the patient and to accommodate lines and tubes coming from the patient. The patient will also be exposed to loud noise. Ear plugs are placed, and eye protection is placed on all patients traveling via rotary wing aircraft. Changes in acceleration typically do not create any major concerns for the patient, however in patients with elevated intracranial pressure the patients are placed with the head toward the nose or large swings in ICP can occur with takeoff and flight (usually there is a slight nose up attitude of a fixed wing aircraft). Adjustments to ventilators and other monitoring equipment are necessary when at altitude. These are just a few of the considerations taken when transferring the critically ill via aircraft [23].

Despite the austere environment, battlefield trauma care is at the forefront of trauma care. The systems in place on the battlefield starting with the highly skilled combat medic caring for his injured friends and fellow soldiers, to the medics, nurses, CRNA and physicians in the role IV hospital have saved countless lives. The remarkable efforts of the soldiers on the battlefield are echoed by the remarkable efforts of the healthcare providers, at all levels, preserving the fighting force. Nurse Anesthesia has been and will continue to be at the leading edge of combat anesthesia.

Additional Information and Recommendations of Combat Trauma Recommendations
Early Recognition for Massive Transfusion and implement to program.
Keep INR less than 1.4 and keep tissue saturation greater than 92%
Prevent dilution of clotting factors.
Use whole blood if available. If FDA ever approves this.
Use component therapy at a ratio of 1:1:1, prevent coagulation problems prior to getting into trouble.
Use the freshest packed red blood cells to minimize the deleterious effects of the storage lesion inherent in stored PRBC
Limit crystalloids to a minimum and allow permissive hypotension with the exception of CNS trauma. Goal SPB to approx. 90 mmHg. This will help prevent clot disruption.
Give platelets early
Thawed FFP should be AB positive (universal donor), can be A positive if out of AB positive. Make type specific if at all possible.

Further Considerations: The use of Cryoprecipitate?
Current laboratory options for the FST do not include monitoring fibrinogen levels so a calculated experienced based decision for the transfusion of cryoprecipitate needs to be made. Cryoprecipitate which is a concentration of factors II (fibrinogen) VIII, XIII and von Willebrand factor. The use of cryoprecipitate can be justified because the deficiency of fibrinogen occurs earlier that other clotting factors and may go unnoticed in the trauma patient. An experience-based decision must be made and should be made by the anesthesia provider.
In closing, the principle of advanced damage-controlled surgery and advances in anesthesia principles have provided for better outcomes of the soldier in surgery. We advocate embracing in the civilian trauma protocols these principles.

Combat Application Tourniquet
http://combattourniquet.com/: "The Combat Application Tourniquet® (C-A-T®) is a small and lightweight one-handed tourniquet that completely occludes arterial blood flow in an extremity. The C-A-T® uses a Self-Adhering Band and a Friction Adaptor Buckle to fit a wide range of extremities combined with a one-handed windlass system. The windlass uses a free moving internal band to provide true circumferential pressure to an extremity. The windlass is then locked in place; this requires only one hand, with the Windlass Clip™. The C-A-T® also has a Hook-and-Loop Windlass Strap™ for further securing of the windlass during patient transport".

Combat Gauze
www.combatgauze.com: "QuikClot® Combat Gauze™ is a soft, white, sterile, nonwoven 3" by 4 yds rolled gauze impregnated with kaolin, an inert mineral that does not contain animal or human proteins or botanicals. Each roll of QuikClot Combat Gauze is individually wrapped in an easy rip, military grade foil pouch. Indicated for temporary external control of traumatic bleeding, QuikClot Combat Gauze is flexible and pliable and contours to all wounds. Recommended as the number one hemostatic agent by the COTCCC (Committee on Tactical Combat Casualty Care Committee), QuikClot Combat Gauze is the only product carried by all branches of the US Military to control life-threatening hemorrhage".

NAR S-Rolled Gauze
North American Rescue; www.NARescue.com; "North American Rescue's S-Rolled Gauze is the ideal solution for a compact, easy to use, cotton s-rolled gauze designed for both linear wound packing and basic bandaging. Made of high-quality U.S. cotton and Berry Amendment compliant, NAR's S-Rolled Gauze can be used to control hemorrhage in conjunction with a compression bandage, used as backing gauze for hemostatic dressings or for minor wound bandaging. The S-Rolled Gauze is packaged in a unique dispenser that allows for controlled application and protects unused portions from contamination during application. Its low cube space requirement and rugged, durable vacuum sealed packaging make it easy to fit in both individual first aid kits and medic kits".

Trauma Wound Dressing
First Care Products: "The Bandage Kit, Elastic" is also called the "trauma bandage", "emergency bandage", the "Israeli bandage", or the "Israeli pressure dressing". It replaces the standard battle dressing issued for decades in the first aid pouch. The main purpose of the trauma bandage is to serve as a pressure dressing. It can also be used to provide a tourniquet-like effect to slow blood circulation, though soldiers should use a Combat Application Tourniquet (CAT) as first choice if a tourniquet is needed. The trauma bandage is available to every service member as a component of the Improved First Aid Kit (IFAK) and the Combat Lifesavers Bag".

NAR Saline Lock Kit
North American Rescue: www.NARescue.com: "Allowing for quick and effective extremity venous cannulation under the most demanding conditions, our system for starting and securing a saline lock has proven reliable and extremely effective during casualty treatment and evacuation where it is common for saline locks and IV lines to become dislodged. Using the NAR RAPTOR™ IV Securing Device (also available separately in a pack of 6), the NAR Saline Lock Kit can be secured in place without the need for tape. The Kit is low-cubed packaged in a vacuum-sealed, rugged pouch, keeping the contents of the kit in prime condition until needed".

Dosage Selection
The authors have made every effort to ensure the accuracy of dosages cited herein. However, this field of trauma resuscitation is changing as more research is being completed with the end of the wars in Iraq and Afghanistan. It is the responsibility of every practitioner to consult appropriate information and sources to ascertain correct dosages and current information for each situation. This is especially important for any unfamiliar drugs, information or protocols and procedures. The authors cannot be held responsible for this changing field of study.

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