Damage Control Resuscitation for the Special Forces Medic — Simplifying and Improving Prolonged Trauma Care Part Two

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Abstract

Present and future Special Forces missions will require prolonged care of the trauma patient. The Special Forces Medic and Independent Duty Corpsman must be prepared to deal with these situations in the most challenging and austere environments. The implementation of damage control resuscitation for prolonged trauma care can maximize results with minimal support while preventing death, priming the patient for surgical success, and expediting recovery. Establishing this model of care and equipping medics with the essential equipment will have a lasting effect on the survival rate of our casualties, and negate the enemy's political victories when American and allied lives are lost.

Damage control resuscitation (DCR) is a proven and successful model of care that has contributed to saving innumerable lives. The principles of hemostatic and hypovolemic resuscitation combined with an understanding of the "trauma triad" of hypothermia, acidosis, and presenting coagulapathy are the basis of success or failure in a trauma patient, and are instrumental in preparing them for surgical success (Figure 1). The success of damage control resuscitation and its widespread implementation as a therapeutic procedure has established it as a standard of care in both the civilian and military arenas internationally.[1] The Institute of Surgical Research Joint Theater Trauma System Clinical Practice Guidelines (JTTC) has implemented DCR protocols since 2004 with documented success.[2] This model of care has also been adopted by numerous nongovernmental organizations (NGOs) such as Doctors Without Borders and the International Committee of the Red Cross, being implemented in the most remote and primitive places of the world (Figure 2).[3] Since the care of NGOs closely mirrors many of our own Special Operations Forces (SOF) medical requirements, their application is not unlike our own.

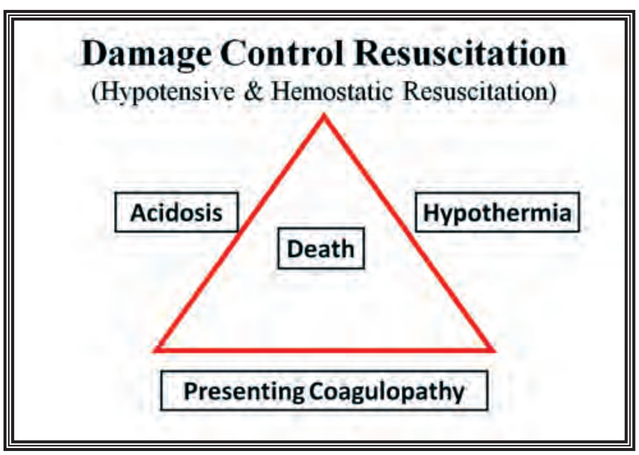

Figure 1:*The lethal triad easily visualized. (attributed to Colonel John Holcomb)*

Figure 2: *An ICRC medical team working in the austere environment of Sudan. (courtesy of CICR/HEGER, Boris)*

Shock is the absence of adequate perfusion of blood to the tissues causing anaerobic metabolism and thereby increasing acidosis with by-products (see Part One in *JSOM* Summer 09 Vol 9, Ed 3). Shock results in an unbalanced and unnatural physiologic state and impedes the body's ability to survive and recover from traumatic wounds. Depending on the amount of blood lost, the body will move into one of several defined levels of shock (Figure 3). Compensation to save the vital organs occurs naturally in the face of blood loss to ensure survival, but not without harmful results. The harm to the vital organs is compounded by the duration the body has to sustain them (in the face of shock) and at what level of compensation is required. Decompensated shock is the most severe, the least reversible, and is extremely difficult to survive in austere environments. Rapid reversal of the effects of shock will shorten recovery time, prepare the patient for more definitive interventions outside our scope of practice, and increase survivability. The actions required to achieve this are the basis of protocol for damage control resuscitation. The overall goal is to return the patient to global homeostasis and thereby reduce the depth and duration of shock. Resuscitation is complete when the oxygen debt has been paid, tissue acidosis eliminated, and aerobic metabolism restored.[4]

	Blood Loss	HR	B/P	RR	Urine Output
Stage I	<750ml	<100	Normal	14-20	>30 ml/Hr
Stage II	750-1500ml	100-120	Normal	20-30	20-30 ml/Hr
Stage III	1500-2000ml	120-140	Decreased	30-40	5-15 ml/Hr
Stage IV	>2000ml	>140	Decreased	>35	Negligible

Figure 3: *Historical and referenced levels of shock as taught by the Advance Trauma Life Support Program.*

More specifically, the SF medic and Independent Duty Corpsman (SOIDC) should be able to predict and negate decompensated shock, minimize the time of compensated shock, and prepare the patient for surgery and advanced care with the ultimate goal being to decrease morbidity and mortality. New requirements exist with this effort; unfamiliar lab values and equipment to obtain them are essential as advanced diagnostics such as base deficit and serum lactate, and trending results from identified endpoints are important for care and their recording is crucial. These markers can be addressed individually, but for an enhanced understanding we will discuss their role in the trauma triad for better interpretation and implementation as medics. Treatment decisions should be based on evidence-based medicine, justified with appropriate findings.

The most significant benefit to DCR is its ability to provide efficient care with minimal assets, which meets a classic requirement for the SF medic in the austere environment. The profiles of SOF independent operations do not lend themselves to doctrinal levels of care or guaranteed tactical evacuation (TACEVAC) capabilities and therefore cannot be relied on. Future requirements to maintain a lower profile while meeting national goals in the overseas operations will bring additional medical challenges to deployed teams. In order to make best possible use of the "knife to skin time" before casualties reach surgical assets, a proactive and goal oriented model is needed to provide us success under the worst conditions.

SF medics should also appreciate that in line with DCR, conventionally defined prehospital care should now be viewed as ***presurgical care*** and thus, should drive their actions accordingly. Many combat casualties will undergo some level of surgical intervention during their care. It could be anything from debridement, exploration, or reconstruction, to massive damage control surgery. The goal in this respect is to prepare patients both physiologically and hemodynamically to optimize the results of extensive damage control of the unstable patient or multi system trauma.[5] The resuscitation of the patient by SF medics may be the foundation of emergency room and operating room success. Damage control resuscitation is not a separate level of care, but completely integrated. The key to the principles for this approach is that the SF medic must fully appreciate hospital requirements and step away from a 'prehospital' mentality. Without doctrinal levels of care the SF medic must integrate the phases of care, and appreciate that DCR is an integrated model throughout (Figure 4).

Figure 4: *SF medics use Damage Control Resuscitation in a prolonged care exercise.*

The author's intent in Part II is to provide a start point for the establishment of an improved and simplified method of resuscitation based on damage control. We will also provide some initial considerations for endpoints in resuscitation that are safe, reliable, proven, response oriented, and can be based on both objective findings and point of care testing (POCT). These endpoints are established and can be measured independently or in conjunction with each other for greater confidence, and always in combination with the physical exam.

These endpoints may require new proficiencies for SF medics and IDCs in prolonged trauma care, and identify the necessary equipment to provide that. These components are derived from the lessons learned since 9/11 and already exist in modalities of care presently in use and are dependent on simple treatment factors that can be trained and sustained to a high level. They may be used judiciously with or without labs while still being advantageous to the patient. We can now combine them to optimize prolonged care for the trauma patient.

Measuring Shock

We must first appreciate that any therapy is significantly impacted by the austere environment. Logistical challenges, limited or interrupted power, lack of refrigeration, and working with indigenous personnel and patients, all present challenges to the effective delivery of care. The goal is to achieve hospital quality care as far forward as possible with measurements providing tangible endpoints in resuscitation such as seen in the U.S. Advanced diagnostics are critical, and those identified endpoints, in whatever form or function, should be proven to have significant prognostic importance.[6] There may also be times where empiric treatments may be the only recourse. This is better accomplished with a thorough understanding of the traumatic shock state.

Patient history, mechanism of injury, and a detailed physical exam are the hallmarks to success and constitute the primary assessment. Patient presentation and especially the secondary survey will provide essential decision-making tools that are needed. The secondary survey may have lost some function as an evaluation tool in today's fast paced battlefield, but it still plays a significant role in prolonged care. A detailed and thorough inspection of the patient is crucial in ensuring knowledge of the challenges and providing a baseline status. This combined with a thorough history of the patient and mechanism of injury, blood loss, and initial treatments will begin to draw the picture needed for subsequent treatments.

Historically, vital signs including blood pressure, pulse, and respirations, have been important in obtaining a physiological status of the patient, and serve as good predictors for life saving interventions (LSIs).[7] Examples essential to initial point of injury assessment are a blood pressure of 90mmHg, or a radial pulse, and mentation which can be used to immediately evaluate the current status of the patient. However, in the SOF population of healthy young adults, these findings can misrepresent the actual physiological status of the patient due to this population's excellent ability to compensate for shock. Vital signs can remain normal while staying in compensated shock.[8] In fact, a young, well conditioned patient will compensate for severe injuries and blood loss with vasoconstriction, shunting, and markedly increased cardiac output for more prolonged periods than older or more sedentary patients are capable of. Only when the patient "falls off the cliff" into decompensated shock, will these findings change enough to initiate required treatments, and by that time interventions may be too late and ineffective to change outcomes.

Advanced diagnostics are essential to improving the level of field care by providing medics with essential data. The equipment to support point of care testing would include devices not currently included in the current TacSet. Requirements for the equipment are as follows:

- Durable
- Fast
- Reliable
- Meets or exceed the specific measurements desired
- Minimal amount of logistical support as possible; i.e., temperature stability, long duration calibration, and minimal power requirements.

Venous blood sampling should serve as the basis of measurement since the attainment of arterial blood measurement is an advanced and perishable skill. Products for point of care testing such as the iSTAT® 1 lab analyzer have provided diagnostic lab values to government agencies, expedition missions, and nongovernmental organizations for years. They may provide medics options for less invasive and more expedient means of obtaining lab values. These measurements will provide the ability to obtain and measure predictive endpoints for evidence-based treatments and evacuations and increase the medic's ability to make sound treatment decisions.

Cellular Effects of Shock

The goal of DCR is to optimize the patient's physiologic state in preparation for definitive care. This focuses on hemorrhage control and the preservation of coagulation factors to prevent the onset of true shock. Shock is defined as the decrease or interruption of adequate tissue perfusion, resulting in lack of adequate oxygen delivery at the cellular level. This leads the cell to undergo rapid conversion from aerobic metabolism generating adenosine triphosphate (ATP), the "cellular energy currency," to anaerobic glycolysis using intracellular glycogen which is approximately 90% less efficient. The hypoxic cell produces pyruvate, but rather than being fed into the Krebs cycle for further oxidative metabolism, it is converted to lactate instead. The accumulation of lactic acid inside the cell, decrease in intracellular pH, and depletion of ATP leads to profound physiologic and structural changes in the cell. The accumulation of toxic byproducts and the reduction in ATP eventually causes the cell wall to lose integrity. As a result, sodium ions begin to leak into the cell along with free water causing cellular swelling or edema. Potassium leaches out to the extracellular space, along with lactate. Depending on the depth and duration of shock, theses disturbances are initially reversible, though with time they become irreversible. Ultimately, cellular death occurs. Understanding shock at the cellular level is essential for appreciating the effects in vivo and potential treatments. It is the ongoing cellular death, which if uncorrected reaches a critical mass and leads to organ dysfunction, massive inflammatory activation, and development of organ failure. This leads to multiple organ dysfunction syndrome (MODS). The ability to appreciate the depth of this shock will be utilized to guide therapy, and to hopefully interrupt this process while still reversible. The ultimate goal to prevent, mitigate, or reverse the effects of this process on coagulation, acidosis, and hypothermia

Oxygen Debt

The concept of oxygen debt was first postulated by Cromwell in 1961.[9] It is the difference between the amount of oxygen delivered to the cells, and the amount required for metabolic needs. This debt must eventually be "repaid" during reperfusion if normal homeostasis is to be restored. The magnitude of oxygen debt correlates with depth and duration of hypoperfusion. This correlates well in both animal and human studies in predicting survival, survival with organ damage, and death.[10, 11] A reasonable analogy for this phenomenon would be that of an underwater diver, who can calculate his risk and nitrogen load by looking at the depth of a dive and the duration of bottom time. The deeper he dives, the less time that can be spent on the bottom, the longer the ascent, and the larger the nitrogen burden. In other words; the deeper the diver goes, the longer and more difficult it is for him to return. As with diving, shock is more dangerous if allowed to progress to a severe depth and if compensation is allowed to continue for too long without restoring perfusion and repaying the oxygen debt. While the total mismatch in oxygen delivery has been measured in animal models, calculating the actual mismatch between oxygen delivery (DO_2) and oxygen consumptions (VO_2) is not practical in trauma patients. There are physiological markers of oxygen debt which have been well studied, and correlate with a high degree of accuracy to the amount of oxygen debt. These can be used to measure the degree of shock, guide therapy, interventions, and predict mortality. These endpoints of resuscitation are considerably more useful than external measures of pulse, blood pressure, and urine output traditionally used in the past to guide field care. In keeping with the new paradigm of DCR, and thinking of this as presurgical care it is necessary to more accurately guide our therapies and correct physiological disturbances with greater speed and accuracy.

Endpoints of Resuscitation

Various biochemical markers or measurements have been proven to accurately reflect the amount of hemorrhage, depth of shock, and degree of oxygen debt. These also correlate well with development of organ failure, MODS, and mortality. As such, they can be used to establish initial baseline for our patients, develop trends, and act as triggers for decisions and interventions. These measures can include clinical parameters such as heart rate, blood pressure, and urine output, but all of these can significantly lag behind the development of shock in the compensated patient, and all can be normalized well before resuscitation in complete. In over 85% of patients resuscitated from hemorrhagic shock, the traditional markers can be normalized well before patients are fully resuscitated.[12] This state of compensated shock carries significant morbidity and mortality. More technical methods of measurements include cardiac output, pulmonary capillary wedge pressure, oxygen delivery and consumption, gastric tonometry, near infrared spectroscopy (NIRS), pH, serum lactate, and base (deficit) excess (BE). We will focus on the last three, as the others involve invasive procedures, complicated monitoring, or are still experimental/exploratory technologies which are less well established. Lactate, pH, and base deficit can all be measured using venous whole blood sampling and relatively simple handheld diagnostic tools.

Arterial pH has long been used to assess patients for presence of respiratory/metabolic acidosis/alkalosis. There is only a narrow physiologic range of intracellular pH which allows for normal function, typically 7.35-7.45. Acidosis below this range inhibits the proteases which govern the coagulation pathways, and inhibit the generation of thrombin, which is the final common pathway in converting fibrinogen to fibrin monomers. This delays the formation of a thrombus at the site of bleeding. While arterial or vascular pH has a place in the evaluation, without full blood gas analysis, the body's compensation mechanisms such as a respiratory alkalosis may maintain a normal or near normal pH even in the setting of significant shock and metabolic acidosis. Another challenge for the medic is the deceptively small changes in the pH scale, which is logarithmic. Hence, a pH change from 7.4 to 7.1 may seem minor, but actually represents a significant increase in free hydrogen ions. Each decrease of 1.0 on the pH scale represents another ten-fold increase in hydrogen ions free in the circulation. Factor VIIa has only 10% of its biological activity at this 7.1, which becomes one rationale for treating potential acidosis if contemplating administering Factor VII. One finds similar alterations in nearly all physiological processes at acidotic pH ranges below 7.3.

The measurement of serum lactate is a more direct measure of levels of tissue hypoperfusion, being the direct metabolic product of anaerobic metabolism, along with hydrogen ions. The two combine to form lactic acid in the extracellular fluid. Lactate is generated primarily as an intracellular byproduct of anaerobic metabolism. As such, its elevation in the serum only becomes evident as once these level reach a critical mass, cell membrane integrity is compromised, or most worrisome, significant cellular death begins to occur. Multiple studies have all demonstrated that initial and peak lactate levels correlate with likelihood of developing MODS.[13] Other studies show a very strong correlation between the time required to clear serum lactate levels and survival. All patients who were treated and their serum lactate levels were normalized at 24 hours survived. Those patients who normalized their serum lactate levels between 24 and 48 hours had a 25% mortality, and those whose lactate levels were persistently elevated beyond 48 hours had an 86% mortality rate.[14]

Base deficit may well represent the most reliable, predictive, well studied, and utilized measure of the shock state. Before going further, realize that while we discuss base deficit, the measure is actually written as base excess, abbreviated as BE. This represents the amount of a strong acid or base which would be required to correct a metabolic derangement. When the number is positive, it represents an excess of base within the body, and hence an alkalotic state. Conversely, when we are dealing with negative BE values, we refer to them as base deficit values inferring a lack of base in the system, or predominance of acids. In the setting of trauma this is primarily a metabolic acidosis due to the previously discussed disturbances. Base deficit then becomes a true measure of the degree and depth of the shock state. Normal ranges for BE are 0 +/- 2. Base deficits >6 (-6) were predictive of need for blood transfusion in one study.[15] Another study found that a base deficit of 15 (-15) was predictive of a 25% mortality in trauma patients less than 55 years old. Various data from other studies would indicate an LD^{50} (the dose or measure of something which represents a lethal dose to fifty percent of the study population) of base deficit at -19. With this information, we can begin to risk stratify the shock patient, make decisions about initiating treatments to interrupt deterioration of patients, tailor interventions, and guide resuscitation.

One issue which arises in any discussion is which of these endpoints of resuscitation is most ideal for our use. It is better to develop a foundation of knowledge and utilize multiple parameters as part of a larger picture of assessing and treating this group of patients. The goal will be to look at how in the DCR paradigm to aggressively treat ongoing hemorrhage, and to consider administration of blood to the patient in ongoing shock.

Fluid Resuscitation

The last point in this theory of care is fluid resuscitation. The choice, routes, and concerns with resuscitation fluids have undergone significant changes in just the past several years. Favor now falls to plasma and blood as the fluid of choice for combat trauma and in support of hypotensive and hypovolemic resuscitation. Colloids and/or hypertonic saline work as temporizing agents, and therefore might be considered second line agents, or as initial agents while preparing for the administration of blood products. These also seem to cause less cerebral edema in blast type injuries when compared to crystalloids. The ongoing use of normal saline (NS) and lactated Ringer's (LR) on the battlefield in tactical combat casualty care is increasingly being called into question. It is time to realize that by replacing lost blood with various salt water solutions, we are contributing little if anything to the resuscitation of the patient, and may well be causing significant harm. Much like filling an empty gas tank with water raises a car's fuel gauge, it contributes nothing constructive and is ultimately damaging to the engine. Resuscitation stretching beyond initial tactical field care will need to consider how to replace lost blood products, namely plasma, platelets, and red blood cells in an earlier time frame and by methods that are not currently in routine practice. When used properly these blood products provide the greatest therapeutic effect in the smallest amounts with the least potential for side-effects. Intraosseous access has proven to be an effective route providing simple, fast, and durable access throughout the many stages of care. It supports any type of fluid infusion and can remain in site for up to 24 hours. If time and situation permit, consider peripheral IV access. Again, if possible, warm all fluids to prevent hypothermia instead of contributing to it.

Hypotensive resuscitation goes hand-in-hand with hemostatic resuscitation as a key intervention in DCR. Although the premise for a lowered pulse pressure comes from trauma, an immediate and complete return to normal vital signs will do more harm than good. An increased blood pressure, no matter how obtained, can potentially dislodge fragile clots and reduce the normal thrombotic process. By maintaining a lower blood pressure in trauma patients we are setting physiological conditions for a more efficient clotting process.

A systolic blood pressure of 90mmHg is the goal for combat applications.[16] A palpable pulse and mentation can serve as a very accurate triage tool for a quick and immediate evaluation, especially in a mass casualty situation. If the patient has a palpable radial pulse and can lift his hand to command then he is stable enough for you to move on and return to later.

The fluid of choice for damage control and active hemorrhage are natural blood products, most specifically fresh whole blood (FWB). Whole blood serves

SF medics as the best force multiplier for massive hemorrhage providing the greatest amount of good in the smallest package and is independently associated with improved 48 hour and 30 day survival.[17] A unit of FWB has an all encompassing contribution of clotting factors, natural acid/base balance, and red blood cells to support efforts against the lethal triad. A single unit (+/- 500ml) is reported to have a hematocrit of 38% to 50%, a platelet count of 150,000 to 400, complete coagulation function, and 1500mg of fibrinogen.[18] Whole blood provides the best all around impact and while it stands solely as a military practice, it is still one with widespread acclaim and applicability.[19] "Walking blood banks" in the form of your own teammates may provide a safe, typed, warm, fresh, and relatively resupplied blood reserve at any given time. This represents a return to WWII practice, prior to the routine separation of blood into various components. This is reflected in the current theater practice of transfusing products in near 1:1 ratios during massive blood transfusions, with improved results compared to the prior practice of initiating FFP/cryoprecipitate only after a threshold of eight to ten units of packed red blood cells had been administered.[20] Whole blood comes conveniently packaged in the appropriate physiological rations, and requires no thawing or warming. The risks of uncrossmatched type specific blood are minimal when the goal is saving lives under austere conditions. While often discouraged in the past, blood transfusion work should be a standard that all SF medics are proficient in, as one required in prolonged care, and in the face of massive hemorrhage. Blood transfusions at the lowest level are not a new concept, and even unscreened blood transfusions may be a venture worth considering in extreme life saving measures. These are skills that SOF medics must know and sustain for confidence in employment. Their use also provides tools that far outweigh the risks once that expertise is attained.

Fresh frozen plasma (FFP) is presently the most employed blood product in theater hospitals overseas with exceptional and well documented results.[21] Plasma is spun from whole blood. While it has no oxygen carrying capability, it still retains all coagulation factors in normal concentrations. Frozen plasma has a shelf life of 180+/- days, but once thawed in a recirculating warm water bath it must be continuously refrigerated at 39ºF (4ºC) and only has a shelf life of five days. FFP also has a completely different cross matching matrix, so appropriate transfusion protocols must be educated and rehearsed. Although it is possible for SF medics to store FFP in their environment, acquisition would have to come from hospital blood banks since there is no practical capability to separate and package it in isolated area. Plasma could always be considered as an adjunct for prolonged care if storage and supply are possible, but in the most austere locations it is far less feasible. The efforts to overcome the limitations of FFP in storage, volumes needed, and mobility would be better served with more efficient options. In the clinical setting, hospitals also institute a blood component therapy in their trauma protocols whereby packed red blood cells (PRBCs), platelets, and cryoprecipitate are given individually and in ratios according to accepted parameters. But as with plasma, this approach also requires significant logistical support and again is not likely appropriate in our environments.

Colloids, in the form of synthetic starches, provide a valid alternative choice for SOF with far less logistical requirements. Hextend® presently serves as the colloid of choice primarily due to its physiologic comparability to our blood as compared to Hespan®. Drawing free fluid into the vasculature increases volume and for a longer duration; however, immediate effects may be no better than crystalloids. Hextend can also be combined with drugs, used to maintain a line TKO, or followed by blood or blood components taking the place of crystalloids and allowing the SF medic to simplify supplies. Remember that there is a ceiling to resuscitation with the amount of Hextend. Present recommendations quote only a 20ml/kg dose, or approximately one liter per patient before the amount can adversely affect the clotting process.[22]

Crystalloids do have a long history in trauma, but research and findings since 9/11, in both the civilian trauma and military sectors, have advocated a departure from their use as they can worsen the physiological response to damage.[23] Lactated Ringers and 0.9% sodium chloride have long been the universal answers for hemorrhagic resuscitation, electrolyte replenishment, hydration, and burn therapy. However, due to the significant amount of data being obtained overseas and in concurrent studies we now know that these favorites play a part in additional damage to the trauma patient. Both solutions are supraphysiologic providing a higher content of chloride than what naturally exists in blood values; NS is labeled with a pH range of 4.5-7.0, and LR has pH levels of 6.0-7.5 making them both acidic. It is now recognized that both NS and LR (although LR less so), can increase metabolic acidosis producing detrimental effects if not used sparingly and proper indications. Excessive use of crystalloids also hemodilutes blood affecting coagulation by lowering the concentration of clotting factors, and decreasing oxygen delivery due to a diluted hematocrit. Although crystalloids are not contraindicated in DCR, their usefulness should be judged on a minimalist approach.

Other Critical Skills

Advanced surgical techniques such as fasciotomies, escharotomies, and tube thoracostomies are also essential to decrease threats to mortality and morbidity, but also to undermine the unknowns of casualty transport affecting patient status. Again, these advanced procedures must be sustained over the long term, and the inclusion of training and reference materials must be provided to SF medics to support success.

Tube thoracostomies provide definitive care and are the treatment of choice for legitimate indications. They can be diagnostic and negate repeated needle decompressions in evacuation and care. This procedure must be done correctly, as aseptically as possible, and must be secured and reinforced to survive the rigors of combat transport. Antibiotic therapy should be administered before the procedure. Combat AB prophylaxis should cover this concern.[24] Nursing care and documentation of any fluids lost will provide critical diagnostic information both for the SF medic and later care. Newer products on the market may provide other options far forward such as the Uresil Tru-Close® Thoracic Vent or the Cook Emergency Pneumothorax Set®. Both are based on a continuous needle decompression theory. Remember that these choices have other risks such as kinking of their catheters, difficulty in securing the devices, less definitive than a chest tube, and possible unfamiliarity with their use. Complete management of a pnuemo or hemothorax is a SF/SOIDC level skill; however, it must be consistent to ensure the quality of care.

Fasciotomies treating compartment syndrome in prevention of morbidity of extremities is a valid and proven treatment.[25] There is a significant threat pattern when considering the destructive results of IED tactics presently used most frequently by the enemy. The consequences of those explosive and overpressure effects provide a high incidence of occurrence, and thus should rate a high index of suspicion for compartment syndrome. This procedure can also again be done empirically to minimize the chance of unrecognized or untreated compartment syndrome during evacuation by unknown or less-trained personnel. Fasciotomies can also assist medics with possible secondary effects of overextended tourniquet use and the prospect of our management of this condition in prolonged care.

Analgesia

One of the challenges for presurgical care in DCR lasting 24 to 72 hours will be the issue of pain management. Besides the impulse to provide humane care and appropriate analgesia to our patients, our ability to perform necessary procedures such as wound care and debridement will be inhibited without appropriate sedation and analgesia. Additionally, there is mounting evidence that the immune system and wound healing are both impaired by ongoing pain, release of catecholamines, and inflammatory mediators.

While a complete overview of pain management is beyond the scope of this article, pain management for the treatment period will require a different approach than that at the point of injury, which relies primarily on parenteral narcotic administration. The issues with giving prn pain medications over multiple days leads to inevitable peaks and troughs, requires considerable time and attention of the medic, and requires considerable logistics. Administering 2-4mg of morphine every1-2 hours to one patient for several days would require multiple vials, with a potential total of several hundred milligrams. A better model for pain management over a prolonged period would be to consider the use of transdermal medications. This route allows for more consistent delivery of dosages, a steady state of pain control, and requires less time and attention on the part of the medic. Additionally, some transdermal patches are available in three day dosages, thereby requiring less weight and cube than the injectable forms, and limit potential for abuse. This allows injectables to be conserved for use on breakthrough pain.

Other concepts to be reconsidered are the use of nerve blocks for extremity injuries, fracture care, procedures, and wound care. Fracture reduction and stabilization would contribute to reduction of hemorrhage and improvement in pain levels. The adjunctive use of dissociative agents such as ketamine, and benzodiazapenes such as Versed, would be an additional consideration dependent on patient condition and the tactical situation.

Prolonged Care Issues

Nursing care is critical to prolonged care in order to stack the deck in the patients favor by providing the critical information requirements to the surgeons and hospital. Basic patient care to include infection control measures, hygiene, maintaining patient mobility, and providing basic protection are key to rounding out complete care. Early and effective wound care with the goal of reducing bacterial load in any wound will prevent infection, promote early wound healing, and reduce the incidence of bacteremia, gangrene, and sepsis. Without appropriate wound care, the contribution of antibiotics may be minimal. Newer approaches adopted by NGOs allow for reduced frequency of wound care and dressing changes, do not rely on sterile supplies, and reduce the logistical requirements. The use of newer silver impregnated dressings, which are far more expensive, but allow for multiday and multiuse applications, and have bacteriostatic (and in some cases bactericidal) properties.

A final point is the consideration of nutritional requirements. Traditional teaching of basic medic skills has emphasized that patients be given nothing by mouth. In a prolonged care situation as envisioned in DCR, some consideration of nutritional requirements needs to be appreciated. The patient in shock, which has converted to anaerobic metabolism, experiences a marked reduction in energy production. This leads to proteolysis, and rather quickly a catabolic state with breakdown of whatever available substrate. Additionally, any severe injuries such as a tissue violation, fractures, and burns will quickly result in increased caloric requirements. The interaction between reduced energy production, increased metabolic requirements, proteolysis, and catabolism can, in a period of days, lead to a malnourished patient. This negatively impacts the immune system and the production of proteins necessary for wound healing. Consideration of enteral feedings with an intact GI tract should be considered in any scenario lasting beyond 24 hours. Oral intake can be considered in the conscious patient, or nasogastric feedings can be instituted. Though critical care teams employ dieticians to calculate caloric requirements and use complicated formulas, the use of readily available products with balanced proteins, carbohydrates, and fats is justified. Several thousand calories per day divided into small feedings every four to six hours would be a reasonable initial goal.

The prehospital use of ultrasound (US) is an emerging capability that needs to be evaluated for SOF use. Far forward ultrasound can easily provide additional critical information in order to make sound diagnostic and evacuation decisions or to confirm or supplement empiric treatments without lab results. Specifically critical to SF medics in trauma care is the focused assessment with sonography for trauma (FAST) exam which provides the ability to confirm abdominal bleeding, which otherwise may not be detected until decompensation occurs (Figure 5). It is important to point out, the absence of fluid in the abdomen does not negate surgical intervention in the hemodynamically stable patient.[26] Other trauma applications include the ability to identify a tension pneumothorax or a hemothorax. Ultrasound also provides the ability to confirm death in the most difficult environments such as on aircraft, in vehicles, or tactically without having to remove the helmet to confirm vital signs. New products such as the Seimens Acuson P10® or the Signostics Signos Personal Ultrasound™ can provide a small, portable, and durable tool to give high confidence information. In non-emergent situations, US can also provide previously unknown capabilities as well such as confirming fractures without X-Ray equipment, identifying abscesses or foreign bodies, and locating significant organs and vessels. With thorough initial training and minimal sustainment, this breakthrough in technology could be used to great advantage in either the trauma or clinical setting with good sensitivity and specificity. Ultrasound has been used in the most remote parts of the world, by government agencies, and expedition teams, and could be of significant use to the SF medics in the future. It has even been used on the International Space Station by a non-medical care provider with minimal training and sustainment.[27] If validated and acquired, this equipment could be maintained at the B or C Team level for training and use when mission requirements and risk assessments demand it, very similar to X-ray equipment in today's TacSet.

Figure 5: *A FAST exam using ultrasound technology being performed on a helicopter in flight. The ability to use this test on the platform was successful.*

DCR as an operational capability clearly requires preparation. Prestaging or prepositioning the appropriate supplies that are required for prolonged care is absolutely necessary. Keeping them on mobility platforms, preparing a speed bullet, resupply drop, or acquiring them from the civilian economy are all logistic issues medics need to consider and plan for. Knowing your equipment and its limitations is just as crucial as having them in the first place.

With respect to the valuable capabilities above, the context of this proposal for the SF medic is meant to fall between TCCC guidelines and damage control surgery where the levels of care in SF operational medicine contrasts conventional definitions. In the end all of these theories, TCCC, DCR, and damage control surgery, could all be consolidated into a structure of care and continuity for the military medical establishment and this initiative has already been proposed at other levels outside of SOF.[28]

Implementation

All aspects of a DCR theory must be trainable, sustainable, and retainable. These efforts implement universally accepted and successful concepts of care that utilize the most recent and validated therapeutics, including those that meet our most austere requirements. These could be implemented across the force as one standard of care. Essential to this is ensuring that SF medics appreciate the importance of their work and their responsibilities to their team and its mission, which will ensure successful implementation and durability of the care.

An independent unconventional warfare (UW) medical exercise may assist in validating this initiative and define specifics and equipment required. A working group preceding the exercise comprised of committed medics and surgeons from every SF Group and the Special Warfare Center could concentrate those who know these issues most intimately to define the best product possible. The exercise could then meet three key objectives: first, to validate DCR and its use in prolonged care; second, to define new TacSet requirements meeting our scope of practice both clinically and with trauma while testing new technological advances; and lastly, to revisit and update tactics, techniques, and procedures for UW medical operations in support of future austere environments.[29] Additionally, consider the participation of the most knowledgeable and experienced DCR experts to provide the best advice and assist in finding solutions as the effort is refined. The deliverable to the schoolhouse would be a sound and tested theory of care for their evaluation and implementation to include the required special equipment added to the TacSet for use as a complete package. This would all be accomplished in the field environment validating all aspects properly in the most operational approach possible. Any prolonged care theory should also include a mandatory review and periodic update of protocols as additional data and technology will drive our efforts.

Point of injury care with confident TACEVAC assets should include some minimum treatment goals before the patient arrives at a surgical asset. This is the basis for Special Operations Combat Medic (SOCM) DCR care. SOCM standards are the foundation of point of injury trauma proficiency for all of SOF and have evolved directly from TCCC work. This capability has led to the greatest statistical success against preventable death in this conflict when compared historically to other conflicts. Principles for SOCM-level care should include those aspects that would directly contribute to both prolonged care and surgical success. SOCM level medics could concentrate their efforts to hypotensive and hypovolemic resuscitation and hypothermia prevention. Hemostatic proficiency should meet the highest standards at this level, especially in the worst case of massive arterial bleeding in areas with difficult access such as bowl type wounds in anatomical girdles. At this level the adage of perfecting the basics must be met in order to set the foundation for later care. Their knowledge and understanding of DCR principles will lead their efforts setting the patient up for success at higher levels of medical care.

Again, these are presurgical goals for all SOF medics to accomplish before TACEVAC and subsequent hospital care. Ensuring that there is a definitive airway completed before movement is critical. A definitive airway is one that cannot be defined as a bridge, supports care up to 24 hours, is confirmed, and anchored by an anatomical structure. The patient must be normothermic and prepared to remain so. Gaining IO access is arguably the fastest, most confident, and most secure means of attaining initial access for fluids and drugs today when conditions preclude gaining peripheral IV access. The ability to provide blood competently is absolutely critical to gaining hemodynamic stability, replenishing clotting factors, and balancing acidosis. An understanding of the importance of early antibiotic therapy and being able to administer antibiotics appropriately is also crucial for negating post operative infections normally occurring 72 hours later. Lastly, but most importantly, all of these actions must be competently recorded for later use and continuity of care (Figure 6).

Point of Injury
Minimum Presurgical Goals

- Achieve hemostasis to your scope of practice
- Provide a definitive airway if needed
- Maintain a normothermic patient (> 96°F/36°C)
- Obtain Intraosseous/Intravenous access
- Provide fluid resuscitation with natural blood products if necessary
- Administer prophylactic antibiotic therapy
- Record and communicate all trending vitals and lab values to the next level of care

Figure 6: *Minimum recommended presurgical goals to be accomplished either during resuscitation or at the point of injury with a confident TACEVAC.*

The authors hope that an introduction of DCR and its consideration for SF medics provides, or at least initiates discussion of, an option for a modern, efficient, and proven approach to critical care under the worst scenarios. As we move out of the asset rich and developed theater of Iraq, our environments and missions will most likely be those we have been the least familiar and experienced with in recent years. Those environments are the ones that require the skills and scope of practice that only Special Operations can provide. It is under those circumstances that we need to work best. And we must understand that our patient care is integral to the larger effort of negating the enemy of his political victories with our attrition while we engage in his destruction.

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