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Cutting-Edge Forward Burn Nutrition: from the Battlefield to the Burn Center

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Abstract The US Army Institute of Surgical Research (USAISR) Burn Center is among the first and largest burn centers in the world and is the only US military burn center. This American Burn Association-verified facility is located on the Fort Sam Houston military base, in San Antonio, TX. It has provided comprehensive burn care to both military personnel and civilians in the South Texas area since the end of World War II. The global mission of the USAISR is to optimize combat casualty care, including care for major thermal injuries. This optimization of combat casualty care is executed clinically in the USAISR Burn Center through interdisciplinary teamwork and by advancing the care provided based on leading edge research. This article focuses on clinical lessons learned in the area of burn nutrition over the last decade at this facility during the support of the combat casualties from Operation Iraqi Freedom and Operation Enduring Freedom; it also provides a review of current evidence-based nutritional medicine practices for treating patients with thermal injuries. The extreme nutritional demand and metabolic changes associated with severe burns have been well described. This hypermetabolic, hypercatabolic response can lead to lean body mass and strength loss, resulting in the lack of ability to perform activities of daily living, as well as infection, wound healing failure, and death. Nutrition is an essential tool to avoid these catastrophic results, but monitoring the nutrition status is complicated by the whole body volume overload, resulting from the initial massive fluid resuscitation, which is required to prevent cardiovascular collapse. Techniques such as estimating weight loss from the caloric deficit must be utilized in place of actual weight loss until the interstitial fluid is reclaimed and a dry weight is achieved. Replenishing the extreme caloric expenditure and nitrogen loss is challenging; hence, careful monitoring of the nutrition intake is an essential component of burn treatment. In addition, there are a number of potential adverse effects of nutritional therapy that must also be factored into the complex decision-making regarding the initiation and delivery of nutrition in the critically ill burn population.

Keywords Nutrition and trauma · Burn nutrition · Thermal injuries · Burn care · Enteral nutrition · Parenteral nutrition · Hypermetabolism

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Clinical Case

A 22-year-old Army soldier was on patrol at a busy market in southern Afghanistan when an Afghani female detonated an

explosive vest she was wearing underneath her clothing. Several soldiers were injured, but this soldier received the most severe injuries: 60 % total body surface area (TBSA) burn, partial traumatic amputations of his bilateral lower extremities, a penetrating abdominal injury with evisceration of intra-abdominal contents, and a traumatic brain injury. Tourniquets were placed above the injuries to his lower extremities, a sternal interosseous infusion device was placed, and two liters of crystalloid were infused. The patient was expeditiously transported to a Combat Support Hospital where he was intubated, and central venous and arterial lines were placed. After transfusion of blood products, the fluid resuscitation was started in accordance with the USAISR "Rule of Tens" formula [1]. He was taken to the operating room where the amputations were completed to his lower extremities (wounds were left open), an exploratory laparotomy was performed with a small bowel resection, and a negative pressure wound device for temporary abdominal coverage was placed. He was transported by the Air Force Critical Care Air Transport Team from Afghanistan to Landstuhl Regional Medical Center in Germany several hours later. The fluid resuscitation was completed shortly after arrival to Germany. In Germany, the lower extremity and abdominal wounds were irrigated, a jejunostomy feeding tube was placed, and the abdomen was closed. The US Army Burn Flight Team changed the burn wound dressings, performed a superficial burn wound debridement, and then transported the patient via military aircraft from Germany to the USAISR Burn Center in San Antonio, TX. Enteral feeding was started via the jejunostomy tube shortly after arrival, and he was taken to the operating room the next day for burn wound excision and allograft placement.

Introduction

Severe thermal injury results in a significant hypermetabolic and catabolic response, but the first hours after injury are characterized by a hypodynamic response, known as the "Ebb" phase, mostly due to systemically circulating cardiodepressants [2]. This initial hypodynamic response quickly yields to a hyperdynamic systemic inflammatory response syndrome (SIRS), known as the "Flow" phase, resulting in hypermetabolism in magnitude and duration that is unmatched in any other patient population (Fig. 1) and that characteristically involves multiple organ systems [5•]. This SIRS response following thermal injury promotes the liberation of catecholamines, cortisol, acute phase reactants, and pro-inflammatory cytokines; these result in the elevation of heart rate and core body temperature and the conversion of amino acids to glucose (gluconeogenesis). Hyperglycemia with insulin resistance also follows. If nutrition is not appropriately initiated and adequately maintained during this period, the
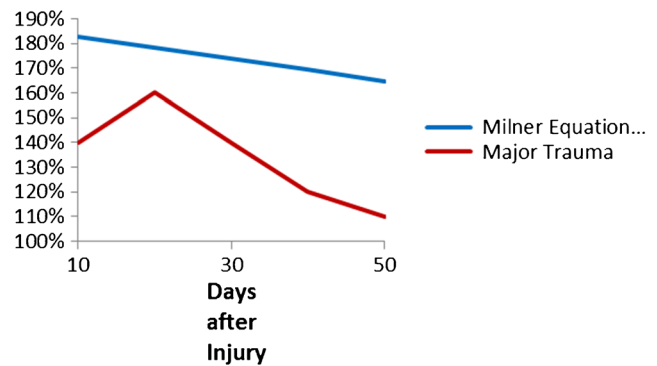
Fig. 1 Long et al. data for non-burn trauma vs. Milner equation for burn showing increased metabolic and catabolic rates [3, 4•]

result is poor wound healing, infection, sepsis, multi-organ dysfunction syndrome, and eventually death. Calories and protein must be supplied at greater than "normal" levels, often in quantities that significantly surpass that of other patients with major traumatic injuries [5•, 6].

Fluid Resuscitation and Electrolyte Management

In addition to the metabolic responses to burn, there is a marked increase in capillary permeability, commonly termed "capillary leak," resulting in loss of fluid into the interstitium. These losses are compounded by wound transudate and evaporative losses. All of these losses must be replaced by continuous intravenous (IV) infusion to prevent cardiovascular collapse [7]. For patients who weigh 40–80 kg, Lactated Ringer's is initiated using the USAISR "Rule of Tens" formula [1]: 10 mL/h multiplied by the %TBSA burn (Ex: 70 % TBSA => initial IV fluid rate of 700 mL/h). This rate can then be adjusted by computerized decision support software or by 20–25 % each hour to achieve urine output goal range of 30–50 ml/h. Fluid resuscitation is discussed in further detail in the *Joint Theater Trauma System (JTTS) Burn Clinical Practice Guidelines (CPGs)*. The fluid resuscitation can last 24 h or more, when capillary membranes regain their normal permeability [7]. As the enteral nutrition (EN) or oral intake advances, IV fluids are minimized as the patient is able to tolerate in an effort to reclaim the interstitial fluid. The gastrointestinal (GI) tract is primarily utilized for achieving calorie and protein goals, rather than correcting the large free water deficits that can occur even after the initial resuscitation period. This fluid lost through the open wounds can lead to severe hypernatremia, which requires IV fluid (5 % dextrose) for correction [8]. A rule of thumb for *estimating* the fluid lost through open wounds (mL/day) is the body weight (kg) multiplied by the %TBSA *open wounds* (Ex: 70 kg, 70 % TBSA open wound => 4900 mL/day), but until all of the edema resolves, the clinical goal stands: minimize IV fluids as much as the patient can tolerate in order reclaim the interstitial fluid.

As the wounds heal and fluid losses decrease, extreme thirst continues and hyponatremia becomes the predominant abnormality due to fluid overload, indicating the need for fluid restriction rather than sodium supplementation.

Initial Nutrition Assessment

The nutrition assessment includes: pre-injury dry weight; height; nutritional, medical, and surgical histories along with current status; medications; biochemical data; and physical examination [9••]. The pre-injury dry weight is used in calculating the calorie goal; ideal body weight (IBW) can be used in calculating protein goals. Pre-existing malnutrition can be determined by recent significant unintentional weight loss (>5 % over 1 month, >10 % over 6 months), poor oral intake prior to injury, a low body mass index, or visible lean body mass wasting. Although serum albumin levels are predictive of overall poor outcomes, they are not useful in assessing nutrition status in the acute phase of any burn or trauma patient [9••, 10].

If the patient is malnourished, severe electrolyte disturbances can be expected upon the initiation of nutrition, especially hypophosphatemia [11•, 12]. This hypophosphatemia can be resistant to replacement. If this resistance occurs, the EN rate should be decreased temporarily until the electrolyte profile normalizes. Electrolytes should be repleted aggressively, and new levels should be drawn after each replacement to determine the need for further repletion and the timing for increasing the EN to the goal rate [9••, 13].

Energy

The Milner equation (Table 1) was recently verified at the USAISR Burn Center and is useful in determining resting energy expenditure in adult patients with ≥20%TBSA burns [3, 15]. Indirect calorimetry is also utilized, as it is a more accurate method of determining resting energy expenditure [9••]. The resting energy expenditure is then multiplied by an activity factor of 1.4 in an effort to maintain weight, hopefully with preservation of lean body mass. Physical activity, medications, and environmental factors are implemented to ensure that the lean body mass retention is maximized [16–19]. Avoiding severe lean body mass loss is essential to prevent infection, poor wound healing, pressure ulcer development, pneumonia, and death. The goal for the entire hospital stay is to maintain less than 10 % weight loss from the pre-injury dry weight. The initial fluid resuscitation frequently results in extreme edema; dry weight is commonly only achieved again when the wounds are healed. Therefore, caloric balance is monitored closely to estimate weight loss until a dry weight is achieved.

Table 1 Estimation of resting energy expenditure using the Milner Eq. 13

| Milner equation (for patients with ≥ 20 % TBSA burn) |
| --- |
| [BMR × (0.274 + 0.0079 × TBSA − 0.004 × PBD) + BMR] × 24 × BSA × AF |
| EER = Estimated energy requirement |
| TBSA = Total body surface area burned (%) × 100, Ex: 20 % burn, enter "20" |
| TBSA does not change with healing; always use the actual initial burn size, no maximum. |
| BSA(m^2)(usual answers: 1.5–2.5) = square root of;(HT × WT)/3600 |
| HT = height (cm) |
| WT = weight (kg) (for obese patients, use actual dry weight) |
| AF = Activity factor (typically 1.4 for weight maintenance, 1.0 when paralyzed) |
| PBD = post-burn day |
| Male BMR = 54.337821− (1.19961 × Age) + (0.02548 × Age^2) − (0.00018 × Age^3) |
| Female BMR = 54.74942− (1.54884 × Age) + (0.03580 × Age^2) − (0.00026 × Age^3) |

Note: BMR units are $kcal/m^2/h$ [14]

The estimated resting energy expenditure is not decreased below the initial level calculated with the Milner equation on the day of injury until <10%TBSA open wound is achieved, then a new level can be determined with the Milner equation, which includes the number of days post-injury to account for the decrease in metabolism over time. This decrease in metabolism can take 1–2 years after full healing has occurred to return to normal.

Protein

The initial daily protein goal is calculated by multiplying the IBW [20] (kg) by the grams of protein per kg IBW for the corresponding burn sizes shown in Fig. 2 [4•, 9••, 21]. This was adapted from urinary nitrogen loss data by Long et al. [4•] and Kagan et al. [21] An alternative method is to provide 20–25 % of the caloric goal from protein, as this range has been found to be associated with improved outcomes, including a decreased number of days with bacteremia and decreased mortality [22••].

In order to meet protein goals earlier, boluses of protein powder mixed in water are given every 3 h during the initiation of EN. As the EN rate is increased, this protein supplementation is decreased to maintain the protein goal shown in Fig. 2 or increased to achieve a positive nitrogen balance using the equation shown in Table 2. All urine output is collected each day to determine the urine urea nitrogen (UUN) or the total urea nitrogen (TUN) [9••]. UUN is more readily available than TUN and can be multiplied by a factor of 1.2 to estimate

Fig. 2 Estimation of initial protein goals based on burn size [17, 18]

Initial protein goals:
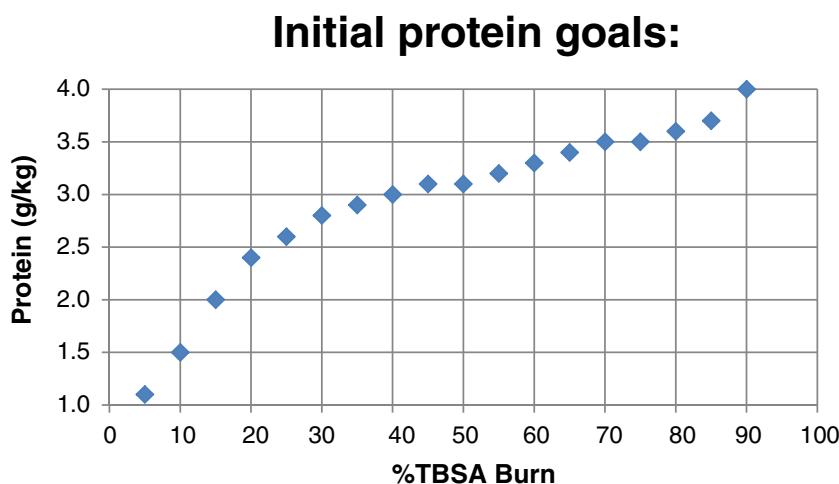
the TUN. Nitrogen is also lost through the transudate and/or exudate from the open wounds. The Waxman equation [23] estimates nitrogen losses through the open wounds. Open wound size is defined as the %TBSA wound that is still weeping, including all unhealed donor sites. The goal is to achieve a positive nitrogen balance (keeping <5 g protein/kg IBW). The protein goal is not decreased below the initial estimate from Fig. 2 or 20–25 % of the caloric goal until approximately hospital day 14, as UUNs have been found to increase during this time. Nitrogen balance studies are inaccurate in patients with poor renal function and, therefore, cannot be utilized during those times to estimate protein goals. Visceral protein (prealbumin, transferrin, retinol binding protein, etc.) levels are not helpful, as they are poor indicators of nutrition status [9••, 10, 24].

When transitioning from EN to oral intake alone (only when <10 % TBSA open wounds), the protein goal is decreased, but ensuring at least 1.5 g protein/kg IBW is achieved with oral intake.

Table 2 Nitrogen balance equation including wound losses

Nitrogen balance = Nitrogen intake − Nitrogen losses

Nitrogen intake = gm protein intake/6.25

Nitrogen losses = TUN + 2 + Waxman

Waxman equations: [23]

Daily nitrogen loss, g, 1st week = 0.3 × BSA × %TBSA Open Wound

Daily nitrogen loss, g, after 1st week = 0.1 × BSA × %TBSA Open Wound

%TBSA Open Wound = Total body surface area open burn wound and total body surface area unhealed donor sites (%) ×100, Ex: 20 % burn + 20 % unhealed donor, enter "40"

%TBSA Open Wound does change with healing

BSA(m^2)(usual answers : 1.5–2.5) = square root of : $(HT \times WT)/3600$

HT = height (cm)

WT = weight (kg) (for obese patients, use actual dry weight)

Fat vs. Carbohydrate

Low-fat formulas (3–15 % of total calories) are associated with decreased pneumonia rates, sepsis, wound infections, length of hospitalization, and healing time for burned patients [25, 26••, 27••, 28••, 29•, 30]. Specialty formulas for diabetes, renal failure, congestive heart failure, pulmonary failure, and acute respiratory distress syndrome should be avoided in burn patients because these formulas are all extremely high in fat content. Rather than switching to one of these high-fat specialty formulas, insulin can correct hyperglycemia and continuous renal replacement therapy can clear waste poor renal function.

Parenteral Nutrition

Patients who are at increased risk of malnutrition from the hypermetabolism and hypercatabolism following severe burns may be started on total parenteral nutrition (TPN) if their EN goals are not met within 48 h of admission. The use of early TPN in these patients with a high mortality risk and inability to tolerate EN goals is advocated at this burn center, but the practice in general remains controversial. For low mortality risk patients with a good nutritional status prior to injury, TPN can be initiated after 7 days of inability to tolerate EN [9••, 31••].

Total caloric goals are not usually achieved with TPN, as the dextrose infusion rate is usually limited to 5 mg/kg/min and lipids are not given unless the patient has not received any fat from EN or lipid-based medications for a full week [9••, 32, 33]. At that time, 500 kcal of lipids is given only 2–3 times per week to avoid continuous infusion of pro-inflammatory lipids, as well as to minimize fat intake for reasons already discussed. When giving IV lipid-based medication (propofol), triglyceride levels should be checked weekly. Liver function tests are monitored each week and renal function and

electrolyte panels are monitored at least daily while initiating TPN. It is important to transition to full EN as soon as possible, as TPN has been associated with increased infection and mortality rates [9••, 34]. However, with modern critical care practices that have significantly reduced the incidence of infections classically associated with TPN (such as catheter-related sepsis and pneumonias), multiple recent controlled trials have found little to no increased risk with TPN use. Although the rule of "use the gut" when at all possible should still be followed, a more liberalized approach to TPN use in the patient with a contraindication or intolerance to EN is becoming widely accepted [9••, 31••].

Enteral Nutrition

EN should be initiated within the first 24 h of admission, as this has been shown to be safe and has been found to be associated with decreased time in the intensive care unit and decreased wound infection rates [9••, 35, 36•, 37, 38•]. Bowel sounds, stool output, and flatus have not been found to be associated with bowel function and should not be a barrier to initiating EN [9••]. EN is initiated in the hemodynamically stable patient in which the base deficit and lactate levels are normalizing [9••]. The initial EN rate is 20 ml/h and is increased by 20 ml/h every 4 h until the target rate is achieved [39]. The goal is to reach the hourly target feeding rate within 48 h of admission and thereafter meet 100 ± 20 % of calorie goal every day starting on hospital day 3 [9••, 40]. Wound healing and minimizing lean body mass loss are the primary goals of this aggressive nutritional regimen.

Interruptions in Enteral Nutrition

EN is the preferred method of feeding, but frequent interruptions are common and can lead to severe weight loss. The EN rate can be increased to compensate for these interruptions. One strategy is to increase the current hourly goal rate by 1/6 for 6 h for every 1 h of EN missed [9••, 40]. The historic practice of holding EN at midnight prior to surgery is not supported in the literature; gastric feeding can be withheld 4 h prior to surgery, and post-pyloric feeding can be held when the patient is transported to the operating room [9••]. The risk of perioperative aspiration is low using these guidelines, and some are advocating continuing post-pyloric feeding without interruption during extra-abdominal surgical procedures. EN can be resumed post-operatively at the hourly rate tolerated prior to surgery, provided the patient is otherwise hemodynamically stable [41].

EN is routinely held when epinephrine or norepinephrine is initiated; however, there appears to be no contraindication to maintaining EN when the patient is otherwise

hemodynamically stable receiving either low-dose vasopressin or dobutamine. Gastric residuals are monitored every 4 h through the nasal gastric tube (NGT), but smaller caliber nasal enteric feeding tubes should not be used to check residuals. Residuals should be returned to the patient (up to 300 mL). When residual amounts are 500 mL or more, EN is held for 2 h. Therapies for treating elevated residuals include gastric promotility agents and post-pyloric dobhoff tube (DHT) placement [9••]. Utilizing both NGT (for decompression and gastric drainage) and post-pyloric DHT (for simultaneous feeding), EN can be continued as long as the gastric output does not reveal EN output.

Monitoring Nutrition Intake

Caloric intake from EN, TPN, IV fluid and oral intake is monitored closely until the patient has <10 % TBSA open wound and caloric goals are consistently being met. Caloric surpluses in excess of 120 % of goal are avoided, as overfeeding can lead to hyperglycemia, ventilator dependence (from increased CO_2 production), and fatty liver. Monitoring CO_2 levels is, at times, useful in determining if the patient is being overfed. When hypercarbia develops in the absence of pulmonary dysfunction, the EN rate can be decreased by approximately 20 %, but only when the patient has been achieving caloric goals consistently. If the CO_2 level normalizes with this adjustment, the caloric goal is decreased. Confirmation with indirect calorimetry allows for the measurement of the metabolic rate and calculation of the respiratory quotient to better set the calorie goal.

Oral Nutrition

Transitioning from EN to oral intake prematurely can lead to serious caloric deficits. A regular diet should be started as soon as the patient can tolerate oral intake. We find no evidence to support a ritualistic slow, multistep progression to a normal diet from clear liquids, and this significantly prolongs the time to adequate oral nutrition intake [9••]. The patient's mental status is evaluated prior to the trial of oral intake. The patient must have clear cognition and be able to manage their own oral and pulmonary secretions. If the patient has both an NGT and a DHT, the NGT should be removed prior to the trial of oral intake to facilitate swallowing. Small amounts of pudding texture are given initially, as this is the easiest texture to swallow. This is followed by sips of supplement drink. Change in voice, coughing, decrease in oxygen saturation, and the appearance of the foods or beverages consumed in the tracheal secretions are all indications that the patient is not tolerating oral feeding. When the patient has no difficulty tolerating oral feeding, soft, bland foods are recommended for

the first meal and chewing foods thoroughly is encouraged. Patients are often easily satiated and therefore have minimal solid food intake, but they are extremely thirsty, which aids in meeting calorie goals by drinking 8–24 supplement drinks per day [42]. Water, Gatorade®, Kool-Aid®, fruit juices, and sodas are not calorically dense enough to adequately support nutrition in the hypermetabolic state. The overactive thirst mechanism can lead to water intoxication (severe hyponatremia) if the patient is allowed to drink all the fluids desired. Fluid restriction is indicated to treat hyponatremia, but the patients must be allowed to meet nutritional goals. Therefore, liquid nutritional supplements should rarely be withheld. The fluid restriction is usually accomplished by providing only supplements and milk for oral fluids.

Medications and Other Treatments for the Hypermetabolic Response after Thermal Injury

Physical therapy aids in the retention of lean body mass, and many medications have been found to do the same. Insulin supports anabolism, and poor glucose control has been found to be associated with increased pulmonary and urinary infections in burn patients [43]. Insulin therapy can result in hypoglycemia if insulin protocols are too restrictive. IV insulin therapy is started with the goal of keeping the blood glucose less than 180 mg/dL. Long-acting insulin is avoided in patients with normal hemoglobin A1c levels on admission in order to avoid hypoglycemia when the inflammatory state begins to abate.

Oxandrolone is an anabolic steroid that has been extensively studied in the burn population and has been shown to significantly increase lean body mass retention and decrease length of hospital stay [44••]. The dosing is 10 mg twice each day and is started as early as post-burn day 5. The only adverse outcome found in a multicenter trial was elevated alanine aminotransferase (ALT) levels; therefore, liver function tests are followed weekly, and oxandrolone is held for ALT over 200 U/L.

In burned children, propranolol was found to reduce heart rate, metabolism, and protein catabolism and thereby increase lean body mass retention [45]. However, propranolol has not been studied extensively in the burned adult population. In our burn center, propranolol is usually started when the heart rate exceeds 120 beats per minute on or after post-burn day 5 in the absence of another obvious source for the tachycardia. The initial dosing is 10 mg two or three times per day and titrated to a goal of decreasing the heart rate by 20 %. Hold parameters should be specified to prevent bradycardia and hypotension. An ongoing prospective, randomized trial on propanolol (the Propanolol Study) should provide evidence to better characterize the appropriate role of propanolol in adults with major thermal injury. Other important treatments to minimize the hypermetabolic response include treatment of pain, infection control, and keeping the room temperature at least 90 °F [46, 47].

Glutamine, Vitamin, and Mineral Supplementation

Glutamine is a nutritional supplement which has been shown to decrease infection rates, improve wound healing, and decrease hospital length of stay for burn patients [48–51, 52•]. However, in non-burned patients with multi-system organ failure, glutamine supplementation has been found to be associated with increased mortality [53]. Therefore, the use of glutamine supplementation in the intensive care unit is a controversial practice. Enteral glutamine is given currently to patients with ≥20 % TBSA burn except in cases of significant hepatic dysfunction or pre-existing kidney disease. The dosing is approximately 0.5 g/kg IBW per day (15 g packs mixed with water and given immediately as boluses, usually twice per day) and is started along with EN initiation. An ongoing prospective, randomized trial of enteral glutamine supplementation (the RE-ENERGIZE Study) should provide evidence to better characterize the appropriate role of glutamine supplementation after major thermal injury. Patients with ≥ 20 % TBSA burn are also given a multivitamin, vitamin C, zinc sulfate, thiamine, folic acid, vitamin E, and selenium as daily supplements [9••, 54, 55•]. Patients with smaller burns are given daily multivitamin and vitamin C. Vitamins C and E are antioxidants and have distinct roles in wound healing. Selenium is another antioxidant and is given as a supplement in critically ill burn patients [9••, 56]. Patients with large burns have been found to be zinc-deficient; therefore, zinc supplementation can aid in wound healing. Thiamine and folic acid can help decrease lactic acid levels in patients with large burns. Vitamin or mineral deficiencies should be treated, although iron may be an exception. Iron is not commonly supplemented as patients often receive several blood products and have ferritin levels indicative of iron overload. Inappropriate iron supplementation has also been found to be associated with increased risk of infections. Sodium replacement should be avoided in cases of hyponatremia, as the cause of the hyponatremia is a free water excess rather than a sodium deficiency. After achieving <10 % TBSA open wounds, zinc, thiamine, folic acid, and vitamin E can be discontinued.

Wound Healing

When there is evidence of poor wound healing, copper and zinc levels should be evaluated to determine if there is a need for IV supplementation. Protein provisions are increased at this time (keeping <6 g protein/kg IBW), in a final attempt to aid in wound healing. Growth hormone is occasionally

prescribed for these patients with wound healing failure in conjunction with IV insulin [57].

Combat Casualty Burn Care

Approximately 1000 combat casualties have been treated at the USAISR Burn Center since 2003. Most of these patients sustained injuries while conducting combat operations in Iraq or Afghanistan. Despite the long distances and logistical problems of evacuating casualties from a combat zone, most casualties arrived at our burn center within an average of 96 h following injury. Initial stabilization and fluid resuscitation occurred during the continuum of care at various medical facilities throughout the theater of operations during the long range evacuation. These patients were initially evacuated to Germany, where they were stabilized and then transported to the USAISR Burn Center in San Antonio, TX. Although enteral feeding tubes were often placed in patients with severe burns, EN was rarely initiated prior to arrival at the USAISR Burn Center. Enteral feeding was generally not performed during aeromedical transport due to the presumed increased risk of aspiration [58, 59].

Combat casualty burn care is complicated by many factors. Some of these factors include: multi-system traumatic injuries in addition to the thermal injury, austere locations of many of the medical facilities that provide care to combat wounded, limited medical equipment and resources at the medical facilities in combat zones, and medical providers with lack of experience and training in burn care. Burn CPGs were first developed in 2006 in an attempt to guide the front line medical providers through the complexities of combat casualty burn care and to improve patient outcomes (see Appendix A).

One area of combat casualty burn care that has been greatly impacted by the JTTS Burn CPGs is fluid resuscitation. In the early part of the conflicts in Iraq and Afghanistan, the fluid resuscitation given after thermal injury was not standardized and many different resuscitation formulas were being utilized. Many patients with larger burn sizes received excessive volumes of crystalloid. This "over-resuscitation" leads to the complications of extremity and abdominal compartment syndrome, increasing morbidity and mortality in this population [60]. The *JTTS flowsheet* was created to track the resuscitation of burn patients from point of injury to 72 h post-injury. The use of albumin, plasma, other colloids and vasopressors was recorded as well. The use of the JTTS flowsheet in conjunction with adherence to Burn CPGs was shown to significantly improve outcomes [61].

Conclusions

After severe thermal injury, the resting energy expenditure can double and protein losses can triple. Careful monitoring of the nutrition status is an important component of burn care. The large volumes required for fluid resuscitation mask some monitors of the nutritional status, so other methods, including estimation of weight loss from the calorie deficit, must be utilized in place of actual weight loss until the edema has resolved. Meeting the hypermetabolic response with appropriate nutrition support can avoid severe weight loss and the associated morbidities, including increased infection rates, decreased wound healing, pressure ulcer development, and pneumonia. Meeting the extreme calorie and protein goals with EN is challenging, as interruptions can occur frequently. Problem solving using enteral feeding practice guidelines as described in this article and close monitoring of nutritional intake is essential for the recovery of the burn patient [9••].

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