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Factors Affecting Fluid Resuscitation in the Burn Patient
The Collaborative Role of the APN

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Abstract
Throughout the first critical 24 hr after the injury is sustained, the burn patient must receive fluid resuscitation to prevent hypovolemia and ensure adequate tissue perfusion. Delayed or inadequate fluid resuscitation results in suboptimal tissue perfusion, which can lead to multisystem organ failure and death. Overresuscitation can be more problematic than underresuscitation and has been associated with the development of abdominal compartment syndrome, compartment syndrome of the extremities, airway obstruction, and pulmonary edema. The term *fluid creep* is used to describe the tendency to give too much fluid and can result from the hemodynamic consequence of *opioid creep*. Experts in the field agree that fluid resuscitation of the burn patient is a priority. Factors affecting fluid resuscitation in the burn patient are at the cornerstone of burn management. The advanced practice nurse (APN) can play a vital role in implementing strategies to ensure optimal resuscitation in the burn patient. Through collaboration, the APN in both the burn center and the emergency department must make certain that the educational needs of the staff are addressed and be diligent in providing significant education, essential tools, and assistance to the staff nurses in an effort to promote best-practice and evidence-based care. **Key words:** burns, burn shock, fluid resuscitation, fluid therapy, Parkland formula

EVERY YEAR, half a million people in the United States present to medical facilities in need of treatment for burn injuries. The most common injuries include those from scald, flame, electrical, and contact burns. Many of these injuries prove fatal; fire and burn deaths total more than 4,000 each year. A total of 3,500 deaths result from residential fires, while the remaining 500 deaths occur because of motor vehicle and aircraft crashes, contact with electricity, chemicals, hot liquids, and other sources (American Burn Association [ABA], 2007). Complex wound management is the treatment modality most often associated with the care of the burn patient. However, throughout the first critical 24 hr after the injury is sustained, the patient must receive fluid resuscitation to prevent hypovolemia and ensure adequate tissue perfusion. Because of the mechanism of injury resulting in increased capillary leak, massive fluid shifts take place from the intravascular space into both the interstitium and the cells of

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burned and nonburned tissues. Delayed or inadequate fluid resuscitation results in suboptimal tissue perfusion, which can lead to multisystem organ failure and death. Furthermore, overresuscitation can be more problematic than underresuscitation and has been associated with the development of abdominal compartment syndrome (ACS), compartment syndrome of the extremities, airway obstruction, and pulmonary edema (Chung et al., 2006). Using evidence-based practice, the advanced practice nurse (APN) can play a vital role in both the burn center and the emergency department (ED) by implementing strategies to ensure optimal resuscitation of the burn patient. Through collaboration, the APNs of these two departments can positively impact the care of this patient population. Moreover, the APN in the burn center serves as an expert resource to healthcare providers less familiar with the care of the burn patient. For optimal patient outcomes, it is essential to establish collaborative relationships between the burn center and outlying EDs and prehospital personnel.

OVERVIEW OF BURN RESUSCITATION

Prior to the development of the Parkland formula, patients with extensive burns (greater than 30% total body surface area [TBSA]) would simply die or suffer from renal failure. Dr. Charles Baxter, a key figure in the investigation of fluid shifts and burn resuscitation during the 1960s and 1970s, was instrumental in developing the Parkland formula, which today is still the most frequently used formula for burn resuscitation. In 1978, the National Institutes of Health Consensus Conference on burn fluid resuscitation yielded no agreement concerning a specific formula (Greenhalgh, 2007). However, the consensus was to give the least amount of fluid necessary to maintain adequate organ perfusion and decrease iatrogenic complications. Since the 1970s, there has not been such an effort to investigate fluid shifts in the burn patient in the first 24 hr after injury. Furthermore, recent concerns have arisen regarding overresuscitation. As coined by Pruitt (2000), the term *fluid creep* is used to describe the tendency of giving patients too much fluid, and this phenomenon is authenticated by reports of adverse outcomes including ACS and acute respiratory distress syndrome (ARDS) (Blumetti, Hunt, Arnoldo, Parks, & Purdue, 2008; Greenhalgh, 2007; Pham, Cancio, & Gibran, 2008; Saffle, 2007). In addition, the tendency toward overresuscitation can result from the hemodynamic consequences of *opioid creep,* which results from increased use of higher doses of opioid agonists given for the treatment of severe pain. Hypotension related to high doses of opioids may contribute to increased fluid volume needs (Ipaktchi & Arbabi, 2006; Saffle, 2007; Sullivan et al., 2004).

In October of 2006, the "State of the Science Meeting" brought leaders in burn care and research together in Washington, DC, to determine and prioritize a national research agenda for evidence-based burn care. A session concerned with resuscitation was convened to not only determine the progress made in resuscitation formulas, but also discuss various aspects of burn shock pathophysiology and whether healthcare providers could do a better job with resuscitation, what resuscitation fluid is best, how newer technologies can assist with resuscitation, and what the endpoints of resuscitation should be (ABA, n.d.-b; Greenhalgh, 2007). Experts in the field agree that fluid resuscitation is a priority. Yet, there is still great debate over exactly how to calculate the volume to be delivered and which fluid should be used. While using various methods to calculate the amount of fluid needed to adequately resuscitate a patient, all clinicians incorporate the actual extent of the individual's injury. Burn injuries are scored by determining the amount of the patient's TBSA that is compromised using the Rule of Nines (Figure 1) and/or Lund–Browder chart (Figure 2). The ABA recommends that all second- and third-degree burns exceeding 15% TBSA be resuscitated by using the appropriate amount of lactated Ringer's (LRs) solution as determined by the Consensus formula (2–4 ml/kg/% TBSA) or the Parkland formula (4 ml/kg/% TBSA) (Ahrenholz et al., 2001). The formula determines the total amount of fluid to be administered in the first 24 hr postburn. The total volume is divided in half and half of the fluid is given intravenously over the first 8 hr postburn. The remaining volume is given over the next 16 hr. In infants and young children, fluid containing 5% dextrose administered at a maintenance rate is given in addition to the LR volume as determined by the Consensus or Parkland formula. Throughout this period, hemodynamic monitoring and measurement of urine output help ensure that the patient is being adequately resuscitated (Ahrenholz et al., 2001; Ahrns, 2004).

A major concern of many healthcare providers in the treatment of burns is underresuscitation (Chung et al., 2006). As a result, patients are often given large amounts of fluid in the prehospital arena and the ED. Recent studies have shown that overresuscitation can, in fact, be more problematic than underresuscitation. A survey of 28 burn centers revealed that 58% of patients received more than the 4 ml/kg/% TBSA as specified by the Parkland formula guidelines (Ipaktchi & Arbabi, 2006). Receiving too much fluid has been associated with the development of ACS, compartment syndrome of the extremities, ARDS, airway obstruction, and pulmonary edema (Chung et al., 2006; Pham et al., 2008).

To properly resuscitate a burn patient, the Consensus or Parkland formula is used only as an initial guideline. Once fluid administration has begun, hemodynamic monitoring of the patient is required to prevent over- or underresuscitation. Urine output and blood pressure are key parameters used to titrate the fluid rate (Ahrenholz et al., 2001). A urinary catheter must be utilized to accurately measure urine output. Current protocols state that sufficient output should be at least 0.5 ml/kg/hr or 30 to 50 ml per hour for adults and 1 ml/kg/hr for children (Ahrenholz et al., 2001). Maintaining a mean arterial blood pressure greater than 70 mmHg and a heart rate less than 120 beats per minute (or age-appropriate values for infants and young children) has historically been considered as standard endpoints of adequate fluid resuscitation and therefore adequate tissue perfusion. However, arterial blood pressure and heart rate can be influenced by multiple factors and therefore may be unreliable indicators of adequate resuscitation in the burn patient (Ahrenholz et al., 2001; Ahrns, 2004).

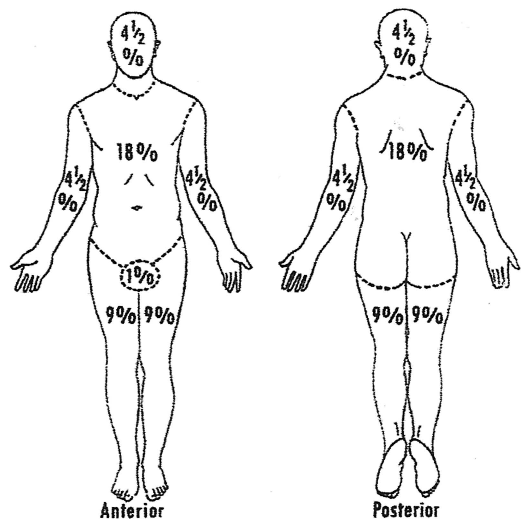
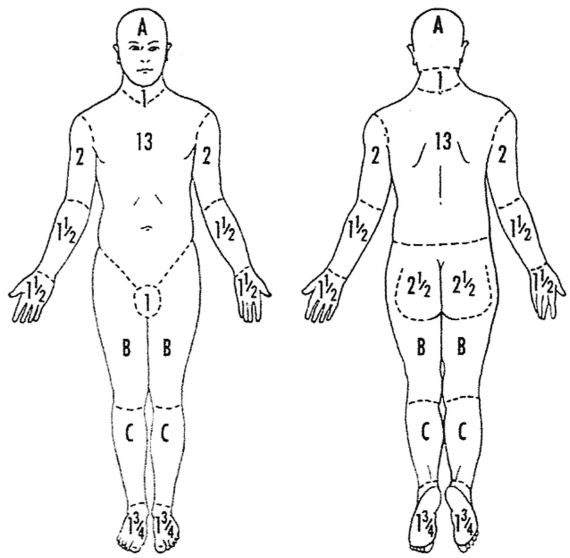


Figure 1. Rule of Nines. A rapid method of estimating percentage of body surface involved. From *Burns: A Team Approach* (p. 153), by C. P. Artz, J. A. Moncrief, and B. A. Pruitt, 1979, Philadelphia: W. B. Saunders. Copyright 1979 by the Elsevier. Reprinted with permission.

PATHOPHYSIOLOGY

Burn injury is classified by size and depth. The physiologic impact of a burn depends on the percentage of TBSA involved and the depth determines the extent of wound care, the need for grafting, and the functional and cosmetic outcomes. First-degree burns are superficial injuries involving only the epidermis. First-degree burns are not included in the determination of percentage of TBSA involved and therefore not considered in the calculations for resuscitation



Relative percentage of areas affected by growth

	Age in years					
	0	1	5	10	15	Adult
A—½ of head	9½	8½	6½	5½	4½	3½
B—½ of one thigh	2¾	3¼	4	4¼	4½	4¾
C—½ of one leg	2½	2½	2¾	3	3¼	3½

Figure 2. Lund and Browder charts. These charts permit a rather accurate method for determining percentage of body surface involved. From *Burns: A Team Approach* (p. 160), by C. P. Artz, J. A. Moncrief, and B. A. Pruitt, 1979, Philadelphia: W. B. Saunders. Copyright 1979 by the Elsevier. Reprinted with permission.

fluid. First-degree burns typically heal with minimal intervention. Second-degree burns, or partial-thickness burns, penetrate variably into the dermis. These injuries produce extreme pain due to damage to sensory nerves. Second-degree burns usually heal spontaneously by migration of cells from epidermal appendages, that is, hair follicles and sweat glands. Third-degree burns, or full-thickness burns, extend through the epidermis and dermis, destroying the epidermal appendages. Also destroyed are the sensory nerves, yielding a less painful injury. Leathery eschar forms on the third-degree burn from coagulated dead skin. These burns require surgical excision and grafting (ABA, 2001b).

The extent of injury in the burn patient is not limited to the obvious cutaneous damage. The burn patient experiences a systemic, hyperdynamic response that can lead to burn shock. Ahrns (2004, p. 75), citing the "Advanced Trauma Life Support" manual, defines *shock* as "inadequate organ perfusion and tissue oxygenation originating from an abnormality of the circulatory system." Burn injury can result in shock due to damage to the microcirculation and resultant capillary leak. In addition, in larger burn injuries, the release of chemical mediators causes a systemic increase in capillary permeability. The leakage of fluids, electrolytes, and protein from the intravascular space into the interstitium results in massive burn edema and, if the patient is not resuscitated adequately, circulatory collapse. Therefore, burn shock results from both distributive and hypovolemic processes because of the generalized microvascular damage and the third-spacing of fluids. The area in which total body fluid is distributed is expanded by third-spacing and includes not only the intravascular space, but also both the intracellular and interstitial spaces. It is the ongoing dynamic fluid shifts that necessitate fluid resuscitation amounts that neither over- nor underresuscitate the patient with significant injury (Ahrns, 2004; Ipaktchi & Arbabi, 2006). The primary goal of resuscitation is to preserve tissue perfusion and oxygenation (Ahrenholz et al., 2001). Likewise, the ABA states, "the goal of resuscitation is to maintain tissue perfusion and organ function while avoiding complications of inadequate or excessive fluid therapy" (ABA, 2001c, p. 34).

Although the exact pathophysiology is not entirely understood, multiple chemical mediators that either increase capillary permeability or increase microvascular hydrostatic pressure are implicated. Burn injury results in an immediate inflammatory response with resultant release of a multitude of chemical and hormonal mediators. Some investigators believe histamine and bradykinin are responsible for the early phase of burn edema formation. Other mediators contributing to the postburn increase in permeability include vasoactive amines, prostaglandins, hormones, leukotrienes, and components of platelet activation and the complement cascade (Ahrenholz et al., 2001; Ahrns, 2004).

The question then remains: How much fluid is too much or not enough? The massive tissue edema that occurs following large burn injuries results in intravascular fluid loss, leading to hypovolemia if the patient is not properly resuscitated. However, aggressive fluid resuscitation, while correcting the hypovolemia, can worsen the edema. Consequential tissue hypoxia and increased compartment pressures may ensue and the need for escharotomy or fasciotomy in circumferential injuries may present (Demling, 2005).

REVIEW OF THE LITERATURE

Determining how best to calculate the fluid needs of the burn patient while maintaining adequate tissue perfusion has been a controversial issue in the treatment of burn patients. This review will examine studies that have attempted to clarify the issue.

An extensive review of the literature was performed by utilizing both Ovid and EBSCOhost and searching the CINAHL and MEDLINE databases. The search consisted of the English-language publications from 2000 to 2009 by using the key words "burn resuscitation," "fluid resuscitation," "Parkland formula," "fluid creep," "opioid creep," and "burn shock."

A study by Klein, Hayden, et al. (2007) found that patients who received a large volume of fluid during resuscitation were more likely to suffer from adverse outcomes such as ARDS, pneumonia, multiple system organ failure, bloodstream infections, and death. Data were collected on adult patients enrolled in a study of inflammation to determine patient and injury variables that influence fluid requirements in the burn patient. Variables included percentage TBSA burned, the patient's age and weight, and intubation status, all of which can significantly influence fluid requirements in the first 24 hr postburn injury. Patients who received large volumes of resuscitative fluid were at increased risk of developing at least one adverse outcome. For each 5-L increase in fluid received, there was a significant increase in risk of pneumonia, bloodstream infections, ARDS, multiorgan failure, and death.

Working from the premise that patients generally receive more fluid than calculated by the Baxter (Parkland) formula, Friedrich et al. (2004) conducted a study of patients treated at a regional burn center to determine whether overresuscitation was a new phenomenon. At this study institution, supra-Baxter resuscitation was found to be a new phenomenon. In analyzing their data, they found that the amount of fluid their patients received was double of what Baxter recommended and what the institution administered 25 years ago. The majority of subjects received two times the amount of fluid initially calculated by the Parkland formula. Pruitt called this phenomenon of overresuscitation "fluid creep."

In an additional study utilizing the same two matched cohorts as the Friedrich et al. (2004) study, Sullivan et al. (2004) attempted to answer the question of why the amount of fluids required often exceeds the recommended volume. The purpose of this study was to compare the administration of opioid agonists in patients treated at a single burn center in the 1970s and in the year 2000 to determine whether there were a correlation between an increased use of opioids and increased fluid resuscitation volumes. The data suggested a positive correlation between the use of opioid agonists and resuscitation volumes. The diversity and number of opioid agonists administered increased from the 1970s to 2000. One explanation of increased fluid volume, or "fluid creep," could be the increased use of opioids, or "opioid creep" (Sullivan et al., 2004, p. 587). In contrast to the patients who were treated with a single medication for pain in the 1970s, the majority of the patients in the latter group received a combination of two or more opioid agonists. The researchers speculated that the increased use of opioids is likely to contribute to hypotension and therefore increase the amount of fluid needed for adequate resuscitation. Furthermore, the authors emphasize the need to incorporate nonpharmacological methods of pain control and limit the diversity of opioid agonists, which could possibly lead to lower doses of medication with better pain control and consequently decreased volume resuscitation.

If the amount of fluid volume calculated by using the Parkland formula is not adequate, maybe the formula itself is lacking. Working under this assumption, Cartotto, Innes, Musgrave, Gomez, and Cooper (2002) evaluated the effectiveness of the Parkland formula. The purpose of this retrospective cohort study at an adult tertiary regional burn center was to compare estimated and actual fluid resuscitation volumes by using the Parkland formula. Thirty-one patients with greater than 15% of TBSA burned were studied. Patients with inhalation injury, high voltage electrical injury, delayed resuscitation, or associated traumas were excluded. Eighty-four percent of the cases in this study were found to have required significantly more fluid for resuscitation than predicted by the Parkland formula. The authors concluded that although the volume calculated by using the Parkland formula was not enough for most burn patients, the formula was still the best available mathematical expression designed for gauging a starting point for fluid administration.

Freiburg, Igneri, Sartorelli, and Rogers (2007) offered an alternative hypothesis. The purpose of their study was to analyze the effect that different burn size estimations and burn resuscitation had on complications and death among transferred burn patients in comparison with outcomes for patients admitted directly to the burn center. For those burn patients transferred from an outside hospital, smaller burns tended to be overestimated and overresuscitated; larger burns tended to be underestimated and underresuscitated. Differences in burn estimation and deviation from the Parkland formula were not statistically significant for the incidence of complications and death. Perhaps this was because upon arrival to the burn center, the patient was rescored and the Parkland formula was recalculated by using the correct percentage of TBSA burned.

Another study found that the average transport time for burn patients to reach a burn center was 7.2 hr (Klein, Nathens, Emerson, Heimbach, & Gibran, 2007). This study aimed to identify systematic errors in either the initial evaluation or care of burn patients requiring transport more than 90 miles to a single regional burn center. Of the 424 transferred patients meeting inclusion criteria (transferred more than 90 miles from the referring hospital), percentage of TBSA burned was overestimated overall by referring physicians. Two patients with small burns (less than 15% TBSA) were misestimated at 50% TBSA by the referring hospital and received four times the amount of fluid they required prior to transfer to the burn center. Twenty-two patients had size misestimates of greater than 20%. Despite the errors in burn size estimates, when comparing the average amount of fluids received for all patients with the average amount of fluids calculated based on the Parkland formula, no significant difference was found. The lack of significant difference may be attributed to the misestimates of burn size, resulting in some patients receiving less fluid than that predicted by the Parkland formula while other patients received more fluid than predicted leading to the cancellation of the two when computing mean fluids administered. However, the authors note, as previously stated, that both under- or overresuscitation can lead to complications.

Unlike the other studies, Hoskins et al. (2006) compared automated computer-controlled resuscitation with manual control as the means for adequate fluid resuscitation. The authors introduced a "closed-loop" resuscitation device through which a computer continuously monitored a patient's urine output and adjusted the fluid rate appropriately. A quantitative animal clinical trial was performed in which some adult sheep were resuscitated by utilizing the "closed-loop" method, while others were monitored hourly by a technician and adjusted accordingly. Urine output per hour in the "closed-loop" group was inadequate 16% of the time and was inadequate 25% of the time in the manual group. The "closed-loop" group also demonstrated less variability in hourly urine output and infusion rate than did the manual group. This study offers a new perspective on the resuscitation problem while piloting a system that may be able to alleviate the issue.

Although these studies revealed issues related to resuscitation of the burn patient, no definitive solution was identified. Therefore, the role of the APN is an important one and is both collaborative and supportive.

CASE STUDY

R.C. was a 59-year-old male transferred to the burn center from an outside hospital after sustaining burns to the head, face, bilateral upper extremities, scattered posterior and anterior torso, buttocks, and left upper thigh because of a house fire. The patient's wife perished in the fire. The initial report from the transferring hospital included an estimate of 80% TBSA burned and administration of 4 L of 0.9% normal saline (NS) within the first 1.5 hr postburn. R.C. presented to the burn center intubated, sedated, and in relatively stable condition.

Vital signs on admission to the burn center were heart rate 118 beats per minute, blood pressure 132/77 mmHg, respiratory rate 16/min (not assisting the ventilator), temperature 36.1°C (rectal), 42 ml clear, yellow urine via urinary catheter per hour, radial pulses 2+ bilaterally, and weight 82 kg. Table 1 provides initial laboratory values.

His past medical history was unremarkable. Fluid resuscitation was initiated with LR by using the Parkland formula at 4 ml/kg/% TBSA. Bronchoscopy was performed for inhalation injury grading purposes, and the aerosolized heparin protocol for inhalation injury was initiated. A major pathophysiologic change occurring in patients with smoke-inhalation injury is the formation of fibrin casts in the airways. It is believed that the fibrin casts, coupled with airway edema, cause airway obstruction contributing to pulmonary failure. In addition, fibrin is known to inhibit the activity of surfactant. Heparin has been

Table 1. Laboratory values on admission

Potassium (K^+)	4.2 mEq/L
Sodium (Na^+)	146 mEq/L
Chloride (Cl^-)	111 mEq/L
Calcium (Ca^{++})	8.6 mg/dl
Magnesium (Mg^{++})	2.1 mg/dl
Phosphorus (P)	2.5 mg/dl
Blood urea nitrogen (BUN)	22 mg/dl
Creatinine (Cr)	0.9 mg/dl
Hemoglobin (Hgb)	9.8 g/dl
Hematocrit (Hct)	29 ml/dl
Arterial blood gas	
pH	7.31
$Paco_2$	45 mmHg
Pao_2	290 mmHg
Bicarbonate (HCO_{3-})	26 mEq/L

found to inhibit airway fibrin clot formation, minimize barotrauma, and reduce pulmonary edema. Current protocols in many burn centers include the administration of aerosolized heparin alternating with *N*-acetylcystine and albuterol for patients with smoke-inhalation injury (Holt, Saffle, Morris, & Cochran, 2008; Miller, Rivero, Ziad, Smith, & Elamin, 2009).

While the patient was in relatively stable condition, the referring hospital misestimated the size of the burn. The overestimation of percentage of TBSA burned was mainly due to inclusion of first-degree burns when determining the extent of injury and subsequently led to administration of a large amount of fluid prior to transport. As the research has shown, overestimation of burn size is a common practice by referring hospitals. In addition, the patient was given a large amount of 0.9% NS, contributing to the increased chloride level and acidosis. LR is the preferred fluid for burn resuscitation. With a sodium concentration of 130 mEq/L, the composition and osmolality of LR most closely resembles that of normal body fluids. In addition, the lactate concentration in LR serves as a buffer to help correct the metabolic acidosis that can occur because of hypoperfusion and burn shock (Ahrns, 2004). Infusion of large volumes of 0.9% NS (which contains sodium and chloride) can result in hyperchloremic acidosis because of a reduction in the strong anion gap by an excessive rise in plasma chloride and excessive elimination of bicarbonate by the kidneys (Eisenhut, 2006; Kellum, 2005).

After arrival at the burn center, the APN recalculated the percentage of TBSA burned by using the Rule of Nines and estimated a 48% TBSA burn (vs. 80% calculated by the referring hospital). Using the Parkland formula with LR, fluid resuscitation was calculated as follows:

4 ml/kg/% TBSA or $4 \times 82 \times 48 = 15{,}744$ ml (over 24 hr)

Half (7,872 ml) to be given over the 1st 8 hr postburn

Remaining half (7,872 ml) to be given over the next 16 hr

The amount of fluid (4,000 ml) given by the referring hospital had to be subtracted from the amount calculated for the first 8 hr postburn. The patient arrived at the burn center 1.5 hr postburn; therefore, 3,872 ml needed to be delivered in the next 6.5 hr (595 ml/hr).

The patient's vital signs remained stable with a heart rate of 118 beats per minute. Tachycardia in the burn patient is not uncommon and is a result of their hyperdynamic state. At 22 mg/dl, the blood urea nitrogen is slightly increased, reflective of protein breakdown from the extensive burn injury. Other laboratory values included an elevated chloride (111 mEq/L) and sodium (146 mEq/L) at the high end of normal due to the large amount of 0.9% NS given by the referring hospital. The hemoglobin (9.8 g/dl) and hematocrit (29 ml/dl) were low, possibly due to the dilutional effect of fluid resuscitation. Adequate urine output (42 ml/hr) was an indication of adequate resuscitation. The clear yellow urine suggested that the patient was not experiencing rhabdomyolysis.

The patient was admitted and went to surgery a few days after admission for split thickness skin grafts to all areas of full-thickness burn. He was extubated 1 week after surgery and his subsequent course of recovery was unremarkable. He was discharged home $4^1/_2$ weeks postadmission with home health nurses for wound care.

SIGNIFICANCE TO NURSING

Nurses in both the burn center and ED are involved in the care of the burn patient. The nurse is often at the frontline of triage of burn patients and plays a vital role in communicating with prehospital caregivers and between the referring hospital and the burn center. Accordingly, the APN in the burn center and the ED must be diligent in providing significant education, essential tools, and assistance to the nurses in an effort to promote

Table 2. Burn center referral criteria

A burn center may treat adults, children, or both.
Burn injuries that should be referred to a burn center include the following:
1. Partial-thickness burns of greater than 10% of the total body surface area
2. Burns that involve the face, hands, feet, genitalia, perineum, or major joints
3. Third-degree burns in any age group
4. Electrical burns, including lightning injury
5. Chemical burns
6. Inhalation injury
7. Burn injury in patients with preexisting medical disorders that could complicate management, prolong recovery, or affect mortality
8. Any patient with burns and concomitant trauma (such as fractures) in which the burn injury poses the greatest risk of morbidity or mortality. In such cases, if the trauma poses the greater immediate risk, the patient's condition may be stabilized initially in a trauma center before transfer to a burn center. Physician judgment will be necessary in such situations and should be in concert with the regional medical control plan and triage protocols
9. Burned children in hospitals without qualified personnel or equipment for the care of children
10. Burn injury in patients who will require special social, emotional, or rehabilitative intervention

Note. From "Burn Center Referral Criteria," by American Burn Association, n.d.-a, retrieved March 23, 2009, from http://www.ameriburn.org/BurnCenterReferralCriteria.pdf. "Guidelines for the Operation of Burn Centers" (pp. 79–86), In *Resources for Optimal Care of the Injured Patient Excerpted from 2006*, by American College of Surgeons, Committee on Trauma.

best-practice and evidence-based care. In most burn centers, the APN and nurses participate in telephone consultation with transferring hospitals concerning the ABA referral criteria (Table 2), Parkland formula guidelines, and calculating percentage of TBSA burned. Nurses are directly responsible for administering intravenous fluid and monitoring the patient. Throughout the first 24 hr after injury, it is crucial for nurses to remain vigilant regarding the timely and accurate administration of LR. If the patient fails to maintain minimum urine output levels or becomes hemodynamically unstable, the physician or APN must be notified immediately. Likewise, if urine output exceeds the anticipated amount, the physician or APN must be notified and fluid resuscitation titrated accordingly. Although the Parkland formula serves as a guideline for resuscitation throughout the initial 24 hr postburn, it is important to remember that the goal of resuscitation is to maintain adequate tissue perfusion while avoiding complications of over- or underresuscitation. The volume of resuscitation fluid infused should maintain a urine output of 30 to 50 ml per hour in adults and 1 ml/kg/hr in children. It is often necessary to modify the resuscitation formula and thus the infusion rate based on the patient's response to therapy. The APN can be a patient advocate by promptly responding to information regarding the progress of the resuscitation and ensuring that the fluid rate is adjusted as necessary for optimal patient outcomes. In addition, guided by APNs, nurses can participate in research studies, both at the design level and in data collection, to determine the best possible resuscitation methods for the burn patient including a clinical trial of a closed-loop monitoring system (Hoskins et al., 2006; Salinas et al., 2008).

IMPLICATIONS FOR THE APN IN THE BURN CENTER AND ED

The role of the APN is evident on many levels, encompassing all members of the healthcare team, the patients and families, and the system. As the literature suggests, the Parkland formula, when based on an accurate percentage of TBSA burned, can be a valuable tool for calculating the amount of fluid to be given during the initial phase of burn resuscitation. Many of the errors associated with fluid resuscitation stem from treatment at facilities that lack burn centers. Proactive establishment of collaborative relationships between the burn center and outlying EDs and prehospital personnel is essential for optimal patient outcomes. As the expert resource, the burn center APN can help facilitate the development of educational programs and competencies for those less familiar with burn injuries. By providing specific education related to stabilization, burn size estimation, and initial resuscitation, early over- or underresuscitation and resultant complications may be avoided.

Because transport time to a burn center may be several hours, the staff at the burn center should become immediately involved with caring for the patient by providing telephone consultation. Upon accepting the transfer, the burn center APN can assign an accurate percentage of TBSA burned to the patient based on either the description of the injury or real-time video in areas where telemedicine is available (Duchesne et al., 2008; Latifi, 2008). An APN who functions both as a collaborator and an educator can help ensure optimal patient outcomes. The APN can offer guidance to the outside hospital regarding type of fluid and rate of infusion by calculating the patient's fluid needs as anticipated by the Parkland formula. Until the patient arrives at the burn center, the APN should maintain contact with the transport team to ensure that the patient is receiving optimal care.

If the institution uses a resuscitation protocol, the staff nurse and APN should strictly adhere to it (Saffle, 2007). If the institution has no protocol, the APN should become involved in developing a protocol to ensure staff awareness and best practice. Resuscitation protocols need to be utilized both in the ED and in the burn center. The protocol should be designed to give the staff nurse the autonomy to titrate fluid based on the patient's response. A resuscitation protocol in the ED can help alleviate over- and underresuscitation issues and help guide those less familiar with burn resuscitation. However, the ED protocol must include guidelines for determining percentage burned as the research has shown that misestimation of burn size is a common problem for nonburn specialist. Fluid resuscitation must begin with an accurate calculation of the percentage of TBSA burned.

Partnering with the burn center APN, the ED APN can develop education and tools to assist the physicians, nurses, and support staff caring for the burn patient. Table 3 provides recommended content for classes.

In addition, valuable tools to assist the ED nurse can be developed by the APN. This can include a "Burn Book" with reference information. Laminated "Rule of Nines" diagrams that can be colored to replicate the burn injury and then used to calculate the percentage of TBSA burned could be extremely useful in prevention of misestimates of injury size and therefore under- or overresuscitation. Preprinted Parkland formula worksheets can be useful to calculate and monitor fluid administration.

Ongoing education is a must, particularly in the ED. Annual unit competencies can be developed for the care of the burn patient. The ABA offers the Advanced Burn Life Support (ABLS) course, which incorporates essential aspects of care needed by a burn patient in the first 24 hr postinjury. Nurses in the burn center should maintain ABLS certification and burn center APNs should consider attaining ABLS instructor status. Furthermore, ABLS is a valuable course to be considered by nurses, APNs, and physicians in the ED as well as by prehospital caregivers. The course may help improve healthcare provider's accuracy of burn estimation and the initial resuscitation of burn patients. The course consists of didactic presentations, case studies, and patient simulations designed to provide clinicians who rarely treat burn patients with the information necessary to assess and

Table 3. Content for in-services.

- Types of burns and corresponding unique considerations as applicable including age specific considerations
- Effects of over- or underresuscitation
  - Fluid creep, opioid creep, and deleterious effects
  - Calculating fluid resuscitation using the Parkland formula
  - Pediatric considerations
- Determining the % total body surface area burned using the Rule of Nines and Lund–Browder
    - Pediatric considerations
    - American Burn Association referral criteria (see Table 2)
    - Management principles
    - ABCs
  - Signs and symptoms of burn shock
  - Monitoring hemodynamic response to fluid resuscitation
  - Monitoring urine output as a guide to resuscitation
  - Initial wound management
  - Assessment of circumferentially burned extremities and management of edema formation
  - Compartment syndrome
  - Temperature control
  - Pain management and the effects of opioids in the resuscitation phase
- Associated trauma
- Patient and community education

stabilize burn patients during the first critical hours following injury and to identify those patients requiring transfer to a burn center (ABA, 2001a; Freiburg et al., 2007).

SUMMARY

The factors affecting fluid resuscitation are controversial. Numerous studies have demonstrated that both over- and underresuscitation can be dangerous and lead to a number of life-threatening complications. Burn specialists agree that close monitoring of patients while they are receiving resuscitation fluid is essential. Because opioids are a mainstay for pain control in the burn patient, resuscitation protocols in the burn center and ED should ensure best practice and give the nurse autonomy to titrate fluids based on specific parameters to help prevent fluid creep and/or opioid creep. If it becomes available, a "closed-loop" system may provide a more accurate method of monitoring the patient and help successfully guide resuscitation. Until then, the nurse must continue to be a patient advocate, follow resuscitation protocols if available, and diligently ensure that the patient is receiving the proper treatment. Working collaboratively, APNs in the burn center and ED provide education, essential tools, and assistance to the nurses to promote best-practice and evidence-based care. Furthermore, it is essential to establish collaborative relationships between the burn center and outlying EDs and prehospital caregivers. APNs can make an authentic contribution toward optimal care of the burn patient.

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