

Chapter 13

CRITICAL CARE AND ANESTHETIC CARE OF MILITARY BURN CASUALTIES AT ROLE 3 FACILITIES

CHRISTOPHER V. MAANI, MD^{*}; MICHAEL K. TIGER, MD[†]; AND JACOB J. HANSEN, DO[‡]

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^{*}Major, Medical Corps, US Army; Chief of Anesthesia and Perioperative Care, US Army Institute of Surgical Research & Army Burn Center, 3698 Chambers Pass, Fort Sam Houston, Texas 78234-6315

[†]Captain, Medical Corps, US Air Force; Anesthesiology Resident Physician, San Antonio Military Medical Center, 3851 Roger Brooke Drive, Fort Sam Houston, Texas 78234

[‡]Major, Medical Corps, US Army; Assistant Chief, Burn Anesthesia, US Army Institute of Surgical Research & Army Burn Center, 3698 Chambers Pass, Fort Sam Houston, Texas 78234-6315

INTRODUCTION

In the written history of wars and conflicts, burn injuries have been described for over 5,000 years. In the austere environment, military personnel are at risk of sustaining a variety of burn injuries, including flash injuries, flame burns, contact burns, scalds, chemical burns, electrical burns, and radiation burns. These injuries can result from both combat and noncombat (eg, waste burning, ammunition handling, gasoline) causes. The majority of combat burn injuries result from the detonation of explosive devices¹; these account for 63% of burn injuries among military personnel. In addition, a military combatant may sustain several types of burn injuries in a single incident. Specific types of burns, risks, morbidity, and mortality are beyond the scope of this discussion.

In Operation Iraqi Freedom and Operation Enduring Freedom, one of the challenges faced by military anesthesiologists was the treatment of the severely burned soldier. Current burn care capitalizes on the recent advancements in evacuation times from point of injury through Landstuhl Regional Medical Center in Germany, to the US Army Institute of Surgical Research (USAISR) Burn Center at Brooke Army Medical Center, Fort Sam Houston, Texas. The USAISR Burn Center is the Department of Defense's only military facility

treating severely burned soldiers. Between January 2001 and December 2010, 691 military burn casualties were admitted to USAISR (Jackson BA. Data from US Army Institute of Research Burn Program Manager, Fort Sam Houston, Texas; December 2010). Of these, 216 casualties (31%) had a total burned surface area (TBSA) of over 20%, compared to only 13% of civilian patients treated nationally with that extent of TBSA.² In addition to their burn injuries, military burn casualties are often subjected to polytrauma. To date, more than 50% of burn patients admitted to the USAISR had at least one other significant injury, most commonly a fractured extremity.³

In the forward deployed environment, burn casualties may initially be treated with the surgical and medical management necessary to save life, limb, and eyesight in the same way as other trauma patients; however, burn casualties have perioperative anesthesia concerns distinct from other surgical populations. These require consideration and planning by the anesthesiologist and surgical team to obtain optimal outcomes. This chapter is written to serve as a guide to anesthesiologists who may have limited experience with burn casualties, and will discuss the practical issues that may be encountered in treating these patients.

ACUTE THERMAL INJURY

The first 24 to 48 hours after a major burn is commonly referred to as the resuscitation phase. The patient will often be treated with massive intravenous (IV) fluids to maintain intravascular volume and urine output. There are several formulas that may guide this therapy (Table 13-1), but the amount is usually titrated to maintain urine output between 0.5 and 1 mL/kg/h.^{4,5} Over-resuscitation must be avoided because it leads to increased edema and related complications.⁶ During this phase the patient may require escharotomy or fasciotomy to preserve blood flow to extremities or to allow ventilation. Less commonly, a laparotomy is required to treat abdominal hypertension. Blood transfusion is typically not required during these early procedures, because these patients have very low blood loss and their measured hematocrit is commonly normal to high, assuming they have not lost blood from a nonburn injury. Nonburn injuries may also mandate other operative procedures during this phase, such as definitive control of exsanguinating bleeding, neurosurgical management of head injuries, and surgical stabilization of severe orthopedic or musculoskeletal trauma. In most cases, when performing procedures during the resuscitation phase, it is helpful to keep in mind the goal of maintaining organ perfu-

sion as demonstrated by urine output, rather than by volume loading to intravascular euvolemia.

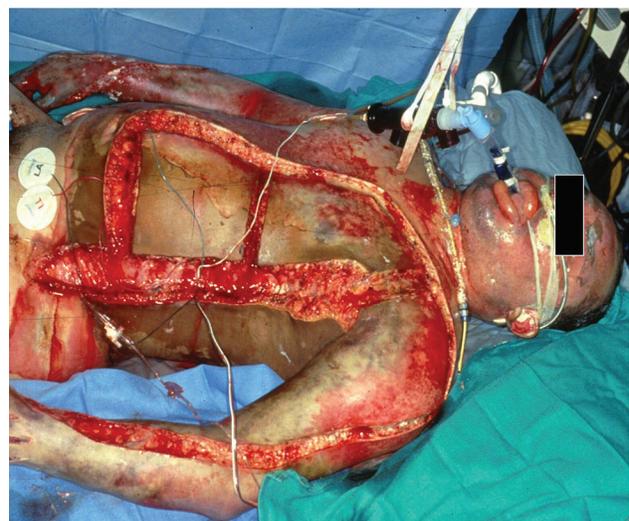


Figure 13-1. Patient with difficult airway and escharotomies performed to facilitate ventilation as well as prevent compartment syndrome of extremities and abdomen.

TABLE 13-1

VARIOUS INTRAVENOUS FLUID RESUSCITATION FORMULAS FOR THE ADULT BURN PATIENT

| Formula | First 24 Hours Post-Burn | Second 24 Hours Post-Burn |
|--------------------|--|--|
| Burn Budget | LR: 1,000 mL–4,000 mL 0.5 NS: 1,200 mL Colloid: 7.5% of body weight Glucose in water: 1,500–5,000 mL | LR: 1,000 mL–4,000 mL 0.5 NS: none Colloid: 2.5% of body weight Glucose in water: 1,500–5,000 mL |
| Monafo Hyper-tonic | 250 mEq Na, 150 mEq lactate, 100 mEq Cl with volume adjusted to maintain UOP of 30 mL/h | 0.5 NS with volume adjusted by urine output |
| Brooke | LR: 1.5 mL/kg/% TBSA Colloid: 0.5 mL/kg/% TBSA D5W: 2,000 mL | LR: 0.5 mL/kg/% TBSA Colloid: 0.25 mL/kg/% TBSA D5W: 2,000 mL |
| Modified Brooke | LR: 2 mL/kg/% TBSA, with half the volume given during the first 8 h and half over the next 16 h | Colloid: 0.3–0.5 mL/kg/% TBSA D5W: to maintain UOP |
| Parkland | LR: 4 mL/kg/% TBSA Colloid: 0.5 mL/kg/% TBSA D5W: 2,000 mL | Colloid: 20%–60% of calculated plasma volume D5W: To maintain UOP of 0.5 mL/kg/h |
| Modified Park-land | LR: 4 mL/kg/% TBSA Colloid: 0.5 mL/kg/% TBSA D5W: 2,000 mL | 5% albumin at a rate of 0.3 mL/kg/% TBSA 16 per h |
| Evans | NS: 1 mL/kg/% TBSA Colloid: 1 mL/kg/% TBSA D5W: 2,000 mL | NS: 0.5 mL/kg/% TBSA Colloid: 0.5 mL/kg/% TBSA D5W: 2,000 mL |

LR: lactated Ringer solution; TBSA: total body surface area; D5W: 5% dextrose in water; NS: normal saline; UOP: urine output

Data sources: (1) Monafo WW. Initial management of burns. *N Engl J Med.* 1996;335:1581–1586. (2) Warden GD. Burn shock resuscitation. *World J Surg.* 1992;16:16–23.

Anesthesiologists may be called on during this period to intubate burn casualties as ventilatory or respiratory failure is commonly encountered during the resuscitation phase. For patients with burns as their sole injury, those with burns of less than 40% TBSA rarely require intubation, and those with burns of greater than 60% TBSA almost always require intubation. Casualties with inhalation injury may require intubation regardless of the size of their burns. Of note, military burn casualties often present with difficult airways (Figure 13-1) and have a higher percentage of inhalational injury (10.3% with inhalational injury, compared to 5.7% of patients from the 2006 National Burn Repository report).⁷ Generally, intubation should be done earlier rather than later in these patients, but it is usually an urgent rather than an emergent procedure. It is paramount to utilize allotted time to optimize and prepare for the procedure. A hastily and poorly planned intubation may bear disastrous consequences.

The decision of whether or not to intubate a given patient in the acute setting often requires considerable judgment. To the astute anesthesiologist, subtle clues such as a subjective change in the patient's voice may tip the decision. The decision having been made, the conduct of acute-phase intubations generally does not require any unusual considerations beyond those for any other trauma patient. If the decision is delayed until the patient is in respiratory distress, the time remaining before hemodynamic compromise may be abridged. Larger endotracheal tubes are much preferred due to the likely need for bronchoscopy and effective respiratory care, including frequent suctioning to clear bronchial clots and mucus plugs. In an emergency situation, a clinician may decide to initially secure the airway with a smaller tube if airway edema makes placement of a larger tube difficult. The smaller tube may then be changed under controlled circumstances, even in the operating room if necessary.

NONSURGICAL BURN CARE

Nonsurgical care of burn wounds is continuously evolving and remains dynamic as new technologies and pharmaceuticals emerge. Antibiotic creams and solutions are often used on partial or full thickness burns. Silver sulfadiazine (Silvadene [King Phar-

maceuticals Inc, Bristol, TN]) and mafenide acetate (Sulfamylon [Mylan Inc, Canonsburg, PA]) are the most commonly used agents. Silvadene is considered less painful to apply but does not penetrate intact burn eschar. Silvadene may also cause signifi-

cant leukopenia, typically in the first few days of use.⁸ Sulfamylon penetrates burn eschar but can be painful to apply. Sulfamylon is a carbonic anhydrase inhibitor.⁹ There are conflicting studies on how often this produces a significant metabolic acidosis.^{9,10} In casualties with large burns or renal failure, a hyperchloremic metabolic acidosis is occasionally

seen that may be attributable to Sulfamylon and may not resolve until the drug is withdrawn. Silver nitrate is also effective but not frequently used due to its staining ability and lack of superiority over other agents. Other dressings and agents that may have anesthetic considerations are in continuous development.

EXCISION AND GRAFTING

Full-thickness burns, unless miniscule burns, must be treated with excision and grafting. Partial-thickness burns may require excision and grafting or may be treated nonsurgically depending on depth, size, and location. Excision of burned skin and placing skin grafts is the mainstay of burn surgery. There is some controversy over the exact timing of this surgery, but most centers conduct the first operation within a few days of the patient being burned. Over the years, the definition of early excision has changed somewhat, with "early" becoming progressively earlier. Previously, burns were left to slough off weeks after injury, and any excision before then was considered early. Currently, an excision within 48 hours of injury would be considered early. Some surgeons will operate as soon as possible, while others prefer to wait 48 hours to allow the patient to undergo complete initial resuscitation.^{11,12} There is no clearly optimal timing for all patients.^{12,13} Some surgeons will restrict the scope of the operation to 20% TBSA to minimize blood loss, surgical time, and length of exposure to anesthetic agents. Other surgeons prefer to remove as much of the burn as possible, if not all, on the first procedure. This variability in treatment necessitates situational awareness, communication with the surgical team, and a flexible anesthetic plan.

Excision may be either tangential, in which the burn is shaved off until unburned tissue is reached, or fascial,

in which all skin and underlying fat is removed down to fascia, usually by using an electrocautery device. Tangential excision generally produces a better functional and cosmetic result. Fascial excision may be faster and usually involves less blood loss. Whichever method is chosen, these procedures can be unexpectedly bloody, with blood loss varying from 123 mL to 387 mL for each 1% of TBSA excised.¹⁴⁻¹⁶ The larger amount of blood loss arises during operations when multiple surgeons and physician assistants simultaneously excise the majority of burned skin during the initial surgical procedure (Figure 13-2). Also, greater degrees of blood loss are typically seen with older burns, infected burns, and extremity burns.¹⁶ Less blood loss is associated with fascial excisions, fresh burns, and more centrally located burns. The use of tourniquets and fibrin glue may reduce blood loss substantially.¹⁵

Harvesting of the skin graft may also produce considerable blood loss, especially if the scalp is harvested. Infiltration of epinephrine solution in the area to be harvested can reduce or eliminate this blood loss.¹⁷ Pitkin solution is lactated Ringer solution with 1 to 2 mg of epinephrine per liter. Other combinations of vasoconstrictors in crystalloid solutions are likely equally effective. Postoperatively, most patients report that the site of graft harvest is much more painful than the site of the excised burn. This should be considered if regional anesthesia is part of the plan.

OPERATING ROOM SET-UP

In the deployed and austere environment, supplies and resources for the anesthesiologist may be limited, and improvising is often necessary to ensure good anesthetic outcomes. Taking this into consideration, the following recommendations are best suited for higher echelons of care at military treatment facilities and the definitive care at established burn centers.

All standard anesthesia equipment should be present and machine checks done as for a routine case. The room should be heated to 90°F or as close to that as possible. Commonly, the entire patient's body must be exposed, thus limiting the usefulness of warming blankets. The inability of damaged skin to mitigate heat

loss often makes maintaining normothermia an anesthetic challenge (Figure 13-3). As previously discussed, burn injured patients frequently present with difficult airways; it is often necessary to have alternative means of securing the airway beyond direct laryngoscopy. An anesthesiologist may be best served by having emergent airway adjuvants immediately available, as well as video-assisted or fiberoptic devices if possible.

A rapid infusion system capable of warming and infusing blood at 200 mL per minute should be available. Blood should be cross-matched, and two to six units, depending on the circumstances, should be immediately available. For large excisions, 10 to 20

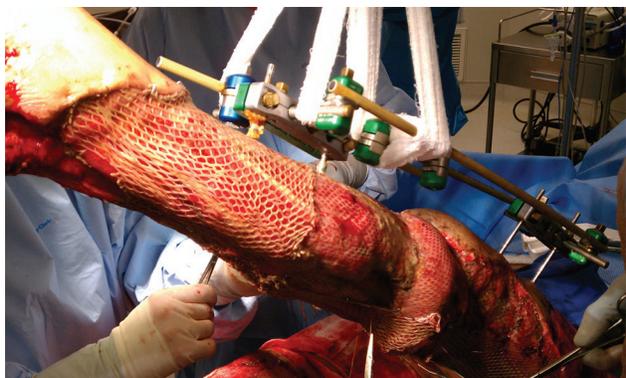


Figure 13-2. This figure illustrates the appearance and placement of a partial thickness skin graft on extensive soft tissue injury of a left lower extremity. Note the external fixating device used to stabilize multiple concurrent fractures.

units of packed red cells may be needed over several hours. Platelets and plasma may also be required for larger excisions, even if the patient starts with normal coagulation. Additional IV or central line supplies should be in the room.



Figure 13-3. Excision and grafting of a severely burned patient. Note the typical amount of exposed body surface area. Extensive surface exposure and damaged skin can make maintenance of normothermia a challenge. In this photo partial thickness autografts are being harvested from the patient's left thigh for grafting onto his left arm. Also note the instrumentation used to harvest skin (top left), and apparent blood loss.

PATIENT EVALUATION

Some burn casualties will be extremely ill when scheduled for surgery. In addition to any preexisting disease, burn casualties often have concurrent coagulopathy, hemodynamic variability, and limited oxygenation/ventilation, and they may also be septic from wound infections. It is paramount to realize the patient may not improve until the burn is removed. For example, abdominal compartment syndrome or chest eschar that inhibits patient ventilation can be immediately resolved by surgical intervention. The question to ask is whether there is a problem that can clearly be improved with nonsurgical treatment. If the answer is no, needed surgery should not be delayed.

In addition to the standard preoperative evaluation, several areas dictate extra attention to detail when accessing burn casualties:

- **Airway.** Mask ventilation may be difficult for patients with burn cream on their faces. A standard hand towel may be used to give the hands additional traction on the face, and two-handed masking may be required. Bandages may also be present on the face, making a mask seal quite difficult (Figure 13-4). Patients in the early stages of care may have a tracheostomy. When a patient is no longer ventilator dependent but may require more

surgical procedures, surgeons may wish to remove the tracheostomy tube. The anesthe-

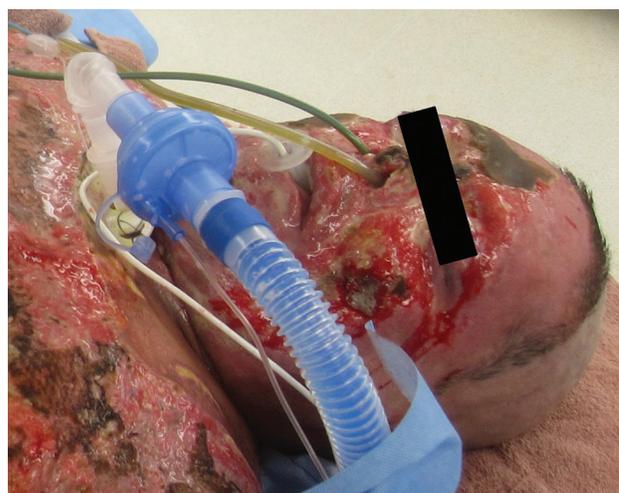


Figure 13-4. With this patient's injuries (without tracheostomy), mask ventilation, securing an endotracheal tube, and providing eye protection may be challenging. Note that the oral airway is being utilized to monitor SpO₂ (oxygen saturation) from the patient's hard palate because of this patient's extensive extremity burns.

siologist should be involved in this decision. Patients with longer times since their injury may develop scarring that limits mouth opening or neck extension. This should be evident from routine examination and may indicate a plan that does not rely on a laryngoscope. For patients who will be intubated in the operating room, some means of securing the position of the endotracheal tube other than adhesive tape should be used. Cloth ties are commonly used, and suturing to a tooth is another viable option. Nasal intubation with cloth ties around the nasal septum is also quite effective.

- **Pulmonary.** The fraction of inspired oxygen (F_{iO_2}), ventilator pressures, and arterial blood gas are very useful in preoperatively evaluating pulmonary issues. Burn patients routinely have higher than normal minute ventilation.⁹ High F_{iO_2} and ventilator pressures combined with poor arterial blood gas signal possible difficulty in the operating room. Patients with inhalation injuries frequently produce plugs or clots that can obstruct an endotracheal tube. This is particularly concerning in a patient who will be placed in a prone position. The combination of marginal lung performance, clot production, and prone position can result in a rapidly fatal loss of airway. The anesthesiologist should have a plan for dealing with a plugged prone tube beforehand and communicate that plan to the rest of the operating room crew. Very ill patients may need to remain on an intensive care unit (ICU) ventilator rather than using the anesthesia machine. In this case, the anesthetic plan will require an IV anesthetic. Patients with high ventilator pressures and high inspired oxygen levels may desaturate very rapidly when disconnected from their ventilator, even briefly. This should be considered when planning patient transportation, and alternative plans to maintain positive end expiratory pressure should be utilized, such as clamping the endotracheal tube or placing a positive end expiratory pressure valve during mask-bag ventilation.
- **Circulation.** Patients who survive their initial injury and shock have essentially passed a stress test. These patients should not require further cardiac evaluation except in unusual circumstances. A large burn frequently results in a rise in troponin, even in patients who do not have cardiac disease.¹⁸ Burn patients are typically hyperdynamic and may remain so

for weeks or months after their injury. Heart rates in adults of 110 to 120 beats per minute are typical.¹⁸ If a patient is hypotensive early in resuscitation, preload is frequently inadequate; later in the course, afterload is more commonly the cause, but either or both may be present. The patient will frequently require blood transfusion. Knowing the hematocrit at the start of the procedure will help guide the timing and volume of blood products. Critically ill patients with multiorgan dysfunction may require platelets or plasma, as will patients undergoing large excisions. Most patients are treated with some form of thromboprophylaxis. This will be a consideration if nerve blocks or neuraxial anesthesia is planned.

- **Neurologic.** The primary neurologic issues are pain control and sedation. Patients may be receiving substantial doses of narcotic or sedative drugs and remain surprisingly awake.¹⁹ Verifying the patient's level of consciousness and drug doses can help with planning the amounts needed in the operating room.
- **Vascular access.** A well-running 18-gauge IV is sufficient for most cases, as is a well-running central line. A second IV usually provides more than enough access. An introducer is needed only for the largest cases. Some planning is required for smaller lines. Fluid therapy or blood transfusion may need to be initiated earlier if multiple large-bore catheters are not available. An arterial line can be very useful for larger excisions, for both monitoring and lab draws. An arterial line may also be indicated if the surgical plan leaves no suitable site for a noninvasive blood pressure cuff. Placement of all lines must be made with the surgical plan in mind. Placing a line in or near an area to be excised or harvested should be done only if there are no better alternatives. Catheters are prepped into the surgical field when necessary. Even peripheral IV catheters are routinely secured with sutures when fundamentals such as burn creams or prep solutions can render tape useless.
- **Nutrition.** Nutrition is very important to burn healing, and the acute burn casualty generally will have an increased metabolic rate. Thus nonoral nutrition times should be minimized whenever possible. For patients with feeding tubes beyond the gastric pylorus, feeds may be continued until transport to the operating room. There is some controversy about the

need to stop feeds even then. The reasoning for stopping feeds in the operating room is that the patients frequently are treated with vasopressors during and after surgery; it may be detrimental to have feeds continuing at the same time. Patients who are able to eat should generally be allowed to do so until 6 to 8 hours prior to their surgical time.

- **Drips and drugs.** Patients may be on many different infusions, especially in the ICU.

Generally, any infusion that is not absolutely necessary is stopped prior to transport to the operating room. This minimizes the equipment needed to transport the patient and reduces the chance of errors, which is especially important in regard to concentrated electrolytes. Preoperative antibiotics are frequently delayed or overlooked. It is worthwhile to verify that any antibiotics ordered have been given.

INTRAOPERATIVE ANESTHETIC MANAGEMENT

Once the patient has been transported to the operating room, the next step is induction of anesthesia. Consideration should be given to induction on the patient's bed if movement is especially painful; however, this is secondary to optimizing a safe and controlled method of securing the patient's airway. Monitor placement and induction are generally routine, with a few exceptions. Monitor placement may be limited by injuries and dressings. Standard electrocardiogram lead placement is rarely essential, and leads may be placed where space can be found. Ordinary leads may not stick to burn patients but may be stapled in place after induction. Noninvasive blood pressure cuffs work surprisingly well over most dressings, but arterial lines are sometimes needed.²⁰ Creativity may be needed in placing a pulse oximeter. Other than fingers and toes, the ears, nose, lips, forehead, and hard palate (via an oral airway) are some of the sites that may be successful (see Figure 13-4). Exhaled carbon dioxide monitoring is essential in burn patients. It is a reliable indicator of adequate ventilation, as well as a rough guide to cardiac output, and it is the monitor least likely to fail in these patients. Temperature monitoring is almost always used. Inability to maintain a temperature of 36°C warrants maximum effort to warm the patient. A Foley catheter should be used for most cases. Movement of patients to or from the operating table is a high risk period for the inadvertent removal of line or tubes. Several people may be involved in this movement, and one of them should be identified to ensure lines and tubes are in position for movement.

Induction of anesthesia usually involves muscle relaxant drugs. Succinylcholine is widely recognized as being contraindicated in burn patients. Succinylcholine is safe for the first 24 hours after a burn, but beyond that period and for up to a year after healing it may cause a dramatic and fatal hyperkalemia.²¹ Nondepolarizing muscle relaxants are regularly used in burn patients, with the understanding that they will require larger doses and will not last as long as in patients without burns.²² The exception to that rule is

mivacurium, which lasts as long or longer in burned patients as unburned patients.²³ Some patients develop a hyperreflexia that is commonly elicited when lifting a leg. This can produce jerking that only stops with muscle relaxation. Aside from that situation, muscle relaxants are generally not required beyond intubation.

Burn patients may be tolerant to opiates, especially if they have been given large doses for several days, but they generally respond normally to the usual induction agents. The burn patient also tends to have an attenuated response to catecholamines. They may require doses of phenylephrine (or other pressors) considerably higher than do unburned patients to achieve the expected hemodynamic response.

Patients who do not require an ICU ventilator may be given inhalational anesthesia. Potent inhalation agents supplemented with opiates work well for most patients. If an IV anesthetic is chosen, propofol supplemented by opiates works well. For patients with a large blood loss, the propofol infusion may have to be decreased to very low rates, even in well resuscitated patients.²⁴ Ketamine has been a traditional choice in burn patients and works well either as the main agent or as a supplement to other IV agents.²⁵ Emergence delirium is seldom an issue in critically ill ICU patients, who are generally maintained on sedatives for days after their surgery. Despite its reputation, long term psychological effects have not been documented with ketamine.²⁶

Once the patient is prepped, the operation may begin. Blood loss during the excision portion may be dramatic, with 1 to 2 liters lost in a short period of time. Large excisions may cause the loss of 5 or more liters over the course of a few hours (see Figure 13-4). When to transfuse is a decision that must be based on individual circumstances. Healthy young adults can easily tolerate hematocrits of 20 or even less. Once the hematocrit drops below 18, the patients typically become hypotensive and poorly responsive to pressors. Older, less fit patients may be less tolerant of anemia. As a general rule, if the patient is hypotensive,

it is rarely wrong to initiate red blood cell transfusion while investigating the cause, especially if the patient is not responding well to fluid and phenylephrine. The choice between crystalloid and colloid will vary. At many burn centers, the principal IV fluid is Plasma-Lyte (Baxter, Deerfield, IL). Plasma-Lyte is not as acidic as saline and is compatible with blood products. The quality of IV access and speed of blood loss will also influence the timing of transfusion. Some patients will require multiple units of packed red blood cells to be transfused in a short period of time. This may lead to decreased ionized calcium in the patient's blood and the need for IV replacement.^{23,24} With larger excisions, other blood products such as plasma and platelets are commonly required. The need for non-red cell blood products varies considerably from case to case and is usually driven by laboratory values, clinically observed bleeding, and the judgment of the staff involved. Recombinant activated Factor VIIa and antifibrinolytics have been used occasionally in cases involving large blood loss, but at present no data proves it is helpful.

For larger excisions or unstable patients, obtaining frequent blood gas measurements may be helpful. The base deficit and hematocrit will guide the choice and amount of fluids used. Venous blood gasses may be used for this purpose if an arterial line is not in place. "Arterialized" venous blood, as it is sometimes called, can be drawn from the distal extremities such as the back of the hand for a more accurate venous estimation of an arterial blood gas. Urine output or lack of it may also guide volume replacement. It is not uncommon to require vasopressors to maintain adequate blood pressure after surgery has begun. This may be due to the release of bacteria or other factors during excision of the wound. Vasopressin, norepinephrine, and

phenylephrine are commonly used with effectiveness that varies from patient to patient, but it is essential to keep in mind that the severely burned patient may be catecholamine depleted and thus require larger than anticipated doses of vasopressor agents. Care must be taken to ensure that anemia or lack of preload is not the cause of hypotension before relying on vasopressors to maintain blood pressure.

If blood loss gets ahead of the resuscitation during surgery, it may be necessary to ask the surgeon to stop so the anesthesiologist can continue resuscitation. The basic life support rule of holding pressure to stop bleeding can be very effective. Epinephrine-soaked lap pads are employed to assist in hemostasis. Patients tend not to show a significant response to the epinephrine.¹⁵ Patients may also receive several milligrams of subcutaneous epinephrine from Pitkin solution without change of heart rate or blood pressure. Halothane has a long history of use in burn patients, but may not be desirable when epinephrine is used to assist with hemostasis, due to the risk of ventricular arrhythmias. At least one study, however, has shown halothane to be safe in this situation.²⁷ In cases of large burns, the patient may receive several liters of Pitkin solution mobilized over the following 24 hours, along with IV crystalloids. This volume must be considered when making decisions such as whether to extubate a patient after surgery.

After skin grafts are placed, they may be covered with a negative pressure dressing or conventional gauze dressings. At this point, protecting the graft from shearing is very important. A smooth, pain-free wakeup will help prevent patient thrashing that may shear the grafts. Narcotic should be titrated to respiratory rate. As noted earlier, patients may require large doses.

POSTOPERATIVE CARE

ICU patients are returned to the ICU and the care of the surgeon or ICU team. With few exceptions, patients should be monitored during this transport. It may also be reasonable to transport them with additional sedating and vasoactive medications, depending on the patient's postoperative stability. Once in the ICU, the anesthesia team should ensure that the patient is rapidly connected to the ICU monitors. If it was necessary to start any vasopressors during the case or if the patient has been unstable, the anesthesiologist should ensure that the physician responsible for the patient in the ICU

is aware of these issues and present to manage them.

Ward patients may be taken to the recovery room and treated in the standard fashion. Patients with negative pressure dressings in place should be reconnected to suction without delay. Pain control usually requires treatment with opiates. Morphine, hydromorphone, and fentanyl titrated to effect work well. Meperidine is not used due to the potential for toxic metabolites to accumulate.²⁸ Methadone has also been used successfully, sometimes when other opiates have failed.²⁹

PROCEDURES OUTSIDE THE OPERATING ROOM

Burn patients often require wound care that may be quite painful. Surgeons will commonly attempt to

treat these patients with a combination of benzodiazepines and opiates. Some patients cannot tolerate

their care without more profound acute pain control. Wound care procedures are often done in a shower room. Sometimes this may involve removing large adherent dressings or debriding wounds. Aggressive wound care can help some patients avoid the operating room. Numerous regimens are acceptable for this sort of pain control. Choosing a plan that is familiar and comfortable for the anesthesiologist is probably more important than any particular drug selection. Propofol infusions can be very effective for these procedures. Infusion rates of 50 to 200 $\mu\text{g}/\text{kg}/\text{min}$ are well tolerated. Patients frequently re-

quire jaw lift to maintain spontaneous ventilation, especially after a bolus dose, but apnea is very rare if opiates have not been added. If propofol alone is inadequate, small doses of ketamine can be added, typically 10 to 20 mg at a time, up to 1 mg/kg. These cases are routinely performed without need for positive pressure ventilation or supplemental oxygen. Pulse oximetry is sufficient monitoring for most patients in this situation. Exhaled carbon dioxide monitoring can also be very reassuring if it is available. Additional monitors may be considered based on individual patient issues.

ELECTRICAL INJURIES

Electrical injuries, while similar to other burns, have a few distinctions. There may be extensive underlying tissue destruction beyond the obvious contact point, especially with high voltage injury.³⁰ Muscle destruction is common with electrical injury; monitoring potassium, creatine kinase levels and serum urea nitrogen/creatinine is mandatory for electrical

injuries. Patients with electrical injuries are usually monitored in an ICU for 24 hours, even with small burns, to observe for cardiac arrhythmias. That said, malignant cardiac arrhythmias are rare.^{31,32} Patients with electrical injury commonly have a superimposed thermal burn injury if the electrical current has ignited their clothing.

NONTHERMAL SKIN DISEASES

Any injury or disease that causes a significant loss of skin may be suitable for treatment in a burn unit. One of the most common disorders is toxic epidermal necrolysis syndrome (TENS). TENS has a reported 30% to 50% mortality rate.³³⁻³⁵ The disease causes a partial thickness skin injury that may also involve the mucosal membranes. TENS does not usually require skin grafting, but the anesthesiologist may be involved for airway issues. An important consideration is that mucous membranes may slough and cause bleeding with manipulation. Direct laryngoscopy in a TENS

patient may result in bleeding sufficient to obscure the view of the airway. The first attempt at laryngoscopy may provide the only good view, and fiberoptic bronchoscopy may be difficult or impossible afterward. This should be considered when planning to secure the airway. TENS patients may also produce plugs that can acutely obstruct an endotracheal tube.

Other skin disorders, such as pemphigus vulgaris, may be treated in a burn unit from time to time, but rarely pose an issue not already considered in the care of burn patients.

CONCLUSION

Burn patients often return to the operating room multiple times over the course of weeks to years. This provides an opportunity for continuity that anesthesiologists seldom get with other patients, as well as the satisfaction of seeing patients progress from critically ill to recovered and functional. Providing anesthetic services to the burn casualty requires knowledge of, and preparation for, several specific issues. The severely burned military casualty is one of the most challenging patient populations to be cared for by perioperative providers and anesthesiology teams alike. In the face of difficult

airways, poor IV access, hypermetabolic states with significant challenges in supporting adequate caloric intake, hemodynamic instability associated with burn shock and cardiovascular compromise often requiring multiple vasoactive infusions, and frequent surgical interventions and painful rehabilitation, provision of care to this select population requires knowledge of and preparation for the many specific issues discussed in this chapter. With proper planning and close coordination with the burn care team, these patients can be cared for effectively, safely, and compassionately.

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