Difficult Airway Management Following Severe Gasoline Burn Injury: A Case Report

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Airway management following severe gasoline burn injury can be difficult. Because patients with severe burns may be treated at a variety of hospitals that provide emergent care, it is valuable for Certified Registered Nurse Anesthetists who work in such facilities to have an understanding of the care of these patients. Airway management is an extremely important consideration in the care of burn victims. If not done in a timely manner, lethal complications may result.

This article reports the experience of caring for a female who was involved in an altercation, doused with gasoline, and set on fire. Consequently, airway obstruction developed and progressively worsened. Airway management interventions began with bag-valve-mask-assisted ventilation and progressed through orotracheal intubation attempts, attempts to insert a laryngeal mask airway, cricothyrotomy, emergency tracheostomy, and surgical tracheostomy.

Keywords: Airway management, burn injury, emergency tracheostomy, inhalation injury.

Airway management following severe gasoline burn injury can be difficult. Because patients with severe burns may be treated at a variety of hospitals that provide emergent care, it is valuable for Certified Registered Nurse Anesthetists (CRNAs) who work in such facilities to have an understanding of the care of these patients. Airway management is extremely important in the care of burn victims, because, if not done in a timely manner, lethal complications may result.

This article reports our experience of caring for a female who was involved in an altercation, doused with gasoline, and set on fire.

Case Summary
A female who was involved in an altercation, doused with gasoline, and set on fire presented to our emergency department (ED) as a priority 1 trauma. Her height and weight were not known. Her ASA physical status was 5E.

The patient was experiencing respiratory distress with a partially obstructed airway when emergency medical technicians (EMTs) arrived at the location where she was injured. They attempted to intubate her but were unable to do so because of upper airway edema and limited range of motion of her neck; therefore, the EMTs assisted her spontaneous respirations with a bag-valve-mask device with 100% oxygen and brought her to the hospital ED.

The patient was conscious, and she attempted to follow commands during the initial assessment but was unable to speak because of second- and third-degree burns to her lips, tongue, face, and mouth. It was not possible to obtain a reliable health history. Additionally, she suffered third-degree burns on her neck, torso, and both upper extremities. Using Wallace’s rule of nines, the trauma surgeon determined that her total body surface area (TBSA) that was burned was 42% (Figure).1

The EMTs had inserted 3 small peripheral intravenous (IV) lines containing 0.9% saline into her lower extremities. Upon arrival at the ED she received 650 mL of IV fluids. For analgesia and sedation she was given morphine, 10 mg, and diazepam, 5 mg, IV. The patient’s natural airway was partially obstructed because of edema from extensive third-degree facial and pharyngeal burns. Her face and lips were badly burned and swollen, and her hair was singed or absent. The patient had soot coming from her mouth and nose. The tongue was swollen and blackened, as were her teeth.

Her initial vital signs were as follows: blood pressure, 154/99 mm Hg; heart rate, 122/min; and saturation of hemoglobin with oxygen (SpO₂), 90% to 100%. Her rapid, shallow respirations were assisted via bag-valve-mask device. Her Glasgow Coma Scale score was 14. It was possible to obtain only a limited number of blood chemistry results because of hemolyzed blood samples; however, the following values were obtained: carboxyhemoglobin, 8.2%; platelets, 476 × 10³/μL; lactic acid, 6.2 mmol/L; ionized calcium, 1.06 mmol/L; prothrombin time, 11.2 seconds; partial thromboplastin time, 22.5 seconds; and international normalized ratio, 1.08. Breath sounds were diminished with bilateral rhonchi, and respirations were labored.

The CRNAs were present in the ED with emergency airway devices and medications when the patient arrived. Because of her deteriorating respiratory status, the deci-
The patient was then ventilated with 100% oxygen by bag-valve-mask device until a video laryngoscope (GlideScope, Verathon) was brought from the surgical suites. Even with video laryngoscopy, it was not possible to visualize laryngeal structures or to insert the endotracheal tube into the trachea. Two attempts were then made to insert a size 3 laryngeal mask airway (LMA, LMA North America Inc), but ventilation with this device was also unsatisfactory, so it was removed, and bag-valve-mask-assisted ventilation with 100% oxygen was resumed.

While still in the ED, the decision was made with the trauma surgeon to perform a cricothyrotomy. The patient's trachea was in the midline; however, because of extensive edema and disfiguration of her neck, it was difficult to evaluate and appreciate any anatomical landmarks. Neck mobility was also impaired. With much difficulty, the trachea was identified with a needle and syringe. A guidewire was passed through the needle into the trachea. At this point, the patient's respirations were rapid and shallow, and her SpO$_2$ was approximately 60%. The surgeon was unable to pass the tracheal dilator and tracheostomy tube, so the needle and guidewire were removed, and a direct cut down into the trachea was performed. A 5.5-mm endotracheal tube (ETT) was inserted into the trachea, and the cuff was inflated to a minimally occlusive volume. She was ventilated with 100% oxygen. Bilateral breath sounds and end-tidal carbon dioxide were present.

Once the ETT was in place, the patient's SpO$_2$ returned to approximately 96%. With positive pressure ventilation, her chest excursion improved, but chest compliance was decreased. As care continued, the patient experienced oxygen desaturation falling to 40%, even following suctioning. We suspected that the ETT had migrated into the right bronchus because of difficulty in securing the ETT to the patient's swollen, blistered neck. The ETT was cautiously repositioned, and she was aggressively ventilated until her SpO$_2$ rose to 90%.

The decision was made to take the patient to the operating room for tracheostomy and escharotomy in order to obtain a more secure surgical airway and to improve chest excursion. The surgical team placed a 12F triple-lumen catheter in the patient's left femoral vein in preparation for the procedure.

The patient was transferred to the operating room with the 5.5-mm ETT in place. Standard monitors were applied. Lactated Ringer's solution was given rapidly through all 3 lumina of the femoral vein catheter. The patient was connected to the breathing circuit of the anesthesia machine and was given 1.5% to 3.0% sevoflurane in 100% oxygen along with IV cisatracurium, 20 mg. The patient was hand ventilated for the entire case in order to continually evaluate lung compliance. Even with small rapid breaths, airway pressures were as high as 46 cm H$_2$O during the operation. Forced warm-air heating was applied, since hypothermia can have perilous consequences for burned patients.

The surgical team performed the tracheostomy, placing a 7-mm Shiley tracheostomy tube. This was secured with circumferential cotton ties. The estimated blood loss was 100 mL. Because of reduced chest compliance, the anesthesia team still experienced difficulty ventilating the patient, although her SpO$_2$ was 100%. The trachea was suctioned several more times, but that did not improve

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Figure. The Rule of Nines

The rule of nines is one way to calculate the percentage of body surface involved in a burn. Specific areas are assigned percentage values as follows: head and neck, 9%; front part of the torso, 18%; back part of the torso, 18%; arms, 9% each; legs, 18% each; and pubic area, 1%.

(Permission to reprint from the Mayo Clinic.)
the ventilation. The surgical team then performed escharotomies on the patient’s chest and arms. Unfortunately, these interventions did not improve chest excursion, most likely because of burn injuries to the lower airways. At this point, she had received 3,750 mL of crystalloid fluids. Because of the busy nature of the case, urine output and body temperature in the OR were not recorded.

Following completion of the surgery, the patient was given 3 mg of hydromorphone and was transferred to the intensive care unit to prepare for transport to a regional burn center. Two months later, the patient died in the regional burn center of complications of her injuries.

Discussion
This case report describes our experiences in caring for a patient who was severely burned on the face, neck, chest, and arms, and who suffered inhalation burns. Airway management in the thermally injured patient presents a host of complex problems. Even in the hands of experienced practitioners, success is not ensured. Edema, bleeding, loss of tissue elasticity, cervical spine immobility, debris in the airway, and pain can contribute to difficulties in airway management for the burned patient. Burns are responsible for substantial mortality and morbidity worldwide and are among the most devastating of all injuries, with outcomes spanning the spectrum from pain, to physical impairments and disabilities, to emotional and psychological consequences, to death.3

Approximately 450,000 people suffer thermal injuries every year in the United States, and 45,000 of these are hospitalized. Burn injuries result in approximately 3,500 deaths each year in the United States. Deaths due to fires and burns are the third leading cause of fatal home injury. Fatal fire and burn injuries cost $3 billion annually, representing 2% of the total cost of all fatal injuries.4,5

Burns are dynamic, complex injuries that peak in severity in 48 to 72 hours.6 They major physiologic and metabolic manifestations appear in a time-dependent manner. The manifestations of burn injury that appear within minutes are listed in Table 1,6,7 and those that appear hours to days later are listed in Table 2.6,8

Gasoline-related burn injury is common, accounting for 19% of adult admissions and 33% of all adult male admissions to one burn center over a 2-year period.9 There are 125 regional burn centers in the United States; however, only 25% of the population lives within a 1-hour drive of a burn center, and only 46% lives within a 2-hour drive; therefore, many burned patients will be initially treated at other facilities.10 Many of the people who suffer burn injuries are first treated in community hospitals and trauma centers that are not designated regional burn centers. The hospital where this patient was treated is a level I trauma center but is not a regional burn center. Importantly, CRNAs who work in settings other than burn centers may find themselves faced with the challenge of providing initial care for patients such as the one described here.

Human skin is composed of 2 layers: the outermost epidermis and the underlying dermis. First-degree burns involve only the superficial epidermis. In second-degree burns, the epidermis is destroyed, and part of the dermis is injured. In third-degree (full-thickness) burns, both layers of the skin are destroyed. First- and second-degree burns are very painful, but third-degree burns are painless. Table 3 gives a more thorough description of the characteristics of the different classifications of burns. Recovery from severe burns occurs in phases: resuscitation, debridement and grafting, reconstruction, and rehabilitation.8,10 It is the intent of this case study only to describe our experiences during the resuscitation phase of care.

Most burn injuries are associated with flames (55%),

<table>
<thead>
<tr>
<th>Shock</th>
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<tbody>
<tr>
<td>Hypermetabolism/catabolism</td>
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<tr>
<td>Increased oxygen consumption</td>
</tr>
<tr>
<td>Evaporative heat loss</td>
</tr>
<tr>
<td>Respiratory insufficiency</td>
</tr>
<tr>
<td>Myocardial depression</td>
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<tr>
<td>Hypovolemia</td>
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<tr>
<td>Pulmonary edema</td>
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<tr>
<td>Increased pulmonary vascular resistance</td>
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<tr>
<td>Hypothermia</td>
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<tr>
<td>Cardiac dysrhythmias</td>
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<tr>
<td>Pain</td>
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</tbody>
</table>

Table 1. Immediate Systemic Effects of Burns6,15

| Chronic obstructive pulmonary disease |
| Pulmonary edema                      |
| Pneumonia                            |
| Pulmonary embolism                   |
| Hypoxemia                            |
| Pain                                 |
| Sepsis                               |
| Deep vein thrombosis                 |
| Paralytic ileus                      |
| Gastric ulcer                        |
| Renal failure                        |
| Compartment syndrome/necrosis        |
| Anemia                               |
| Electrolyte abnormalities             |
| Increased number of postjunctional acetylcholine receptors |
| Death                                |

Table 2. Later Systemic Effects of Burns6,9

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followed by scald burns (40%). Prolonged exposure to temperatures higher than 40°C leads to denaturation of proteins and loss of plasma membrane integrity. This process is rapid and may only take 1 second when tissue is exposed to temperatures higher than 60°C, as with flame burns.6

Severe burn injury is followed by a substantial systemic inflammatory response. The activation of the complement and coagulation systems may result in thrombosis within the microvasculature. The release of histamine and bradykinin results in increased capillary leakage and tissue edema. An increased level of oxygen free radicals, such as xanthine oxidase, also plays a major role in the formation of burn edema.8

Massive tissue edema after thermal injury is a well-recognized entity. Although this process is responsible for the patient’s large fluid needs during resuscitation, there have been no effective treatment modalities introduced into clinical care to control the degree of edema formation.11 Histamine is most likely to be the primary mediator responsible for the early phase of increased microvascular permeability seen immediately after a burn injury.

Flame burns are often associated with inhalation injury.6 Vigilant attention should be given to the airway of the burned patient to ensure that it is patent and that oxygenation and ventilation are optimized. Table 4 lists the airway interventions that we performed in caring for this patient. The ASA Difficult Airway Algorithm is an established guide to managing patients who are difficult to mask ventilate, intubate, or both.12

Upper airway swelling is a very dangerous sequela of inhalation injury. Swelling begins within hours after injury and persists for 2 to 4 days until tissue edema wanes.8 As with the patient described in this report, every unsuccessful attempt to insert an artificial airway device may worsen the patency of the natural airway. The indications for endotracheal intubation of burned patients include decreased mental status resulting from inhalation of metabolic asphyxiants such as carbon monoxide or hydrogen cyanide, airway obstruction caused by edema and debris, and respiratory failure due to pulmonary edema.13 If orotracheal intubation is not possible, cricothyrotomy should be performed.

Patients with soot in the oral cavity, facial burns, and/or body burns are more likely to experience laryngeal edema and to require intubation. Edema of the true or false vocal cords detected by fiberoptic laryngoscopic examination also is predictive of the need for intubation.14 The absence of classic signs of inhalation injury

Table 3. Clinical Characteristics of Burn Wounds of Various Depth

<table>
<thead>
<tr>
<th>Degree and depth</th>
<th>Causes</th>
<th>Layer of skin involved</th>
<th>Appearance</th>
<th>Pain</th>
<th>Healing time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superficial, first degree</td>
<td>Sun exposure, hot liquids with low viscosity and short exposure</td>
<td>Epidermis only</td>
<td>Pink to red, moist, no blisters</td>
<td>Moderate to severe</td>
<td>3-7 d</td>
</tr>
<tr>
<td>Superficial, partial second degree</td>
<td>Hot liquids, chemical burns with weak acid or alkali, flash</td>
<td>Superficial (papillary) dermis</td>
<td>Blister, red, moist, intact epidermal appendages, blanches on pressure</td>
<td>Severe</td>
<td>1-3 wk</td>
</tr>
<tr>
<td>Deep partial, second degree</td>
<td>Flame, electrical, chemical, hot liquids with high viscosity</td>
<td>Deep layer (reticular) dermis</td>
<td>Dry, white, nonblanching, loss of all epidermal appendages</td>
<td>Minimal</td>
<td>3-6 wk, with scars</td>
</tr>
<tr>
<td>Deep, third degree</td>
<td>Flame, electrical, chemical, blast, self-immolation</td>
<td>Full thickness of skin and into subcutaneous fat or deeper</td>
<td>Leathery, dry, white or red with thrombosed vessels</td>
<td>None</td>
<td>Does not heal by primary intention; requires skin graft</td>
</tr>
</tbody>
</table>

Table 4. Airway Management Interventions

Abbreviations: LMA, laryngeal mask airway; ETT, endotracheal tube.

At the site of the burn injury (patient’s home):
- Bag-valve-mask ventilation with 100% oxygen
- Failed intubation
- Bag-valve-mask ventilation with 100% oxygen

In the emergency department:
- Failed rapid sequence induction/intubation
- Failed intubation with video laryngoscope (GlideScope, Verathon)
- Failed satisfactory ventilation with LMA
- Failed satisfactory ventilation with cricothyrotomy kit
- Successful surgical cut down, insertion of 5.5-mm ETT into the trachea

In the operating room:
- Surgical tracheostomy
Inhalation injury, in addition to inflicting structural damage on the respiratory tract epithelium, impairs surfactant production and mucociliary transport, impairs pulmonary macrophage function, and produces atelectasis. The net result of these changes, combined with global immunosuppression, is often respiratory tract infection.15

Burn injury produces dramatic fluid shifts that result in a state of intravascular hypovolemia. Prompt establishment of large-bore IV access and rapid initiation of fluid resuscitation are vital to the survival of patients with severe, extensive thermal injuries. No factor other than airway protection is as critical in the early period after a burn.7 For determination of proper fluid replacement amounts, several formulas can be used. One of the most common is the Parkland formula: 4 mL of lactated Ringer’s solution per kilogram of body weight per percentage of TBSA during the first 24 hours. One-half of this fluid is given during the first 8 hours; the remaining half is given over the next 16 hours. Hourly urine output of at least 0.5 mL/kg/h is a well-established parameter for guiding fluid resuscitation. A delay in fluid resuscitation increases the incidence of renal failure and death.16

Circumferential burn eschar of the extremities can prevent swelling of the underlying tissue. The result is elevated tissue pressures and impairment of tissue perfusion.8 Sustained compartment pressures in the range of 30 mm Hg suggest compartment syndrome. Pressures above 40 mm Hg necessitate escharotomy or fasciotomy to improve tissue perfusion. Inflexible eschar and underlying tissue edema can also prevent chest wall motion and thus limit ventilation. In the present case, the surgeon made upper extremity and chest incisions in an effort to correct these problems.

In conclusion, airway management of the patient with severe, extensive burns of the face, neck and chest requires a coordinated effort by the entire care team. Rapid initial assessment should guide the CRNA to move quickly through established difficult airway maneuvers. Initiation of a surgical tracheostomy may prove to be the only satisfactory method of ventilation. Even with successful ventilation, the outcome may be dismal.

REFERENCES

AUTHORS
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