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Case Report

Lightning Strike-Induced Cutaneous Burns and Airway Injury: A Case Report Highlighting Recurrent Extubation Failure in a Critically Ill Patient

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Highlights

What are the main findings?

- Circumferential neck burns from lightning-heated jewelry may cause direct thermal injury to the adjacent supraglottic airway, contributing to extubation failure even without classic smoke inhalation.
- Three sequential extubation failures in this patient were driven by a combination of upper airway mucosal edema, pleural effusions, hospital-acquired pneumonia, and neurological depression, ultimately requiring tracheostomy.

What are the implications of the main findings?

- Lightning strike victims with cervical burns warrant the same systematic airway evaluation applied to inhalation injury patients, including a cuff-leak test and upper airway endoscopy before planned extubation.
- Early elective tracheostomy should be considered when multiple extubation risk factors coexist to prevent cumulative laryngeal trauma from repeated intubations.

Abstract

Introduction: Lightning strikes cause a unique spectrum of cutaneous burn injuries that differ substantially from conventional thermal or high-voltage electrical burns. Despite the well-documented systemic lethality of lightning injuries, the burn-specific sequelae—including airway involvement and its contribution to ventilatory failure—remain underreported in the burn literature. **Case Report:** We present a 31-year-old woman who sustained multiple cutaneous burns following a lightning strike, including a circumferential necklace-pattern burn to the neck, a large midline torso burn, and burns to the right lower extremity and foot. Following resuscitation from ventricular fibrillation cardiac arrest, she required mechanical ventilation and experienced three sequential extubation failures before ultimately requiring tracheostomy. We propose that airway mucosal edema secondary to localized thermal and electrical injury of the neck, compounded by systemic inflammatory and infectious complications, was an underrecognized contributor to her inability to sustain independent ventilation. **Conclusions:** In lightning strike victims with burns involving the neck or thorax, airway thermal injury should be actively excluded

and closely monitored as a potential cause of extubation failure. A low threshold for early bronchoscopic airway assessment and conservative extubation protocols is warranted.

Keywords: lightning strike; cutaneous burns; airway burns; extubation failure; Lichtenberg figures; inhalation injury; tracheostomy; intensive care

1. Introduction

Lightning strikes are one of the most powerful natural phenomena capable of inflicting human injury, delivering currents exceeding one million volts over an interval of 0.001 to 0.1 seconds. In the United States, lightning is responsible for an estimated 400 injuries and 40 deaths annually, though the true incidence is likely underreported [1]. The mortality rate following a lightning strike ranges from 10–30%, and approximately 76% of survivors experience long-term sequelae [2].

The pathophysiology of lightning-related burns differs markedly from that of conventional high-voltage electrical injuries. Because the contact duration is so brief, lightning energy preferentially travels over the body surface via the "flashover" effect rather than penetrating deeply through tissues [3]. As a result, lightning burns are typically superficial and may cover large surface areas, taking characteristic forms including linear burns from vaporized sweat, punctate burns at current exit points, contact burns from heated metallic objects, and—most pathognomically—Lichtenberg figures (fernlike erythematous skin patterns) [2,4].

Despite their predominantly superficial character, lightning burns in anatomically critical locations, particularly the neck and anterior thorax, pose distinct risks. Burns in the cervical region may involve the upper airway mucosa, even in the absence of enclosed-space smoke inhalation, the traditional trigger for suspecting inhalation injury. The possibility that direct thermal injury from a necklace-pattern cervical burn could extend to the supraglottic and glottic mucosa and thereby impair airway patency after extubation [5] has not been systematically examined in the burn literature.

We report the case of a lightning strike survivor who presented with extensive cutaneous burns in a pattern consistent with the flashover mechanism. Her protracted course in the Intensive Care Unit (ICU) was marked by three extubation failures before tracheostomy was required. We argue that subclinical airway mucosal involvement, in the context of a circumferential neck burn, was a critical and underrecognized contributor to her ventilatory failure, and we discuss the implications for burn unit airway management protocols.

2. Case Report

2.1. Patient Demographics and Presentation

A 31-year-old woman with no significant past medical history was transported to the emergency department by emergency medical services after bystander-initiated cardiopulmonary resuscitation (CPR) and subsequent return of spontaneous circulation (ROSC) following ventricular fibrillation cardiac arrest caused by a direct lightning strike. She had been walking her dog on a beach when she was struck and lost consciousness. Emergency medical services defibrillated the patient and administered three doses of epinephrine (1 mg each) per Advanced Cardiovascular Life Support (ACLS) guidelines. She was intubated in the field and arrived with oxygen saturations in the 70% range and a Glasgow Coma Scale score of 3T.

2.2. Burn Description and Distribution

Secondary survey on arrival to the emergency department identified four distinct burn regions consistent with the flashover mechanism of lightning injury (**Figure 1**). The most clinically significant finding from a burn standpoint was a circumferential necklace-pattern burn encircling the entire neck (**Figure 1A**). This linear burn followed the anatomical path of the patient's necklace, which had been heated by the lightning current, producing a full-thickness contact burn in direct proximity to the supraglottic airway.

Burns to the right posterior leg, spanning the popliteal fossa and calf, represented a secondary arc pathway (**Figure 1B**). A punctate burn on the right lateral foot marked the current exit point (**Figure 1C**). A large midline torso burn extending from the upper chest across the abdomen was also identified, consistent with a flashover arc following the anterior surface of the body (**Figure 1D**). Visible thermal damage to the patient's right sneaker corresponded to the foot exit wound location (**Figure 1E**). A left parietal scalp laceration was also documented. Collectively, these injuries were consistent with lightning entry via the head and scalp, propagation of current over the anterior torso and around the neck, with exit through the right lower extremity.

Initial wound care consisted of bacitracin ointment applied to all burn surfaces; silver sulfadiazine was added several days later. The patient was monitored closely for compartment syndrome throughout her ICU course, and serum creatine kinase (CK) was measured every six hours. No escharotomy was required.



Figure 1. Pathway of lightning strike evidenced by dermal injuries and material damage on a patient with darker skin complexion. (A) Initial strike on chest and necklace burn. B) Path of electricity across right popliteal fossa to right calf. (C) Burn on right lateral foot demonstrating location of

electricity exit from patient. (D) Path of grounding across abdomen. (E) Patient's right shoe demonstrating exit point of electricity from foot.

2.3. Airway Management and Extubation Failures

The patient arrived intubated with an endotracheal tube initially found in the right mainstem bronchus on chest radiograph. Oxygen saturations fell to 60%, and the tube was repositioned above the carina with immediate improvement. Initial ventilator settings were: FiO_2 35%, respiratory rate 16 breaths per minute, tidal volume 350 mL, and PEEP 5 cmH_2O. The patient tolerated minimal pressure support ventilation by hospital day 10, at which point extubation was attempted.

Prior to the first extubation attempt, diuretics and nebulized albuterol were administered. Despite these precautions, the patient maintained independent breathing for only 40 minutes before developing progressive tachypnea with oxygen saturations falling to the low 70s. She reported subjective dyspnea and fatigue and requested reintubation, which was performed with a smaller-calibre endotracheal tube. The clinical suspicion at this point was airway edema related to the circumferential neck burn, and a 48-hour course of systemic corticosteroids was administered before a second extubation attempt.

The second extubation likewise failed, with tachypnea and oxygen saturations in the mid-80s. Bilevel positive airway pressure (BiPAP) temporarily stabilized oxygenation. However, within two days, the patient became increasingly somnolent on 100% FiO_2, with tidal volumes falling to 100–150 mL, necessitating a third reintubation. Given three sequential extubation failures with a pattern of progressive upper airway and ventilatory compromise—in the setting of a circumferential neck burn and compounding pulmonary complications including pleural effusions and staphylococcal pneumonia—a decision was made to proceed with elective tracheostomy.

The patient tolerated the tracheostomy without complication. Initial suctioning requirements were hourly, suggesting significant ongoing airway secretion burden. After transition to a cuffless tracheostomy tube, suctioning frequency decreased to every eight hours, and she was fitted with a speaking valve. She was transferred from the ICU to a step-down unit after four weeks, and by hospital day 40 passed a swallowing evaluation and was discharged to an acute rehabilitation facility. She continues to experience dysphonia and is receiving speech-language therapy.

2.4. Additional Diagnostic Findings

Initial laboratory investigations revealed leukocytosis of 46 K/μL (attributed to a leukemoid reaction), peak troponin of 15,563 ng/L (decreasing to 1,817 ng/L on day 2), and peak creatine kinase of 3,169 U/L, consistent with rhabdomyolysis. CT imaging of the chest, abdomen, and pelvis demonstrated diffuse multifocal ground-glass opacities (pulmonary edema/contusions). CT brain demonstrated global cerebral edema. MRI brain identified small infarcts in the left caudate head and bilateral cerebellar hemispheres. Bedside transthoracic echocardiogram showed global hypokinesis with an ejection fraction of 50%, and an initial right bundle branch block resolved spontaneously. A chest CT two weeks after admission revealed left lower lobe consolidation consistent with pneumonia, with respiratory cultures growing Staphylococcus aureus; antibiotics were adjusted accordingly.

Bedside flexible bronchoscopy performed during the ICU stay demonstrated minimal secretions with gram-positive colonies, but no formal structured assessment of the supraglottic or glottic mucosa for edema, erythema, or friability was documented at the time of the extubation failures.

3. Discussion

3.1. The Spectrum of Lightning-Induced Cutaneous Burns

Lightning burns occupy a distinct niche in the burn literature. Unlike conventional thermal burns or high-voltage electrical injuries from power lines, lightning burns rarely cause deep tissue destruction because the brevity of current contact precludes sufficient energy transfer for extensive electrothermal heating [3]. The predominant mechanism is the flashover effect, in which current arcs over the moist skin surface, causing superficial injury over wide anatomical territories [6]. This case illustrates the classical anatomical distribution of lightning burns: linear neck burn following a metallic necklace, broad anterior torso flashover burn, posterior leg arc burn, and a punctate exit burn on the lateral foot.

Lichtenberg figures, the fernlike erythematous patterns that are pathognomonic of lightning injury, were not documented in this patient, possibly because her darker skin complexion made these transient markings more difficult to identify. This highlights an important limitation in burn assessment: visual detection of lightning-specific skin patterns may be less reliable in patients with Fitzpatrick skin types IV–VI, underscoring the value of systematic examination protocols and high-quality clinical photography that are not reliant solely on pattern recognition [4].

The circumferential necklace-pattern burn in this case deserves particular emphasis. Contact burns produced by heated metallic jewelry can be full-thickness and sharply demarcated. When these occur at the neck, the burn encompasses the anterior and lateral cervical soft tissues overlying the larynx and upper trachea. Even without the enclosed-space smoke inhalation typically associated with inhalation injury, such burns may produce mucosal edema in the hypopharynx and supraglottis through direct thermal conduction and inflammatory mediator release [7].

3.2. Airway Burns and the Mechanism of Recurrent Extubation Failure

Inhalation injury in conventional burn patients is a well-established predictor of extubation failure and prolonged mechanical ventilation [7,8]. The triad of airway mucosal edema, impaired mucociliary clearance, and bronchospasm leads to increased work of breathing, atelectasis, and susceptibility to pneumonia. In lightning strike victims, this mechanism has not been systematically described because lightning injuries rarely occur in the context of smoke or superheated gas inhalation.

We propose that a functionally analogous process may occur in patients with cervical lightning burns, even in the absence of classic inhalation injury. The circumferential cervical distribution of injury adjacent to a metallic necklace suggests localized concentration of electrical current and heat dissipation, potentially amplifying soft tissue and airway damage. In this case, thermal injury to the superficial cervical tissues, combined with the systemic inflammatory response following high-energy trauma and cardiac arrest, may have produced sufficient edema and mucosal fragility to critically narrow the upper airway after endotracheal support was withdrawn.

This hypothesis is supported by the clinical course. Each extubation failure was characterized by rapid-onset tachypnea and hypoxia, consistent with increased resistive work of breathing from upper airway narrowing rather than intrinsic lung parenchymal failure. The transient benefit of BiPAP after the second failure also supports a component of dynamic upper airway collapse partially offset by positive airway pressure. The decision to administer systemic corticosteroids after the first failure, a strategy used in conventional inhalation injury to reduce airway edema, lends further implicit credence to the hypothesis that mucosal swelling was a primary driver.

Compounding the airway mucosal injury were several co-existing factors that increased the cumulative burden on the respiratory system: bilateral pleural effusions requiring chest tube drainage, hospital-acquired staphylococcal pneumonia with left lower

lobe consolidation, high secretion burden, and neurological impairment from global cerebral edema and scattered infarcts that likely depressed the central respiratory drive and protective airway reflexes necessary for safe extubation (**Figure 2**). Notably, secretion burden has previously been identified as an important predictor of decannulation and extubation failure in critically ill patients. The Murray Secretion Scale specifically quantifies secretion severity and clearance ability in patients with tracheostomies and has been associated with unsuccessful decannulation outcomes [8]. Similarly, extubation prediction tools such as the ExPreS and VISAGE scores incorporate factors including neurological status, secretion management, cough effectiveness, and airway protective reflexes to estimate extubation readiness and risk of failure [9,10]. These frameworks support the concept that impaired secretion clearance and compromised airway protection may substantially contribute to extubation vulnerability in complex critically ill patients such as ours.

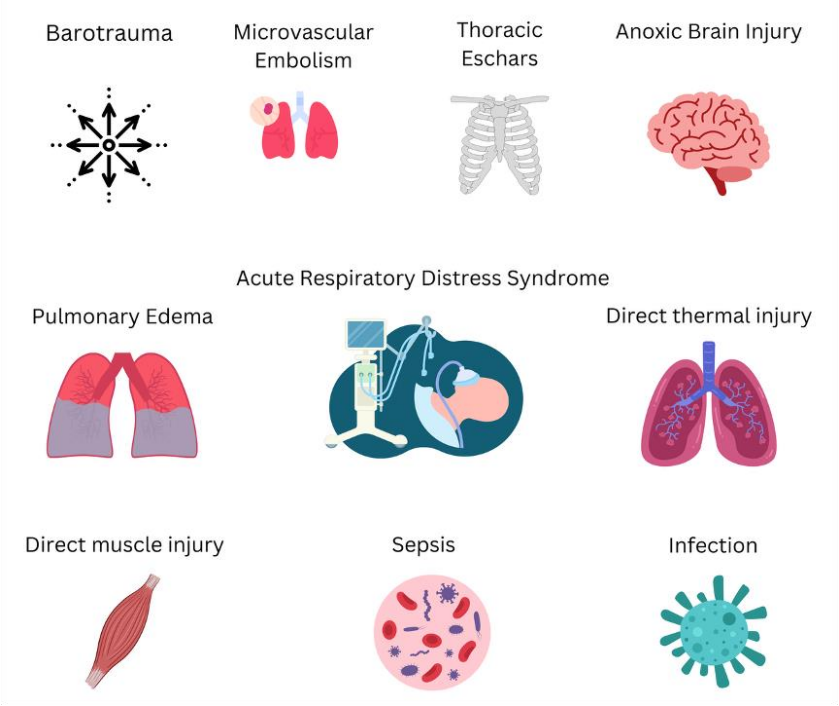


Figure 2. Proposed multifactorial mechanism contributing to recurrent extubation failure following lightning strike injury. Circumferential cervical burn from lightning-heated metallic jewelry likely caused supraglottic and upper airway mucosal edema through direct thermal injury and inflammatory soft-tissue swelling. Additional contributors included pulmonary edema and pleural effusions after cardiac arrest and aggressive resuscitation, hospital-acquired pneumonia with secretion burden, and neurological impairment from cerebral edema and ischemic infarcts, collectively increasing respiratory workload and impairing airway protection.

3.3. Absence of Bronchoscopic Upper Airway Assessment

A notable gap in the management of this patient was the absence of a formal laryngoscopic or bronchoscopic assessment of the upper airway mucosa prior to or following extubation attempts. In patients with conventional inhalation injury, direct airway visualization is standard practice and informs the timing of extubation [11]. The bronchoscopy performed in this patient documented distal airway findings but did not include a structured evaluation of the supraglottic and glottic mucosa for edema, erythema, or friability.

We suggest that in any lightning strike victim with a burn involving the neck, regardless of the absence of inhalation injury by conventional criteria, a cuff-leak test and formal upper airway endoscopic evaluation should be performed before planned extubation. The cuff-leak test, which measures airflow around a deflated endotracheal tube cuff, provides

a simple bedside surrogate for the degree of subglottic and glottic edema and has demonstrated utility in identifying patients at high risk for post-extubation stridor [12]. A low or absent leak should prompt corticosteroid therapy and reassessment before extubation is attempted.

3.4. Burn Wound Management Considerations

Initial management with bacitracin ointment followed by silver sulfadiazine was appropriate for the acute ICU setting where systemic priorities dominate. Silver sulfadiazine provides broad-spectrum antimicrobial coverage widely used in burn units for partial- and full-thickness burns [13]. The circumferential nature of the neck burn raises the theoretical concern for progressive swelling and extrinsic airway compression, analogous to the circumferential burn phenomenon that mandates escharotomy in the thorax or extremities. In practice, the patient was already intubated throughout the acute burn phase, affording airway protection during the period of maximal swelling (typically 24–72 hours post-injury). However, the persistence of airway edema beyond this window, evidenced by extubation failures at day 10 and beyond, suggests that mucosal rather than extrinsic soft-tissue edema was the dominant mechanism by the time extubation was attempted.

Lightning-induced rhabdomyolysis, with a peak CK of 3,169 U/L in this case, carries a risk of acute tubular necrosis [14] requiring aggressive fluid resuscitation, which in turn may exacerbate pulmonary and airway mucosal edema. Beyond rhabdomyolysis, high-voltage electrical injuries, including lightning strikes, have been associated with profound transient hypokalemia through catecholamine-mediated intracellular potassium shifts and disruption of voltage-gated potassium channels, an underrecognized metabolic complication that warrants close electrolyte monitoring in the acute setting [15].

3.5. Implications for Burn Unit Practice

This case offers several practical lessons for burn clinicians. First, the location of the burn—not merely its depth or total body surface area—should guide airway vigilance. A cervical burn, even if superficial, should prompt the same systematic airway evaluation performed for inhalation injury. Second, extubation readiness assessments should incorporate a cuff-leak test and, where possible, direct laryngoscopy. Third, the risk of recurrent extubation failure is elevated when cervical burns co-exist with systemic factors (pleural effusions, pneumonia, cerebral injury, inflammatory state), and clinicians should have a low threshold for elective tracheostomy rather than repeated intubation–extubation cycles, which carry cumulative laryngeal trauma risk. Fourth, the high suctioning requirements after tracheostomy in this patient suggest that "minimal" distal airway secretions on bronchoscopy may underestimate the true upper airway secretion burden.

4. Conclusions

Lightning strike-induced burns present a distinctive pattern of cutaneous injury that differs fundamentally from conventional thermal or high-voltage electrical burns. In this case, a circumferential neck burn produced by metallic jewelry heated by the lightning current was anatomically situated to generate thermal injury to the adjacent supraglottic airway, contributing, alongside pulmonary and neurological complications, to three sequential extubation failures and the eventual need for tracheostomy.

The key take-home messages for burn clinicians are: (1) cervical lightning burns should trigger the same systematic airway evaluation applied to inhalation injury victims; (2) a cuff-leak test and direct upper airway endoscopy should be performed before planned extubation in this population; (3) systemic corticosteroids may attenuate mucosal edema in the peri-extubation period but are insufficient when compounding factors are present; and (4) early elective tracheostomy should be considered when multiple

extubation risk factors coexist, to prevent cumulative laryngeal injury and to facilitate airway clearance, communication, and rehabilitation.

Further prospective study of airway outcomes in lightning burn victims with cervical injury is needed to define optimal surveillance and extubation protocols for this uncommon but high-stakes patient population.

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Abbreviations

The following abbreviations are used in this manuscript:

CPR	Cardiopulmonary resuscitation
ROSC	Return of spontaneous circulation
ACLS	Advanced cardiovascular life support
ICU	Intensive care unit
BiPAP	Bilevel positive airway pressure
CK	Creatine kinase

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