



Lightning Strike Injuries

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INTRODUCTION

Lightning strikes are an uncommon but potentially devastating environmental hazard. Although most incidents are nonfatal, they demand prompt recognition and rapid intervention to prevent death and long-term complications. This review summarizes key epidemiologic patterns, mechanisms of injury, clinical manifestations, and management principles relevant to emergency and wilderness medicine.

EPIDEMIOLOGY

Lightning occurs worldwide 50–100 times per second, with roughly one-fifth of strikes reaching the ground [1,2]. Worldwide an estimated 24,000 people die from lightning related injuries annually, though reliable data from low-income regions remain limited. For every death, roughly ten nonfatal injuries occur [2]. In the United States, lightning causes about 27 deaths each year, with an annual lifetime odds of 1 in 1.2 million [3]. Victims are predominantly males aged 20–45, engaged in outdoor work or recreation between May and September. Globally, the highest mortality rates occur in Sub-Saharan Africa and the Himalayan region, where warm, moist air rises rapidly along mountain ranges and access to shelter is limited [1-4]. Within the U.S., Florida leads in lightning frequency and fatalities, followed by other southeastern states where outdoor summer exposure and activities are common [5].

PHYSICS OF LIGHTNING

Lightning forms when unstable layers of warm and cold air generate vertical convection winds and currents, causing charged ice and water particles to separate within clouds. This creates an electrical potential that eventually discharges in the cloud itself, amongst other clouds, or between the cloud and the ground [6]. A single bolt can generate up to a billion volts, with temperatures exceeding 50,000°C—four times hotter than the surface of the sun. This rapid heating of air produces an explosive shockwave perceived as thunder. Because sound travels slower than light, the interval between the flash and thunder can provide an estimate of strike distance.

MECHANISMS OF INJURY

Lightning affects victims through several pathways [7,8]. The most common way is via **ground current**, which occurs when electrical energy spreads outward after a terrestrial strike and potentially injures multiple nearby people or animals simultaneously. **Side splash** occurs when lightning arcs from a struck object to a nearby person, while **contact injury** results from touching a conductive object that is struck. Less commonly, an **upward streamer** forms when current flows upward from the ground through the body. Finally a **direct strike** delivers a continuous bolt directly to the victim and is the deadliest but rarest mechanism.

PATHOPHYSIOLOGY AND CLINICAL FEATURES

Lightning exerts its effects through massive electrical discharge, heat, and concussive force. The electrical current may cause flashover burns, disrupt cardiac or respiratory electrical activity, or produce explosive trauma analogous to a blast injury.

CARDIOPULMONARY EFFECTS are the most lethal. Cardiac arrest may result from ventricular fibrillation, asystole, or secondary hypoxia due to loss of respiratory drive and respiratory failure [9,10]. Immediate rescue breathing, CPR and defibrillation are lifesaving and survivors typically have good neurologic recovery. Other cardiac sequelae include transient arrhythmias and hypertension, conduction abnormalities, and reversible cardiomyopathy or vasospasm mimicking myocardial infarction [9-14]. Long term complications like pericarditis or cardiomyopathy can occur but are much less common.

NEUROLOGICAL INJURIES are diverse and generally transient. Victims may present with confusion, seizures, amnesia, blindness, deafness, or headache [1-16]. A distinctive entity, **kerunoparalysis**, produces temporary limb paralysis, cyanosis, and absent pulses due to intense vasospasm rather than spinal cord injury or vascular occlusion [17,18]. Long-term sequelae may include movement disorders, chronic headaches, personality changes, cognitive deficits, PTSD, or depression [16-20].

CUTANEOUS FINDINGS can include burns to more transient skin changes. Burns can range from superficial to full thickness and occur from rapid heating of superficial skin moisture or associated overlying synthetic clothing, metal in jewelry or accessories that become superheated and cause subsequent contact burns to the skin and underlying tissue. Unique skin findings called **Lichtenberg figures** are pathognomonic for lightning strikes and form feather or fern-like erythematous patterns that fade within days [21-23].

OCULAR INJURIES can include iritis, uveitis, and retinal detachment. Direct trauma from the blast injury can also cause corneal abrasions, hyphema, or a ruptured globe. The most frequent eye complications are cataracts, which may develop immediately or months later [24,25].

TRAUMATIC INJURIES often result from the concussive blast or subsequent falls. The primary blast wave from the lightning strike can lead to tympanic membrane rupture, pneumothorax or further hollow organ injury. Explosive force and subsequent falls can also include wounds, fractures, traumatic brain injury, or other blunt trauma. Management of these injuries follows all current trauma care guidelines and standards of care.

PREHOSPITAL MANAGEMENT

Scene safety is paramount and is both the most immediate and most important initial consideration. Rescuers should avoid ongoing storm hazards and initiate the emergency response system except in the direst of circumstances. In lightning-related mass casualty incidents, **reverse triage** is essential: victims without pulse or respirations should be treated first, as many suffer only transient respiratory paralysis or cardiopulmonary arrest and may respond to early resuscitation [1-26]. Those with spontaneous breathing are likely to survive.

Standard trauma algorithms guide assessment—control hemorrhage, ensure airway, support ventilation, and identify burns or trauma. Lightning victims do not retain electrical charge, and rescue efforts should

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not be delayed once the scene is secure. Rescue breaths, CPR, and AED use should be applied per standard protocols. Survivors should be kept warm and placed in a recovery position to prevent hypothermia and aspiration.

HOSPITAL EVALUATION AND TREATMENT

Upon arrival, clinicians should obtain a full history, ECG, and targeted labs including electrolytes and CK if rhabdomyolysis is suspected [1]. Imaging is directed by symptoms and mechanism and include chest X-ray for pneumothorax and potentially CT for head, spine or pelvic trauma. After the initial EKG, all patients should be placed on continuous cardiac monitoring to detect any ongoing or delayed arrhythmias. Treatment follows standard trauma and burn care: airway protection, IV fluids, analgesia, and tetanus prophylaxis [1-27]. Antibiotics are unnecessary unless wounds are contaminated and are generally avoided.

Patients with abnormal ECGs, chest pain, dyspnea, syncope, loss of consciousness, or neurologic deficits warrant at least 24 hours of hospital observation with continuous cardiac monitoring [1]. Pregnant patients beyond 20 weeks gestation require fetal monitoring given elevated risk of fetal demise and placental abruption. Others can be discharged safely with follow up as an outpatient and close instructions to be vigilant for any potential long-term complications.

PREVENTION

Lightning injuries are largely preventable. Individuals and organizations should develop safety plans including weather monitoring, predetermined shelters, and evacuation routes. Activity should cease when thunder is audible, with a 30-minute waiting period after the last thunderclap before resuming. Fully enclosed buildings or hard-top vehicles offer the best protection; open shelters, ridgelines, and isolated trees should be avoided [1-15]. In remote terrain, descending to valleys or crouching with feet together minimizes ground current exposure. Water-based activities must stop immediately at the first sign of a storm.

SUMMARY

Lightning is among the leading causes of weather-related mortality worldwide. Despite its destructive potential, most victims survive when promptly recognized and managed. Understanding the unique mechanisms, characteristic injuries, and priorities of care—particularly reverse triage—improves outcomes in both prehospital and hospital settings. Long-term follow-up is essential to identify delayed neuropsychiatric or ophthalmologic complications. Ongoing education and public adherence to preventive strategies remain the most effective means of reducing lightning-related morbidity and mortality.

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