Chemical, Electrical, and Radiation Injuries

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KEYWORDS

• Chemical injury • Ocular injury • Electrical injury • Fasciotomy • Compartment syndrome
• Radiation injury

KEY POINTS

- Chemical, radiation, and electrical injuries pose a unique challenge for burn surgeons acutely and during the reconstructive phase.
- Each chemical has unique concerns, but all benefit from immediate removal and dilution.
- Electrical injuries can cause both external flame burns and internal muscle injury.
- Compartment syndrome is an important and potentially destructive clinical sequela of electrical injury that warrants early diagnosis and treatment.
- Radiation exposure causes both short-term damage (skin, gastrointestinal tract) and long-term sequelae (increased risk of malignancy, central nervous system changes, and poor wound healing).

CHEMICAL INJURIES

Epidemiology

Chemical burns are an uncommon form of burn injury, accounting for 2.1% to 6.5% of all burn center admissions.[1] According to the 2015 National Burn Repository report of the American Burn Association, chemical injuries represented 3.4% of patients admitted to participating hospitals over the 2004 to 2015 period. The mean hospital charge for patients with chemical burns was approximately $30,000, which was significantly lower than flame, scald, or electrical injuries. More than 13 million workers in the United States are at risk for dermal chemical exposures, particularly those employed in the agricultural and industrial manufacturing industries. Skin disorders are among the most frequently reported occupational illnesses, resulting in an estimated annual cost in the United States of more than $1 billion.[2]

Overall, chemical burns in the United States occur in roughly equal proportions at work (42.9%) and at home (45.9%), with most work-related exposures occurring in an industrial setting. The highest incidence occurred in the male population between 20 and 60 year old, representing most of the industrial work force. Similarly, a 10-year retrospective study of 690 chemical burn patients admitted to a large hospital in China reported the vast majority of chemical burns occurring in the 20- to 59-year age group (95%), which were most frequently related to work. The most common burn sites were the upper extremities (32%), followed by the head and neck (28%), and lower extremities (20%).[3]

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A vast number of hazardous chemicals are capable of damaging tissue. The Hazardous Substances Emergency Events Surveillance database of the Centers for Disease Control and Prevention published an analysis of 57,975 chemical injuries over the 1999 to 2008 time period. The chemicals most frequently associated with injury were carbon monoxide (2364), ammonia (1153), chlorine (763), hydrochloric acid (326), and sulfuric acid (318).[4] A 2004 study of military-related chemical burns treated at Brooke Army Medical Center reported 52.9% resulting from munitions (mostly white phosphorus), followed by acid exposures (9.1%), alkali exposure (6.5%), and other chemicals, such as phenol, fluorocarbon, and oven cleaner (6.2%).[1]

Beyond the initial tissue injury, sequelae of chemical burns can include wound infections, cellulitis, sepsis, and complications from scarring. Increasing age is associated with an increase in complications from chemical burns (mostly cellulitis and wound infections), with children under the age of 2 experiencing the lowest rate (2.5%). Complications in the 20- to 50-year age range plateau at 6.4% to 6.7%, which increases significantly with every decade greater than 50 to a maximum of 20.9% in patients older than 80.[5] Sepsis is the most serious complication of chemical burns, which has an overall rate of around 0.6%.[5] Mortality from chemical burns is fortunately low. In the 2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System, 151,796 dermal chemical exposures reported to the agency, and only 8 proved fatal.[6]

Chemical burns are infrequent in children, afflicting 0.9% of admitted pediatric burns at the Parkland Burn Center.[7] It is also not a common form of child abuse, with only 1.4% of nonaccidental pediatric burns resulting from chemical contact.[7] Another study at Children's Hospital Michigan grouped chemical burns in a miscellaneous category of 22% of admitted pediatric patients.[8]

The following article focuses on the dermal and ocular chemical burns most frequently encountered by plastic surgeons. Although oral ingestion is a more common route of toxic chemical exposure,[6] the cause and management are beyond the scope of this article. According to the 2014 Annual Report of the American Association of Poison Control Centers' National Poison Data System, the route of exposure is usually ingestion (83.7% of cases), followed in frequency by dermal (7.0%), inhalation/nasal (6.1%), and ocular (4.3%).

Emergency Management of Chemical Burns

A general approach to the patient with chemical burns involves scene safety, protecting health care workers from exposure, removing the patient from exposure, removing any necessary clothing and jewelry, and brushing off dry chemicals with a suitable instrument. Dry lime in particular should be brushed off before attempting irrigation, because it contains calcium oxide that reacts with water to form calcium hydroxide, a strong alkali. In contrast to thermal burns, many chemicals will continue to induce injury until removed, so immediate clearance of the offending agent is paramount in the intended treatment plan.

For most chemical burn injuries, copious irrigation with water or saline is the initial treatment. The exceptions to this are elemental metals and possibly phenols. Elemental metals produce exothermic reactions when combined with water, whereas aqueous irrigation of phenols may cause deeper infiltration into tissue. Gentle irrigation of chemical burns under low pressure is essential, because higher pressure irrigation can cause deeper infiltration of the chemical into the skin and place the patient and provider at risk for splatter injury. Moderately warm water is often advised. Irrigation should be started promptly, because started initial treatment in the field has been associated with reduced severity of burn injury and a shorter length of hospitalization.[9] Irrigation should begin with the eyes and face, which prevents further inhalation or ingestion or toxin. Treatment should continue until the pH at the skin surface is neutral, which may take 2 hours or more in the case of alkali burns. Ideally, pH at the skin surface should be measured 10 to 15 minutes after discontinuation of irrigation. Litmus paper, if available, is ideal for this purpose. Neutralizing agents are generally not recommended given the potential for an exothermic reaction to occur between the 2 substances. The delay in obtaining the neutralizing agent will also allow for deeper tissue injury if water is readily available.

Ocular injuries should be similarly irrigated with water or saline or until neutral pH is achieved. Concentrated ammonia can induce severe anterior structural injury within 1 minute of exposure, whereas lye can cause deeper injury within 3 to 5 minutes.[10]

The initial management of phenol injuries is also somewhat controversial, with some arguing that irrigation may enhance dermal spread and penetration of the compound. Polyethylene glycol (PEG) has both hydrophilic and hydrophobic properties, which may be the ideal method of phenol decontamination. However, animal studies have not shown a significant difference in phenol plasma levels when burns were irrigated with PEG or water.[11] Furthermore, because of the rarity