Pathophysiology

Most acids produce a coagulation necrosis by denaturing proteins, forming a coagulum (eg, eschar) that limits the penetration of the acid. Bases typically produce a more severe injury known as liquefaction necrosis. This involves denaturing of proteins as well as saponification of fats, which does not limit tissue penetration. Hydrofluoric acid is somewhat different from other acids in that it produces a liquefaction necrosis.

The severity of the burn is related to a number of factors, including the pH of the agent, the concentration of the agent, the length of the contact time, the volume of the offending agent, and the physical form of the agent. The ingestion of solid pellets of alkaline substances results in prolonged contact time in the stomach, thus, more severe burns. In addition, concentrated forms of some acids and bases generate significant heat when diluted or neutralized, resulting in thermal and caustic injury.

The long-term effect of caustic dermal burns is scarring, and, depending on the site of the burn, scarring can be significant. Ocular burns can result in opacification of the cornea and complete loss of vision. Esophageal and gastric burns can result in stricture formation

- Clinical signs and symptoms vary depending on the route of exposure and the particular substances involved. Because of the variety of presentations, emergency clinicians must be prepared to handle all possibilities. Some exposures, such as hydrofluoric acid, may present without immediate pain and should be considered in patients with complaints of slow-onset deep pain occurring after exposure to an appropriate product.
- Patient history should include the following:
- Offending agent, concentration, physical form, pH
- Route of exposure
- Time of exposure
- Volume of exposure
- Possibility of coexisting injury
- The timing and extent of irrigation

- For children presenting with chemical burns a thorough history of the situation should be obtained, considering possible neglect and/or abuse. Children may be exposed to caustic substances in methamphetamine labs.

Physical

- If the exposure was by ingestion, the immediate concern is to protect the patient's airway. If there is evidence of airway compromise (eg, oropharyngeal edema, stridor, use of accessory muscles), consider establishing a definitive airway.
- Dermal exposures
- Size
- Depth
- Location
- Circumferential burns

- Ocular exposures
- Visual acuity

- Presence of periorbital dermal lesions
- Scleral and corneal lesions (eg, ulcerations, fluorescein uptake)
- Leakage of vitreous humor

- Ingestions
- Presence of oral burns or edema, drooling
- Dysphagia, stridor, wheezing, dyspnea, tachypnea
- Abdominal tenderness, guarding, crepitus, subcutaneous air (Hamman crunch)

Causes

A large number of industrial and commercial products contain potentially toxic concentrations of acids, bases, or other chemicals that can cause burns. Some of the more common products are listed as follows:

- Acids
- Sulfuric acid is commonly used in toilet bowl cleaners, drain cleaners, metal cleaners, automobile battery fluid, munitions, and fertilizer manufacturing. Concentrations range from 8% acid to almost pure acid. The concentrated acid is very viscous and denser than water. It also generates significant heat when diluted. These attributes make sulfuric acid an effective drain cleaner. Concentrated sulfuric acid is hygroscopic. Thus, it produces dermal injuries by dehydration, thermal injury, and chemical injury.
- Nitric acid is commonly used in engraving, metal refining, electroplating, and fertilizer manufacturing.
- Hydrofluoric acid is commonly used in rust removers, tire cleaners, tile cleaners, glass etching, dental work, tanning, semiconductors, refrigerant and fertilizer manufacturing, and petroleum refining. This is actually a weak acid, and, in dilute form, it will not cause immediate burning or pain on contact.
- Hydrochloric acid is commonly used in toilet bowl cleaners, metal cleaners, soldering fluxes, dye manufacturing, metal refining, plumbing applications, swimming pool cleaners, and laboratory chemicals. Concentrations range from 5-44%. Hydrochloric acid is also known as muriatic acid.
- Phosphoric acid is commonly used in metal cleaners, rustproofing, disinfectants, detergents, and fertilizer manufacturing.
- Acetic acid is commonly used in printing, dyes, rayon and hat manufacturing, disinfectants and hair wave neutralizers. Vinegar is dilute acetic acid.
- Formic acid is commonly used in airplane glue, tanning, and cellulose manufacturing.
- Chloroacetic acids
- Monochloroacetic acid is used in the production of carboxymethylcellulose, phenoxyacetates, pigments, and some drugs. It has significant systemic toxicity because it enters and blocks the tricarboxylic acid cycle, inhibiting cellular respiration. It is highly corrosive.

- Dichloroacetic acid is used in manufacturing chemicals. It is a weaker acid than trichloroacetic acid, and it does not inhibit cellular respiration.
- Trichloroacetic acid is used in laboratories and in chemical manufacturing. It is highly corrosive and "fixes" tissues it contacts. It does not inhibit cellular respiration.

- Phenol and cresols
- Phenol, also known as carbolic acid, is a weak organic acid used in the manufacture of resins, plastics, pharmaceuticals, and disinfectants.
- Cresols are dihydroxybenzenes that are used as wood preservatives, degreasing agents, and chemical intermediates. These substances are very irritating to the skin and can be absorbed through the skin to produce systemic toxicity.

- Bases
- Sodium hydroxide and potassium hydroxide are used in drain cleaners, oven cleaners,

Clinitest tablets, and denture cleaners. They are extremely corrosive. Clinitest tablets contain 45-50% sodium hydroxide (NaOH) or potassium hydroxide (KOH). Solid or concentrated NaOH or KOH is denser than water and generates significant heat when diluted. Both the heat generated and the alkalinity contribute to burns.

- Calcium hydroxide also is known as slaked lime. It is used in mortar, plaster, and cement. It is not as caustic as NaOH, KOH, or calcium oxide.
- Sodium and calcium hypochlorite are common ingredients in household bleach and pool chlorinating solution. Pool chlorinators also contain NaOH and have a pH around 13.5, making them very caustic. Household bleach has a pH around 11 and is much less corrosive.
- Calcium oxide, also known as lime, is the caustic ingredient in cement. It generates heat when diluted with water and can produce a thermal or caustic burn.
- Ammonia is used in cleaners and detergents. The dilute form is not highly corrosive. Gaseous anhydrous ammonia is used in a number of industrial applications, particularly in fertilizer manufacturing. It is very hygroscopic (has a high affinity for water). It produces injury by desiccation and heat of dilution in addition to causing a chemical burn. It can cause severe skin burns as well as pulmonary injury.
- Phosphates commonly are used in many types of household detergents and cleaners. Substances include tribasic potassium phosphate, trisodium phosphate, and sodium tripolyphosphates.
- Silicates include sodium silicate and sodium metasilicate. They are used to replace phosphates in detergents. Dishwashing detergents are alkaline, primarily to builders such as silicates and carbonates. They are moderately corrosive.
- Sodium carbonate is used in detergents. It is moderately alkaline, depending on the concentration.
- Lithium hydride is used to absorb carbon dioxide in space technology applications. It vigorously reacts with water to generate hydrogen and lithium hydroxide. It can produce thermal and alkaline burns.

- Oxidants
- Bleaches: Chlorites are the primary chemicals used as bleaches in the United States. Household bleach is alkaline with a pH of 11-12, but it is dilute enough that it is minimally irritating to the skin. More concentrated, industrial strength chlorites may be more damaging to the skin.
- Peroxides: Household-grade hydrogen peroxide (3%) produces minimal-to-no skin irritation. Concentrations of 10% may cause paresthesias and blanching of the skin. Concentrations of 35% or more will cause immediate blistering.
- Chromates: Potassium dichromate and chromic acid are common industrial chemicals used in tanning, waterproofing fabrics, corrosion inhibitor, painting, and printing, and they are also used as an oxidizing agent in chemical reactions. Chromates can result in severe skin burns and subsequent systemic toxicity, including renal failure.
- Manganates: Potassium permanganate is a strong oxidizing agent that is used in dilute solutions as a disinfectant or sanitizing agent. In dilute solutions, it is minimally irritating to the skin. In concentrated form or pure crystals, it can cause severe burns, ulcerations, and systemic toxicity.

- Other substances
- White phosphorus: This chemical is used as an incendiary in the manufacture of munitions, fireworks, and fertilizer. White phosphorus is spontaneously oxidized in air to phosphorus pentoxide, giving off a yellow flame and a dense white smoke with a garlic odor. After explosions of munitions or fireworks, small particles of phosphorus can become embedded in the skin and continue to smolder. [3]
- Metals: Elemental lithium, sodium, potassium, and magnesium react violently with water, including water on the skin.
- Hair coloring agents contain persulfates and concentrated solutions of peroxides. Straightening agents may contain concentrated alkali. Chemical burns can result if these are not diluted properly or have a prolonged contact time with the scalp. Burns with various products have been reported in the literature. [5]
- Airbag injuries: The rapid inflation of airbags is accomplished through the rapid decomposition of sodium azide to produce nitrogen gas. The sodium generated then reacts with potassium nitrate and silicon dioxide to produce gas. In the second step, small amounts of sodium hydroxide and sodium carbonate are generated. Airbags can produce abrasions, lacerations and contusions through the physical force of the rapid expansion. They can also produce alkaline chemical burns. These are especially concerning when corneal abrasions occur due to airbags. [6]

- Vesicants: These agents are primarily chemical warfare agents and are also known as blister agents

Laboratory Studies

- Lab studies depend on the burn type and extent of exposure.
- Severe burns
- Electrolytes
- Creatinine
- BUN
- Glucose
- Urinalysis
- CBC
- Creatine phosphokinase
- Coagulation profile

- Localized burns - Usually no lab tests required
- Hydrofluoric acid burns
- Calcium

- Magnesium
- Potassium

- Ingestions of caustics
- Hemoglobin/hematocrit
- Pulse-oximetry or ABG if respiratory symptoms

- Oxalic acid burns
- Calcium

- Chromic acid
- BUN
- Creatinine

- Monofluoroacetic acid burns
- Electrolytes
- ABG

- Phenol
- Electrolytes
- CBC
- Urinalysis
- Creatinine
- Liver function tests

Imaging Studies

- Ingestions
- Chest radiography if any respiratory symptoms
- Abdominal radiography (flat and upright) if signs of peritonitis are present

Other Tests

- Endoscopy for ingestions
- Perform esophagoscopy and gastroscopy on all patients with symptomatic ingestions and on patients who are asymptomatic but have a history of a significant ingestion of a substance

with the potential to cause major injury. [7,8]

- Findings on esophagoscopy do not correlate well with physical signs and symptoms. Of patients with esophageal injuries, 2-15% have no oral burns.
- Burn findings are classified as superficial, transmucosal, or transmural.
- Esophagoscopy findings are used to guide further treatment. The presence of full-thickness or circumferential burns is associated with future stricture formation.
- The issue of whether to extend the endoscopic examination past the first site of injury is controversial.

- Check the pH for any chemical exposure to the eye or for airbag injuries

Prehospital Care

Prompt wound irrigation is the most critical aspect in preventing the extent of dermal burns from exposure to caustic substances. Animal studies have shown that irrigation of both acid exposures and alkaline exposures within several minutes decreases the pH change in the skin and the extent of dermal injury. A burn center case series found that patients who received irrigation within 10 minutes had a 5-fold decrease in full-thickness injury and a 2-fold decrease in length of hospital stay.[9]

- Prevent contaminated irrigation solution from running onto unaffected skin.
- Remove contaminated clothes.
- Special situations
- If contamination with metallic lithium, sodium, potassium, or magnesium has occurred, irrigation with water can result in a chemical reaction that causes burns to worsen. In these situations, the area should be covered with mineral oil and the metallic pieces should be removed with forceps and placed in mineral oil. If forceps are not available, soak the area with mineral oil and cover it with gauze soaked in mineral oil.
- If contamination with white phosphorus has occurred, thoroughly irrigate the area with

water then cover the area with water-soaked gauze. Keep the area moist at all times. The area can also be covered with petroleum jelly.

- If eye exposures have not been irrigated, then this should be started immediately. Immediate removal of caustic substances in the eye is critical. [10]

Emergency Department Care

The first priority in treatment is to ensure complete removal of the offending agent. Thorough decontamination is key. Adequate irrigation is difficult to define and depends on the amount of exposure and the agent involved. Using litmus paper to measure the pH of the affected area or the irrigating solution is helpful. Complete removal and neutralization of concentrated acids and alkalis may require several hours of irrigation. Tap water is adequate for irrigation. Low-pressure irrigation is desired; high pressures may exacerbate the tissue injury.[9,11,12,13]

- If a question of airway compromise exists, secure the airway.
- Large surface burns require the same fluid therapy as that for thermal burns. See Burns, Thermal.
- After initial decontamination, the full extent of the injury must be ascertained and the patient must be treated as a typical burn patient. Based on the degree of injury, ensure adequate fluid resuscitation and take precautions to prevent complications (eg, hypothermia, infection, rhabdomyolysis).
- Special situations
- Elemental metals: The elemental forms of lithium, potassium, sodium, and magnesium react with water. If these metals are thought to be on the skin of a patient, do not irrigate with water. The metallic pieces should be removed manually with forceps and placed in a container of mineral oil.
- White phosphorus: Keep the area immersed in water and manually remove any phosphorus particles seen. Visualization under a Wood lamp may aid in detection and removal of retained phosphorus particles. [3]
- Phenol: Polyethylene glycol 300 or 400 and isopropyl alcohol have been recommended for the removal of phenols and cresols. If skin damage has already occurred, isopropyl alcohol may be very irritating. Polyethylene glycol should be diluted with water to form a 50:50 ratio prior to using. One study showed polyethylene glycol no more efficacious than copious water irrigation for phenol exposures. [14]

- Hydrofluoric acid burns
- These burns require special consideration. They should initially be treated as any other burn, with thorough irrigation. However, due to the penetrating power of the fluoride ion, specific neutralization procedures are indicated. Fluoride can be neutralized by either calcium or magnesium. For small superficial burns, topical calcium or magnesium gels can be applied. Deeper burns usually require subcutaneous injections of calcium gluconate. Hand burns can be difficult to manage; these burns can be treated with subcutaneous injections of calcium, intra-arterial calcium infusions, or intravenous infusions of magnesium. Keeping the hand warm and adequately treating pain will help to increase local circulation and the body's natural supply of calcium and magnesium. [15]
- No objective studies comparing intra-arterial calcium to other treatments have been done. Studies on animals demonstrated that intravenous magnesium is as effective or more effective than subcutaneous injections of calcium in treating local hydrofluoric acid burns. When local treatment of hydrofluoric acid burns is not possible, this treatment is safe and should be considered. [16]

- Ocular exposures[10]
- The goal for decontamination should be to achieve a pH (of the eye wash) of at least 7.3, preferably 7.4. If the pH remains below this, check the pH of the irrigating solution. The pH should be rechecked 30 minutes after irrigation has been completed.
- If pH paper is not available, an adequate guideline is decontamination with 2 L of irrigation fluid over 30-60 minutes. A Morgan lens is recommended for irrigation. Use a topical anesthetic prior to use.

- Caustic ingestions
- Gastric emptying is contraindicated. Activated charcoal is not useful and may interfere with subsequent endoscopy. Dilution with milk or water is contraindicated if any degree of airway compromise is present. Milk may interfere with subsequent endoscopy. Water is benign. Some substances, such as drain cleaners containing sulfuric acid or sodium hydroxide, generate heat when diluted with water. Local areas of heat generation can be minimized by diluting with a moderate quantity of fluid (250-500 mL). [17,18,19]
- Do not attempt to neutralize the caustic agent. Neutralizing the caustic agent may generate excessive heat from the exothermic reaction of neutralization.

Medications have a limited role in the treatment of most chemical burns. Topical antibiotic therapy is usually recommended for dermal and ocular burns. Calcium or magnesium salts are used for hydrofluoric acid burns. Pain medications are important for subsequent burn care.

Steroid therapy is controversial for caustic ingestions but may be helpful for treating upper airway inflammation. No evidence indicates that steroid therapy decreases incidence of stricture formation. Steroids may predispose the patient to infection and may mask signs of perforation. There has been some use of aloe products on mild burns; however, currently, no definitive information on their use for chemical burns is available.[20,18]

Nonsteroidal anti-inflammatory agents do provide some degree of pain relief for mild burns by inhibition of prostaglandin mediators. These have not been evaluated for chemical burns and should be avoided in all cases of GI burns from ingestions.

After decontamination is performed on patients with chemical burns affecting a significant portion of the body, administer standard IV fluid and narcotic therapy as used for thermal burns