Chemical Burn First Aid

"The solution to the pollution is dilution"

INTRODUCTION

Toxic chemicals react with the skin, may not be easily removed, and thereby continue to cause injury for an extended time. The severity of a chemical burn is reduced by prompt recognition and reducing the duration of contact.

Chemicals cause injury in four ways:

- Absorption through the skin and mucous membranes
- Oral Ingestion
- Inhalation
- A combination of any of the three (i.e., a scald burn with chemicals in the water)

Chemical burns are progressive injuries , and it is often very difficult to determine the severity early in the course of treatment. The initial appearance of a chemical burn can be deceptively superficial and any patient with a serious chemical burn injury should be referred to a burn center for evaluation and definitive management.

CLASSIFICATION

- **Alkalis (pH>7)**

Alkalis damage tissue by liquefaction necrosis and protein denaturation; essentially melting any tissue in their path (alkalis react with lipids to form soaps). This process allows for a deeper spread of the chemical and progression of the burn than with acids. Alkalis, including lye and other caustic sodas, may contain the hydroxides, or carbonates of sodium, potassium, ammonium, lithium, barium and calcium.

They are commonly found in oven, drain and toilet bowl cleaners, and heavy industrial cleansers like wax stripping agents. Hydrated calcium hydroxide forms the structural bond in cement and concrete. Wet cement, with a pH of approximately 12, can cause a severe alkali chemical burn. Another common alkali is anhydrous ammonia (which is discussed in another section).

- **Acids (pH<7)**

Acids damage human tissue by coagulation necrosis and protein precipitation (leather is manufactured when dermis comes in contact with a weak acid). Thus, acids cause a leathery eschar of variable depth, which, unlike alkalis, may limit the spread of the injury. Like alkalis, acids are also prevalent in both the home and in industry. They may be found in many household products. Bathroom cleansers and calcium or rust removers may contain hydrochloric acid, oxalic acid, phosphoric acid or hydrofluoric acid.

Concentrated hydrochloric (muriatic) acid is the major acidifier for home swimming pools and is used to clean masonry and brick. Concentrated sulfuric acid is utilized in industrial drain cleaners and lead-acid car batteries.

- **Organic Compounds**

Organic compounds cause cutaneous damage due to their solvent action on the fat in cell membranes. Here again, they essentially melt the fatty tissue in their path. Once absorbed, they can produce harmful effects, especially on the kidneys and liver**.**

Can result in multi-system organ injury and failure. Many organic compounds, including phenols, creosote, and petroleum products, produce contact chemical burns and systemic toxicity. Phenols are prevalent in a variety of chemical disinfectants. Petroleum, including creosote, kerosene, and gasoline, is commonly used in the home, in industry, and in recreation.

Factors that determine injury severity

The severity of a chemical injury is related to:

- Chemical composition of the agent and the mechanism of action
- Concentration of the agent
- Temperature of the agent
- Volume or quantity of the agent
- Duration of contact

The chemical composition of the agent (alkali, acid, or organic compound) determines its interaction with the skin, and the potential depth of tissue penetration. Temperature affects the rate at which a chemical reacts with the tissue.

Concentration and duration of contact influence the depth of injury, and the volume of the chemicals affects the extent of body surface area involved. Immediate removal of affected clothing and on-site irrigation can result in decreased morbidity.

GENERAL APPROACH

The potency and concentration of the toxic agent and the duration of contact primarily determine the degree of tissue destruction. Therefore, it is critical that treatment be started immediately. In the great majority of cases, the management of topical chemical burns consists of the following general steps:

- Ensure protection of rescuers and health care workers from exposure
- Remove the patient from the area of exposure
- Remove all clothing and jewelry
- Brush any dry chemicals off the patient; any suitable instrument may be used (eg, dry brush, towel)
- Avoid hypothermia

Leave dry chemicals dry! Brush off chemical, do not wet a dry chemical!!

TREATMENT PRINCIPLES

Certified nurse and pharmacist specialists in poison information and board-certified medical toxicologists are available 24/7 to provide patient-specific treatment recommendations for chemically exposed patients. Contact your poison center at 1-800-222-1222.

- ### Personal Protection Equipment and Decontamination – Protect yourself!

Body Substance Isolation (BSI) must be observed in the treatment of all patients with a suspected chemical injury. All pre-hospital and in-hospital personnel should wear chemical-protective gloves, suit gown, and eye and respiratory protection as needed prior to contact with the patient. The level of personal protective equipment should be tailored to the toxicity of the substance. Remember that patient's clothing often contains remnants of the toxic agent, and "off-gassing" may occur. Contaminated clothing can release toxic fumes, exposing first responders to inhalation injury. Failure to take simple precautions can lead to significant provider injury. Don't become a victim!

All chemical burns should be immediately decontaminated while using BSI protection. Decontamination is the process of removing or neutralizing a hazard from the victim to prevent further harm and enhance the potential for full clinical recovery. For all chemical burns, immediate removal of the contaminated clothing (including underwear, gloves, shoes, jewelry and belongings) is critical, since at least 80% of chemicals can be removed from the body by taking these steps. All contaminated clothing and belongings should be handled or disposed of according to organizational/institutional protocols to prevent secondary contamination to others.

- ### Water Irrigation – "The solution to the pollution is dilution!"

Brush any powdered chemical from the skin prior to beginning irrigation. Then, begin continuous irrigation of the involved areas with copious amounts of water. No substance has been proven to be superior to water for initial therapy. Irrigation should be continued from the pre-hospital scene through emergency evaluation in the hospital. Irrigation alone is not sufficient for substances that are not soluble in water (such as hydrocarbons); these skin exposures require removal with soap and water.

Efforts to neutralize the chemical are contraindicated due to the potential generation of heat (an exothermic reaction), which could contribute to further tissue destruction. Irrigation in the hospital should be continued until the patient experiences a decrease in pain or burning in the wound or until the patient has been evaluated in a burn center. Skin pH can be checked by using pH test strips and should be performed before and after irrigation. It may take 30 minutes of irrigation or more, depending on initial skin pH, to achieve a normal skin pH level.

If the chemical exposure is to a large body surface area, caution must be taken to avoid hypothermia. Use warm water for irrigation and maintain a warm environment whenever possible.

- **Primary Survey**

Support the "ABCs" (airway, breathing, circulation); volatile chemical agents like ammonia can have profound respiratory effects. It is important to continually evaluate the patient's airway status and to address promptly any evidence of airway compromise. Intravenous access should be obtained for all significant chemical injuries.

Patients who are wearing contact lenses, with or without facial burns, should have the lenses removed prior to development of facial and periorbital edema. Chemicals may also adhere to the lenses, prolonging exposure to the chemical and presenting further problems.

Only after initial therapy has begun, it is helpful to try and identify the causative agent and any associated medical risks, including potential systemic toxicity. However, initial therapy should NOT be delayed while attempts are made to identify the agent involved.

- **Chemical Injuries to the Eye**

Alkalis cause chemical eye injuries twice as frequently as acids, and occur primarily in young adults at home, in industrial accidents, and in assaults. Alkalis bond to tissue proteins and require prolonged irrigation to dilute the chemical and stop progression of the injury. Chemical eye injuries cause severe lacrimation, conjunctivitis and progressive injury to the cornea that can lead to blindness. A patient who develops an opaque cornea on exam may have limited prognosis for recovery. Water or saline irrigation is the emergency treatment of choice. Irrigation from the scene to the emergency room is mandatory to minimize tissue damage. In the case of a chemical burn to the eye, consult an ophthalmologist and continuously irrigate the eye.

The majority of patients presenting with an alkali eye burn will have swelling and/or spasm of the eyelids. To adequately irrigate for extended periods of time, the eyelids must be forced apart to allow flushing of the eye. In the emergency department, irrigation should be performed by placing catheters in the medial sulcus for irrigation with normal saline or a balanced salt solution (nasal canula oxygen tubing placed over the bridge of the nose irrigating the globe medial to lateral, attached to bag of fluid is another adaptation for eye irrigation).

This allows for prolonged irrigation without runoff of the solution into the opposite eye. Alternatively, an irrigating catheter (Morgan lens) may be fitted over the globe. Extreme caution should be used when employing this irrigating modality to prevent additional injury to the eye. Patients who wear contact lenses, with or without facial burns, should have the lenses removed prior to development of facial and periorbital edema. Chemicals may adhere to the lenses, prolonging exposure to the chemical and causing further injury. Continue irrigation until the patient has been fully evaluated by a qualified professional. An ophthalmologist in consultation with the burn center should see all chemical injuries to the eye.

Severe alkali burn to the right eye

- ## Pediatric Chemical Burns

Children have thin skin which is easily injured by toxic chemicals. In addition to skin injuries, remember that children are more likely to ingest chemicals than adults. Lye ingestion is especially dangerous and may lead to esophageal perforation. Children are less able to process and eliminate chemicals and the developing brain and organs may be more susceptible to damage associated with chemical injuries.

SPECIFIC CHEMICAL BURNS

- ## Cement Burns

The active ingredient calcium oxide (quicklime) can combine with water to form calcium hydroxide with a pH >12. For instance, cement powder exposure at a construction site can lead to severe alkali burns. Often, the unsuspecting worker is exposed to cement powder in their socks, or around the knees while kneeling at work. Sweat will activate the powder and lead to chemical injury that will evolve over 6–12 hours. The injury site will first be erythematous and may not be recognized as a chemical injury by the patient or a health care provider unless the exposure is obtained during history- taking. Hours later, a full-thickness eschar often develops at the site of exposure.

- ## Anhydrous Ammonia

Anhydrous ammonia is commonly used as a fertilizer, industrial refrigerant and in the illicit manufacture of methamphetamine. It is a strong base (pH 12), with the penetrating odor of smelling salts. **Anhydrous ammonia is activated when it comes in contact with body moisture**. Moist or sweaty areas of the body such as the axilla or groin are frequent sites of serious injury; see examples discussed below.

- Skin Exposure: Exposure causes blistering of the skin. Contact with vaporizing liquid anhydrous ammonia may cause frostbite due to rapid evaporative cooling.
- Eye Irritant: Anhydrous ammonia is an eye irritant that may cause severe eye irritation with corneal injury and permanent vision impairment. Eye injuries require prolonged irrigation of the eye and need to be evaluated by an ophthalmologist.

Respiratory Effects**: Inhalation of anhydrous ammonia may result in serious injury to the entire respiratory tract.** Delayed effects may include potentially life-threatening edema of the upper and lower airway. Chemical pneumonitis and pulmonary edema may develop up to several hours after exposure.

At high concentrations, laryngeal spasm may occur, resulting in rapid asphyxiation. At lower concentrations, effects are more pronounced in children, elderly, and persons with impaired lung function. Inhalation injuries with hypoxemia and copious secretions may require ventilatory support.

Immediately after exposure, all clothing (including undergarments), shoes, and jewelry should be removed and disposed of according to organizational protocols. The eyes and affected areas should be copiously irrigated with water for at least 30 minutes.

- ## Hydrofluoric Acid (HF)

Hydrofluoric Acid is a corrosive agent used in industry in a variety of ways such as glass etching, the manufacture of Teflon, and to cleanse metals and silicon semiconductors, and for a variety of other uses. It is used in home and industrial cleaners as a rust remover and is often combined with other agents in these products. HF may cause damage to the skin and eyes, and when inhaled, leads to severe respiratory problems.

While the local effects of HF are limited because it is a weak acid, the fluoride ion is very toxic. Fluoride rapidly binds with free calcium in the blood. Cardiac dysrhythmias and death from hypocalcemia may occur. Higher concentrations cause immediate intense pain and tissue necrosis. **Death can occur from hypocalcemia as the fluoride rapidly binds free calcium in the blood**. Cardiac dysrhythmias may occur. Exposure to at low concentrations (less than 10 percent) causes severe pain, which does not appear for 6- 8 hours.

After hydrofluoric acid exposure, all clothing including undergarments should be removed and disposed of appropriately. The affected areas should be copiously irrigated with water beginning at the scene for at least 30 minutes.

Once in an appropriate facility, topical calcium gel may be used to neutralize the fluoride (one ampule of calcium gluconate and 100 gm of water-soluble lubricating jelly). ***This is one of the rare exceptions of a direct neutralizing agent being used to acutely treat a chemical exposure***. The gel is applied with a gloved hand to avoid spread of the fluoride to other body parts or to medical personnel.

This calcium mixture can be placed inside a surgical glove worn by the patient to treat injuries of the hand. Patients who have persistent pain may require intra-arterial infusion of calcium gluconate at a regional burn center and require careful monitoring.

Severe pain indicates exposure to a high concentration, which may also cause life-threatening hypocalcemia. In addition to topical calcium, begin cardiac monitoring and place an intravenous catheter in anticipation of calcium gluconate infusion to treat hypocalcemia. Poison center and burn center consultation is required, since aggressive calcium infusion and early excision of the wound may be lifesaving.

- ## Phenol Burns

Phenol is an acidic alcohol with poor solubility in water, and is frequently used in disinfectants, chemical solvents, and wood and plastic processing. It damages tissue by causing coagulation necrosis of dermal proteins. Initial treatment consists of copious water irrigation followed by cleansing with 50% polyethylene- glycol (PEG), isopropyl or ethyl alcohol, which increases the solubility of the phenol in water and allows for more rapid removal of the compound. Of note, diluted solutions of phenol penetrate the skin more rapidly than concentrated solutions, which form a thick eschar via coagulation necrosis.

- ## Petroleum Injuries (Not Due to Flame Burns)

Gasoline and diesel fuel are petroleum products that may cause severe tissue damage. Prolonged contact with gasoline or diesel fuel may produce (by the process of de-lipidation) a chemical injury to the skin that is actually full thickness but initially appears to be only partial thickness or second degree. Sufficient absorption of the hydrocarbons can lead to organ failure and even death. It is important to look for petroleum exposure in the lower extremities, the back, and the buttocks after a motor vehicle crash, especially if patient extraction is delayed.

Clothing and belongings exposed to the fuel are potentially flammable, and must be kept away from any ignition source until appropriate disposal. Systemic toxicity may be evident within 6 to 24 hours, with evidence of pulmonary insufficiency, hepatic and renal failure. Within 24 hours, hepatic enzymes are elevated and urinary output is diminished. Patients with these injuries require immediate transfer to a burn center.

- ## Chemical Warfare Agents

The use of chemicals in warfare has been practiced for hundreds of years. Chemical agents played a major role in the morbidity and mortality associated with World War I and have also been used in terrorist attacks. Chemical warfare agents can be divided into categories like vesicants, such as mustard agents, Lewisite and chlorine gas, and nerve agents, such as Sarin.

These chemicals are highly toxic and can produce cutaneous, respiratory, and systemic toxicity, including pulmonary, hepatic, and neurologic damage. Protection of responders and healthcare workers with appropriate personal protective equipment is critical. Antidotes are often needed, and the poison center should be quickly contacted for treatment advice.

These agents affect all epithelial tissues, including the skin, eyes, and respiratory epithelium. Symptoms described after exposure to mustard gas include burning eyes, a burning throat, and a feeling of suffocation. This is followed by erythema of the skin within 4 hours and blister development within 12 to 48 hours. Severe pruritis develops, particularly in moist areas such as the axilla and perineum. When the blisters rupture, they leave painful, shallow ulcers. Exposure to larger quantities of these agents produces coagulative necrosis of the skin, with either no blistering or “doughnut blisters” surrounding a central necrotic zone.

Lewisite is an arsenical compound. It is more powerful than the mustards, and the symptoms occur sooner.

Phosgene oxime is another common agent in chemical warfare. It is the most widely used halogenated oxime and has the immediate effect of stinging, likened to contact with a stinging needle. Affected areas quickly become swollen with blister formation, and eschars develop over the ensuing week. Wound healing is slow, typically over 2 months. Eye involvement is extremely painful and can result in permanent blindness. Inhalation leads to hypersecretion and pulmonary edema.

Treatment of victims of chemical attacks must follow the same principles used for other chemical agent exposures: use of Body Substance Isolation gear, removal of all patient clothing, shoes and jewelry, and copious irrigation with water. Patients with respiratory compromise should be intubated if necessary. Facilities should establish a single area for isolation of contaminated clothing and equipment when treating multiple casualties in order to avoid secondary injury in providers. Agents used in chemical attacks frequently have both short and long-term morbidity and toxicity.

- **Burns Associated with Illicit Drug Manufacturing, Methamphetamine Fires and/or Explosions:**

Burns associated with illicit drug manufacturing such as methamphetamine {meth lab} explosions pose additional dangers to all healthcare providers. There are many hazardous chemicals involved. Pseudoephedrine, iodine, red phosphorus, ether, hydrochloric acid, sodium hydroxide and methanol can be used to produce methamphetamine. Unsafe manufacturing procedures, dangerous combinations and storage often result in explosions and fires, placing first responders at even greater risk.

Patients involved in these incidents are sometimes vague about the circumstances of injury, reporting that he/she was involved in a "fire" of some type. Upon evaluation, the pattern of burn injury is inconsistent with the history being reported. The patient may present with serious burns that appear to be thermal/flame burns in appearance but actually are a combination of flame and chemical injuries. Methamphetamine producers may also be chronic users who also manifest severe tachycardia, dehydration, agitation and paranoia. If it is possible the patient was injured in an illegal drug or meth lab explosion, treatment must include appropriate protective clothing by healthcare providers, decontamination of the skin and eyes, proper disposal of contaminated clothing and belongings, and treatment of the thermal injuries.

The most important component of active therapy is irrigation of all wounds and areas of exposure thoroughly with copious amounts of water!

- **SUMMARY**

Chemical burns constitute a special group of injuries and require referral to a burn center for evaluation and definitive management. Individuals caring for patients exposed to chemical agents must always wear protective clothing to avoid personal contact with the chemical. To limit tissue damage, immediate removal of the agent and contaminated clothing, followed by copious irrigation with water is essential. Irrigation should be continued through transport until patient pain is relieved or the patient is transferred to a burn center. Ammonia, phenol, petroleum, and hydrofluoric acid burns, as well as any chemical injury to the eye, require special consideration. Adherence to basic therapeutic treatment principles can significantly decrease patient morbidity after a chemical injury.

Complete removal of the toxic chemical is essential. Tissue damage continues for as long as the chemical remains in contact with skin.

To ensure thorough decontamination, remove all clothing and jewelry, brush off all dry agents, and begin irrigation with copious amounts of water immediately at the scene of exposure and continue until arrival at the ED, burn center or until neutral pH is achieved. Thirty minutes to 2 hours of lavage is often necessary.

REFERENCES

- American Burn Association Advanced Burn Life Support Provider Manual, 2016 Update, Chemical Burns; 77-86.
- Herndon, DN, Williams, FN, Lee, JO. Total Burn Care, 5th Edition, Chemical Burns; 408-413.
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