CHEMICAL BURNS

- **ACCOUNT FOR 5-10% OF BURN CENTRE ADMISSIONS**
- **DEATHS ARE RARE (<1% OF EXPOSURES) AND USUALLY RESULT FROM *CAUSTIC INGESTION***
- **MOST OFTEN BURNED ARE FACE, EYES AND EXTREMITIES,**
- **WOUND HEALING AND DURATION OF STAY ARE USUALLY LONGER**

PATHOPHYSIOLOGY:

- Chemicals can produce burns, dermatitis, allergic reactions, thermal injury or systemic toxicity.
- Skin damage by chemicals may demonstrate the classic signs of thermal injury.
    - Early on, INJURIES MAY APPEAR DECEPTIVELY MILD, but continued chemical damage through the dermis or into the hypodermis results in a full thickness burn
- General rules:
    - ACIDS TEND TO CAUSE ***COAGULATION NECROSIS*** WITH PROTEIN PRECIPITATION THAT FORMS A TOUGH LEATHERY ESCHAR
        - This eschar typically limits deeper penetration of the agent
    - ALKALIS PRODUCE ***LIQUEFACTIVE NECROSIS*** AND SAPONIFICATION OF LIPIDS
        - THE RESULT IS A POOR BARRIER TO CHEMICAL PENETRATION AND DEEPER, ONGOING BURNS.
- There are multiple factors that influence tissue damage and absorption of chemicals

Table 211-1 Factors Influencing Tissue Damage
Strength and concentration of agent
Manner of contact
Quantity of agent
Phase of agent—liquid vs. solid
Duration of contact
Mechanism of action
Extent of penetration

Table 211-2 Factors Influencing Percutaneous Absorption of Chemicals
Body site
Areas of thin skin (i.e., genitalia, face, and skinfolds are particularly vulnerable)
Amount of surface area
Integrity of skin
Increased vulnerability: traumatized skin, elderly skin, dehydration, inflammation
Nature of the chemical
Lipid solubility, pH, concentration
Occlusion
Garments, occlusive dressings

GENERAL APPROACH:

- The goal of treatment is to minimise any area of irreversible injury and maximize salvage in the zone of reversible damage.
- *AGGRESSIVE IRRIGATION WITH WATER IS THE CORNERSTONE OF MANAGEMENT.*
    - Also: remove clothes etc also exposed.
- Dry chemicals (e.g. lime) should be brushed away before irrigation.
- Cover sodium metal (and related compounds) first with mineral oil
    - Water can cause severe exothermic reaction
- Dilution of phenol (carbolic acid) with water may enhance penetration.
- In general, however, earlier irrigation means a better prognosis
    - The amount of elapsed time to initiation of dilution or removal of the chemical is DIRECTLY RELATED TO THE EVENTUAL DEPTH AND DEGREE OF INJURY.
- Irrigate with gentle flow to avoid driving the chemical deeper into tissue
- TIME REQUIRED:
    - Varies, severe alkali burns may require several hours.
    - Use pH indicator paper to guide duration
        - Continue until pH is neutral
- Following initial therapy, treatment is similar to that of thermal burns.
    - Allergic response to chemicals is also common.

SPECIFIC CHEMICALS

ACID BURNS:

- Examination should not be limited to the skin as several acids are respiratory and mucous membrane irritants as well.
- *With the exception of HYDROFLOURIC ACID*, STRONG ACIDS PRODUCE COAGULATION NECROSIS.
- Most substances with a pH <2 are strong corrosives, but important characteristic that define tissue-damaging properties include:
    - Concentration, molarity, complexing affinity for hydroxyl ions --> the higher each of these, the greater the tissue damage
- CONTACT TIME WITH THE SKIN IS THE MOST IMPORTANT CHEMICAL BURN FEATURE THAT WE CAN ALTER AS CLINICIANS.

ACETIC ACID:

- Most common cause of chemical burns to the scalp as it is used in “hair-wave neutralizers”
- Partial thickness burns, especially in those with already damage scalps
- Copious water irrigation

CARBOLIC ACID (PHENOL):

- Corrosive organic acid
- Paradoxically, DILUTE PHENOL PENETRATES TISSUE MORE READILY THAN CONCENTRATED FORM
- Creates relatively painless white or brown coagulum
- Water lavage alone may *NOT* be totally effective, because the necrotic coagulum inhibits water penetration to the deeper layers
    - Alternative is an isopropyl alcohol rinse similar to polyethylene glycol can be used

CHROMIC ACID:

- Hexavalent chromium compounds are powerful oxidizers producing chronic penetrating ulcer lesions
- Systemic chromium toxicity = liver/renal failure, GI bleeding, coagulopathy, CNS disturbances.
    - Significant symptoms may occur with only 1-2% BSA burns.
    - 10% BSA cutaneous burn caused by chromic acid can be fatal due to systemic toxicity.
- Aggressive excision has been shown to be the best method for prevention of systemic effects because depth of the burn is difficult to determine and absorption may continue after irrigation
- Topical agents (5% thiosulfate, ascorbic acid) have been shown to be useful while waiting for surgery

FORMIC ACID:

- Used by acrylate glue makers **-->** Coagulation necrosis of the skin
- Systemic effects = decreased respiration and anion gap metabolic acidosis

HYDROCHLORIC AND SULPHURIC ACIDS:

- Incl. toilet & drain cleaners (80-98%). Car batteries ~24% sulphuric acid.
- Early decontamination usually prevent serious burns
- Burn the skin dark brown or black
- Water irrigation usually prevents severe burns

HYDROFLOURIC ACID --> **SEE TOXICOLOGY NOTES**

METHACRYLIC ACID:

- Artificial nail cosmetic products (severe dermal burns, usu. in toddlers)
- Copious irrigation with water

NITRIC ACID:

- Used for casting iron and steel
- Can produce tissue damage by oxidation

OXALIC ACID:

- Like hydrofluoric acid, it poisons enzymatic processes, binds calcium and prevents muscle contraction
- Irrigate wounds with water and IV calcium may be required

ALKALIS:

- Alkalis penetrate skin deeper & longer than acids and present a greater danger of toxicity from systemic absorption
- Wound may initially look superficial only to become full-thickness burns in 2-3 days
- Alkalis combine with protein and lipids in tissue to form soluble protein complexes & soaps that permit passage of hydroxyl ions deep into tissue
    - Soft, gelatinous, friable eschars are often produced
- Strong alkalis have a pH >12

LYES:

- Incl. ammonium, barium, calcium, potassium & sodium hydroxides.
- Drain & toilet cleaners, detergents & paint removers.
- *EXTREMELY CORROSIVE AND PENETRATING, BURNS REQUIRE COPIOUS IRRIGATION FOR LONG PERIODS*
- Victims suffer long-term pain, scarring and blindness
- Suicidal ingestion of lye may result in rapid death from upper airway occlusion
    - Late morbidity related to oesophageal and gastric necrosis may be minimized by early surgical intervention with oesophagogastrectomy.

LIME:

- aka. *calcium oxide*
- Lime is converted by water to the alkali *calcium hydroxide* and upon skin contact, it draws water out of the skin
    - ∴ particles should be brushed away before irrigation
- Small amounts of H2O may generate an exothermic reaction
    - Use LARGE AMOUNTS AND A STRONG STREAM OF WATER TO DECONTAMINATE (avoid splashing to the eyes).

METALS:

- Elemental sodium, lithium, potassium, magnesium, aluminum and calcium may all cause burns
- When exposed to air, some elemental metals spontaneously ignite
- WATER IS GENERALLY CONTRAINDICATED in extinguishing burning metal fragments embedded in skin because of the EXPLOSIVE EXOTHERMIC REACTION THAN MAY RESULT --> SMOTHER WITH SAND
- Cover with mineral oil to prevent further ignition
- Excision of metal fragments that cannot be wiped away

OTHER CHEMICAL BURNS:

HYDROCARBONS:

- **GASOLINE:**
    - Resembles a thermal scald and causes a fat-dissolving corrosive injury to the skin
- **HOT TAR:**
    - Roofing tars and asphalt are heated to temperatures up to 260C --> burns are usually more thermal than chemical
    - Solidified material stuck to skin and hair is hard to remove --> should be cooled to prevent thermal injury
    - Many antibiotic ointments can be used to remove tar

VESICANTS:

- eg. mustard gas, dimethlyl sulfoxide (DMSO)
- Vesicants are drying agents than cause skin oedema and blister formation and these injuries occur due to anoxic/ischemic necrosis at the site of contact
- Skin damage following vesicant exposure can be severe and result in deep skin penetration.
- Irrigate burns copiously with water or saline

LACRIMATORS (TEAR GAS)

- E.g. chloroacetophenone, dibenzo-oxazpeine
- Case skin and mucosal irritation and contact dermatitis
- Skin injury is usually limited but inhalation injuries may be severe
- Skin burns treated with water irrigation
- Ocular irritation is treated with copious water irrigation followed by slit lamp examination for corneal damage and close follow up
- High-concentrations of lacrimators cause structural damage of the cornea
- Inhalation injuries are treated with respiratory support
- PEPPER GAS: causes mucous membrane, ocular and upper airway irritation --> irrigate with saline.

POTASSIUM PERMANGANATE:

- In concentrated form, this oxidizing agent produces dermal burns with a thick eschar and should be copiously irrigated with water

WHITE PHOSPHORUS:

- Used as an incendiary in munitions and fireworks
- Can ignite spontaneously when exposed to air
- Flaming droplets may embed in the skin --> heat of the reaction causes tissue destruction
- Particles continue to oxidize slowly until either debrided, neutralized or completely oxidized.
- May reignite if allowed to dry, so wounds should be submerged in water or covered with water-soaked-dressings
- Burns are characterised by slow-healing and ongoing burning --> early and aggressive treatment are required
    - Hypocalcaemia, hyperkalaemia & hepatic and renal injury have all been reported

AIRBAG BURNS:

- **Approximately 8% of those injured by airbags are burned**
- Airbags deploy by ignition of solid propellant that creates an exothermic reaction leading to rapid inflation of the airbag
- Can cause friction, thermal and chemical burns. Look for chemical keratitis.

OCULAR BURNS:

- Chemical burns to the eyes are OCULAR EMERGENCIES REQUIRING IMMEDIATE TREATMENT.
- Early signs/symptoms:
    - tearing, rubbing, redness, pain and belpharospasm
- If the conjunctiva are severely injured --> may appear pale due to ischaemia and destruction of vascular supply
    - Swelling of the corneal epithelium, clouding of the anterior chamber, pupillary dilatation and corneal ulceration all occur
- If the nature of the chemical is not known --> *apply pH indicator paper*

Acid quickly precipitates superficial tissue, producing “ground-glass” appearance

- Penetration is limited by local buffering and barrier effects of precipitated proteins
- Damage is immediate and localised to area of contact

ALKALI BURNS ARE MORE SEVERE AND RESULT ARE FREQUENTLY UNSIGHTLY AND DISASTROUS

- In general, the higher the pH, the worse the damage.
- In a short period of time, strong alkali can penetrate the cornea, anterior

chamber and the retina, with DESTRUCTION OF ALL SENSORY ELEMENTS, THUS CAUSING COMPLETE BLINDNESS !!
- Penetration can continue for hours-days, resulting in globe perforation.

Other complications;

- cataract formation, scarring and marked revascularisation with scarring of both palpebral and bulbar conjunctiva with adhesions between lid and globe

TREATMENT SHOULD BEGIN IMMEDIATELY --> irrigate with copious and continuous water irrigation

- In general, should be started at the scene and continue with 1-2L of normal saline for each eye for 30 minutes with MORGAN LENS
- *Do not use neutralizing substances*
- During irrigation, the eyelid may have to be held open manually or with retractors due to severe orbicularis spasm
- Sweep the fornices with a wet cotton applicator to remove any particulate matter, especially if the pH is not responding well to irrigation
- EMERGENCY OPHTHALMOLOGY CONSULTATION IS REQUIRED FOR CORNEAL BURNS
- Consideration of cycloplegics, mydriatics and antibiotics.

SYSTEMIC TOXICITY:

- Death after sever chemical burns is usually related to hypotension, acute renal failure and shock as a result of FLUID LOSS
- Acidosis, hypotension and shock can occur with systemic absorption of certain acids

Table 211-5 Systemic Effects Associated with Chemical Burns

Chemical	Systemic Toxicity
Hydrofluoric acid	Hypocalcemia, hypomagnesemia, hyperkalemia, cardiac arrhythmias, sudden death
Tannic acid, chromic acid, formic acid, picric acid, phosphorus	Hepatic necrosis, nephrotoxicity
Cresol	Methemoglobinemia, massive hemolysis, multiple organ failure
Gasoline	Severe pulmonary, cardiovascular, neurologic, renal, and hepatic complications
Phenol (carbolic acid)	Intravascular hemolysis and cardiovascular, pulmonary, and central nervous system toxicity
Sodium nitrate, potassium nitrate	Severe methemoglobinemia with refractory cyanosis
Dichromate solution	Liver failure, acute renal failure, death despite hemodialysis

OVERVIEW OF TREATMENTS:

Table 211-3 Treatment of Select Chemical Burns

Chemical	Treatment	Comments
Acids		
All acid burns require prompt decontamination and copious irrigation with water.		
Acetic acid	Copious irrigation.	Consider systemic antibiotics for extensive scalp burns.
Phenol (carbolic acid)	Copious irrigation.	Isopropyl alcohol may also be used.
	Swab with polyethylene glycol 300 and industrial methylated spirits in a 2:1 mixture.	
Chromic acid	Copious irrigation.	Observe for systemic toxicity.
	5% thiosulfate soaks or ascorbic acid creams.	
Formic acid	Copious irrigation.	Dialysis may be needed for severe toxicity.
Hydrofluoric acid	Copious irrigation.	Consider SC or intradermal injection of 5% calcium gluconate or intra-arterial calcium gluconate for severe cases.
	Calcium gluconate gel.	
Nitric acid	Copious irrigation.	Consult with burn specialist.
Oxalic acid	Copious irrigation.	Evaluate serum electrolytes and renal function.
	IV calcium may be required.	Cardiac monitoring for serious dermal exposure.
Alkalis		
All alkali burns require prompt decontamination and copious, prolonged irrigation with water.		—
Portland cement	Prolonged copious irrigation.	May need to remove cement particles with a brush, such as a preoperative scrubbing brush.
Elemental Metals		
Water is generally contraindicated in extinguishing burning metal fragments embedded in the skin.		
Elemental metals (sodium, lithium, potassium, magnesium, aluminum, and calcium)	Cover metal fragments with sand, foam from a Class D fire extinguisher, or with mineral oil.	—
	Excise metal fragments that cannot be wiped away.	
Hydrocarbons		
Gasoline	Decontamination.	—
Tar	Cool before removal.	Mayonnaise can be used.
	Remove using ointment containing polyoxylene sorbitan (polysorbate) or De-solv-it.	
Vesicants		
Mustards	Decontaminate.	If limited water supply, adsorbent powders (flour, talcum powder, fuller's earth) can be applied to the mustard and then wiped away with a moist towel.
	Copious irrigation.	
Reducing Agents		
Alkyl mercury compounds	Copious irrigation.	Blister fluid is high in metallic mercury content.
	Debride, drain, and copiously irrigate blisters.	
Lacrimators		
Tear gas	Copious irrigation.	May cause respiratory symptoms if inhaled.
Pepper spray	Copious irrigation.	May cause respiratory symptoms if inhaled.
Miscellaneous		
White phosphorus	Remove clothing.	Systemic toxicity is a significant concern.
	Copious irrigation.	
	Debride visible particles.	
Airbag	Prolonged copious irrigation.	—