Hydrofluoric Acid Burns
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Introduction

Background:

Hydrofluoric (HF) acid, one of the strongest inorganic acids, is used mainly for industrial purposes (eg, glass etching, metal cleaning, electronics manufacturing). HF acid also may be found in home rust removers. Exposure usually is accidental and often is due to inadequate use of protective measures.

HF acid burns are a unique clinical entity. Dilute solutions deeply penetrate before dissociating, thus causing delayed injury and symptoms. Burns to the fingers and nail beds may leave the overlying nails intact.

Severe burns occur after exposure of concentrated (ie, 50% or stronger solution) HF acid to 1% or more body surface area (BSA), exposure to HF acid of any concentration to 5% or more BSA, or inhalation of HF acid fumes from a 60% or stronger solution. The vast majority of cases involve only small areas of exposure, usually on the digits.

Pathophysiology:

The 2 mechanisms that cause tissue damage are corrosive burn from the free hydrogen ions and chemical burn from tissue penetration of the fluoride ions.

Fluoride ions penetrate and form insoluble salts with calcium and magnesium. Soluble salts also are formed with other cations but dissociate rapidly. Consequently, fluoride ions release, and further tissue destruction occurs.

Frequency:

- **In the US:** More than 1000 cases of HF exposure are reported annually. Actual incidence rate is unknown.

Mortality/Morbidity:

- Local effects include tissue destruction and necrosis. Burns may involve underlying bone.
- Systemic fluoride ion poisoning from severe burns is associated with hypocalcemia, hyperkalemia, hypomagnesemia, and sudden death.
- Deaths have been reported from concentrated acid burns to as little as 2.5% BSA.

Sex: Males are affected more commonly, which reflects occupational patterns.

Age: The majority of exposures occur in adults.

Clinical

History:

- Time of exposure to onset of symptoms is related to the concentration of the HF acid.
  - Solutions of 14.5% immediately produce symptoms.
  - Solutions of 12% may take up to an hour to produce symptoms.
  - Solutions of less than 7% may take several hours before onset of symptoms, resulting in delayed presentation, deeper penetration of the undissociated HF acid, and a more severe burn.
  - Concentrated solutions cause immediate pain and produce surface burns similar to those produced by other common acids (eg, erythema, blistering, necrosis).
  - Pain typically is described as deep, burning, or throbbing.
  - Pain often is disproportionate to apparent skin involvement.
- Obtain history of potential exposure to cleaning solutions within the last 24 hours, to include the following:
  - Duration of exposure
  - Concentration of acid
  - Use of protective measures
  - Other agents in the solution
  - Symptoms of hypocalcemia
    - Tetany
    - Chvostek sign
    - Trousseau sign
  - Cardiac arrhythmias
- Additionally, obtain history of medications and intercurrent illness that predispose patient to hypocalcemia or hypomagnesemia.

Physical:

- Weaker solutions penetrate before dissociating.
- Surface involvement in these cases is minimal and may be absent.
- Three categories of appearance include the following:
  - A white burn mark and/or erythema and pain
  - A white burn mark and/or erythema and pain, plus edema and blistering
  - Ocular burns, which present with severe pain
- Patients with inhalation burns may develop acute pulmonary edema.

Differentials

See: Burns, Chemical
See: Burns, Ocular

Workup

Lab Studies:

- Electrolytes - Severe disturbances can occur, especially the following:
  - Hypocalcemia
  - Hypomagnesemia
  - Hyperkalemia

Imaging Studies:

- Radiographs
  - Obtain chest x-ray (CXR) if pulmonary edema is suspected.
  - If burns to the fingers exist, perform digital x-rays to evaluate bone integrity.

Other Tests:

- Electrocardiogram
  - Cardiac monitoring is necessary if burn is significant.
  - Arrhythmias are a primary cause of death.
  - Monitor for QT prolongation from hypocalcemia or signs of hyperkalemia.

Treatment

Prehospital Care:

Treatment for HF acid burns includes basic life support and appropriate decontamination, followed by neutralization of the acid by use of calcium gluconate. If exposure occurs at an industrial site, obtain and transport any available treatment literature.

- Assess and manage acute life threatening conditions in the usual manner. Emergency Medical Services (EMS) personnel should use gloves, masks, and gowns, if necessary.
- Remove soiled clothing. Initially decontaminate by irrigation with copious amounts of water.
- Ice packs on the affected area may alleviate symptoms by retarding diffusion of the ion.
- If calcium gluconate gel is available, apply liberally to the affected area.
- For digital burns, if calcium gluconate gel is not available, the fingers may be soaked in magnesium hydroxide containing antacid preparations (eg, Mylanta) en route to a medical facility.
- Treat inhalation injuries with oxygen and 2.5% calcium gluconate nebulizer.
- Transport the patient to the nearest appropriate medical facility.

Emergency Department Care:

- Remove soiled clothing.
- Decontaminate by irrigation with copious amounts of water.
- Assess and manage life-threatening conditions as with any other cause.
- Commence comprehensive monitoring for significant exposures.
- With any evidence of hypocalcemia, immediately administer 10% calcium gluconate IV.
- Apply 2.5% calcium gluconate gel to the affected area. If the proprietary gel is not available, constitute by dissolving 10% calcium gluconate solution in 3 times the volume of a water-soluble lubricant (eg, KY gel). For burns to the fingers, retain gel in a latex glove.
- If pain persists for more than 30 minutes after application of calcium gluconate gel, further treatment is required. Subcutaneous infiltration of calcium gluconate is recommended at a dose of 0.5 mL of a 10% solution per square centimeter of surface burn extending 0.5 cm beyond the margin of involved tissue. Do not use the chloride salt because it is an irritant and may cause tissue damage.
- Burns to the digits: Local infiltration of digits is not recommended because of pain, disfigurement, and potential complications. Alternative treatment methods follow.
    - IV regional calcium gluconate: 10-15 mL of 10% calcium gluconate plus 5000 units of heparin diluted up to 40 mL in 5% dextrose. Use a Bier ischemic arm block technique to infuse the solution intravenously. Release the cuff when any of the following conditions first occur: (1) pain from the digits resolves, (2) the cuff becomes more painful than the burn, or (3) 20 minutes of ischemic time elapses. Treatment can be repeated after 4 hours if needed. Continuous ECG and clinical monitoring are essential during this procedure.
    - Intra-arterial calcium gluconate: Place an arterial catheter in the radial or brachial artery to perfuse the affected digits. Infuse a solution of 10 mL of 10% calcium gluconate in 40 mL of 5% dextrose over a 4-hour period. Follow with further infusions repeated after 4-8 hours, if necessary. Several treatments may be needed. Exercise great care to ensure that the catheter is appropriately placed intravascularly (ie, by continuous waveform analysis), as tissue necrosis and digit loss have occurred following extravasation of

calcium salts. Continuous ECG and clinical monitoring are essential during this procedure.

- Ocular burns: Generously irrigate with sterile water or saline for at least 5 minutes. Local anesthetic may be required. If pain persists, irrigate with a 1% solution of calcium gluconate, which is made by diluting the 10% solution in 10 times the volume of normal saline. Do not use undiluted 10% calcium gluconate.

- Inhalation burns: Exposures to the head and neck should arouse suspicion of pulmonary involvement. If any doubt is present, admission for observation is advised.

- Specific treatment
  - Provide 100% oxygen by mask, 2.5% calcium gluconate by nebulizer with 100% oxygen, continuous pulse oximetry, ECG, and clinical monitoring.
  - Pulmonary edema is treated along conventional lines, as needed.
  - Despite concerns of perforation, consider gastric lavage with calcium chloride (ie, 20 mmol calcium in 1000 cc normal saline solution) early in overdose. One series of autopsies performed on decedents who had received calcium chloride lavage after HF acid ingestion demonstrated hemorrhagic gastritis; however, no evidence of perforation was revealed. Secure the airway prior to gastric lavage.

Consultations: Consultation with specialty units may be required depending on individual circumstances.

- Toxicology service
- Burn surgery
- Intensive care
- Ophthalmology
- Hand surgery
- Gastroenterologist (following ingestions)

Medication

The goal of pharmacotherapy is to reduce morbidity and prevent complications.

Drug Category: *Pharmacologic antidote*

The major pharmacologic intervention is with calcium gluconate. Depending on the clinical situation, it may be used in a gel, intravenously, or intra-arterially. May also be used to irrigate ocular burns.

Drug Name	Calcium gluconate (Kalcinate) -- Moderates nerve and muscle performance and facilitates normal cardiac function. For systemic hypocalcemia, can be given IV initially, and calcium levels maintained with high calcium diet. Some patients will require oral calcium supplementation. For topical pain, can be applied as a water-soluble gel mixture. For IV, intra-arterial, or ocular administration, please refer to discussion in Treatment.
Adult Dose	May apply 2.5-5% calcium gluconate to affected area; repeat prn pain; if not available commercially, can be prepared by simple 3:1 (for 2.5%) or 1:1 (for 5%) dilution of a 10% IV solution in a water-soluble surgical gel or similar sterile base
Pediatric Dose	Apply as in adults
Contraindications	Renal calculi; hypercalcemia; hypophosphatemia; renal or cardiac disease; digitalis toxicity
Interactions	May decrease effects of tetracyclines, atenolol, salicylates, iron salts, and fluoroquinolones; antagonizes effects of verapamil; large intakes of dietary fiber may decrease calcium absorption and levels
Pregnancy	B - Usually safe but benefits must outweigh the risks.
Precautions	Caution in digitalized patients, respiratory failure, acidosis, or severe hyperphosphatemia Serum calcium should be monitored when calcium gluconate is given parenterally

Drug Name	Calcium chloride -- Manages underlying hypocalcemic effects.
Adult Dose	Initial dose: 1-2 g (1-2 ampules) IV slow push of 10% calcium chloride solution (10 mL each); repeat doses to obtain desired serum calcium level; for severe poisoning, may need to give multiple grams for the first several h
Pediatric Dose	20-25 mg/kg IV push of calcium chloride; repeat prn; may need massive doses with severe poisoning
Contraindications	Ventricular fibrillation not associated with hyperkalemia; digitalis toxicity; hypercalcemia; renal insufficiency; cardiac disease
Interactions	Coadministration with digoxin may cause arrhythmias; with thiazides, may induce hypercalcemia; may antagonize effects of calcium channel blockers, atenolol, and sodium polystyrene sulfonate
Pregnancy	B - Usually safe but benefits must outweigh the risks.
Precautions	Administer slowly (not to exceed 0.5-1 mL/min) to avoid extravasation; hypercalcemia may occur in renal failure

Follow-Up

Further Inpatient Care:

- Admission to a burn service or ICU may be required if burns are extensive or if any clinical, laboratory, or electrocardiographic evidence of complications is present.

Further Outpatient Care:

- Patients are suitable for discharge only when pain has been controlled adequately.
- Patients with serious exposures can be discharged once electrolytes return to normal, arrhythmias are absent, and ECG is normal, provided other complications are managed adequately.
- Patients with finger burns can be discharged with calcium gluconate gel on the affected digits. Instruct patients to keep affected digits in a latex glove for 24 hours.
- Prudence requires physicians to provide follow-up care with all patients after 24 hours, at least by telephone.

Deterrence/Prevention:

- Most burns are a result of inadequate use of safety devices.
- Patient education is important to prevent recurrences.

Complications:

- Airway compromise
- Systemic fluorosis
- Pulmonary edema
- Electrolyte abnormalities
- Arrhythmias
- Scarring
- Loss of digits
- Corneal perforation
- Blindness

Prognosis:

- Prognosis varies depending on burn severity and site.
- Poor prognosis follows fluoride inhalation.

Miscellaneous

Medical/Legal Pitfalls:

- Several features of HF acid burns may lead to delayed or missed diagnosis.
  - Significant delays may occur between exposure and onset of symptoms.
  - Marked pain in the absence of significant surface dermal injury should raise suspicion of HF acid burns.
  - HF acid penetrates fingernails and burns the pulp beneath without destroying the nails. Adequate treatment of these cases requires removal of the nails and/or IV and/or intraarterial infusion of calcium gluconate.
  - Severe burns may produce severe electrolyte disturbances and arrhythmias. These must be monitored expediently and corrected.
  - All exposures to the head and neck may be associated with respiratory burns. Keep patients for observation with that possibility in mind.
  - Although 10% calcium gluconate is the agent of choice for counteracting most sites of exposure, irrigate burns to the eye with

    1-2% dilute solution.
- Dislodgement of intra-arterial catheter may result in extravasation of calcium salts and subsequent tissue necrosis and/or digit loss.

Pictures

Caption: Picture 1. Grade 1 hydrofluoric (HF) acid burns of the fingertips. The patient has severe pain (maximum middle digit) with only minimal redness of the nail beds.

Caption: Picture 2. Grade 3 hydrofluoric (HF) acid burns of the fingertips. Note how the nailbed and tip of the fingers have severely been injured, but the nails show no damage.

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