

Treatment protocol for hydrofluoric acid burns

Warning:

Burns with concentrated hydrofluoric acid (HF) are usually very serious, with the potential for significant complications due to fluoride toxicity. Concentrated HF liquid or vapor may cause severe burns, metabolic imbalances, pulmonary edema, and life-threatening cardiac arrhythmias. Even moderate exposures to concentrated HF may rapidly progress to fatality if left untreated. Burns larger than 25 square inches (160 square cm) may result in serious systemic toxicity. Relief of pain is the only indication of effectiveness of treatment. Therefore the use of any analgesic agents is not advisable.

Properties

Hydrofluoric acid (HF) is an extremely powerful inorganic acid and a vigorous dehydrating agent. Anhydrous hydrofluoric acid and hydrofluoric acid in aqueous solutions range in appearance from colorless to slightly tinted. HF has a pungent odor. It is extremely corrosive.

General health hazards

Hydrofluoric acid exposure requires immediate specific and specialized medical treatment. Not only can this strong acid cause burns, but the fluoride ion can be quickly absorbed through the skin. Fluoride ions can then attack underlying tissues and can be absorbed into the bloodstream. HF, liquid or gaseous, may cause severe burns of the skin and deep tissues. If the eyes are exposed to HF, it may penetrate to internal structures. HF inhaled in high concentrations may cause glottitis (obstruction of the airway) and acute pulmonary edema.

Absorption of HF may cause hypocalcemia and hypomagnesemia because fluoride ions complex with blood calcium and magnesium. Hyperkalemia may occur if severe hypocalcemia appears. A person who has HF burns greater than four (4) square inches should be admitted immediately to an intensive care unit and carefully monitored for 24 to 48 hours. Anyone who has been exposed to gaseous HF and experiences respiratory irritation should also be admitted to and monitored in an intensive care unit. Blood sampling should be taken to monitor fluoride, potassium, and calcium levels. In some cases, hemodialysis is necessary for fluoride removal and for correction of hyperkalemia.

The effects of exposure to HF may be delayed depending on the strength of the solution. Solutions containing greater than 50% HF will normally cause an immediate recognizable and painful burn. Solutions containing 20% to 50% HF may cause delayed symptoms that can manifest in one (1) to eight (8) hours. Solutions with less than 20% HF may not cause symptoms for up to 24 hours. A similar delay in symptoms may be seen with respiratory and dermal contact.

HF skin burns are usually accompanied by severe, throbbing pain that is thought to be due to irritation of nerve endings by increased levels of potassium ions entering the extracellular space to compensate for the reduced levels of calcium ions, which have been bound to the fluoride. **RELIEF OF PAIN IS AN IMPORTANT GUIDE TO THE SUCCESS OF TREATMENT.**

Safety precautions

Be prepared!! Adequate personal protective equipment must be provided to each employee who may be exposed to HF. **FIRST AID RESPONDERS AND MEDICAL PERSONNEL MUST WEAR RUBBER (NEOPRENE, NITRILE OR POLYVINYL CHLORIDE [PVC]) GLOVES WHEN TREATING HF BURNS TO AVOID HAND BURNS!!** Employees must be properly trained in the wearing of personal protective equipment. Safety and handling procedures must be taught to all relevant personnel and these procedures must be enforced. Personnel who have been trained in the specialized HF first aid procedures must be available immediately. Medical supplies must be readily accessible at all times. (See Medical Supplies List.)

Local emergency medical responders and hospitals must be included in the first aid and medical training for the facility. Effects of HF exposure are unique and must be treated in a specialized medical fashion. An appropriate first response coupled with HF-specific medical treatment is imperative.

First aid and medical treatment

Skin burns

Skin contacted by HF, vapor, or aqueous solution rapidly produces an erythematous (reddened) area, often with a white or gray color at the surface caused by coagulation of tissue.

1. Immediately go to a safety shower or other available water and flush with copious amounts of water. Rinse off excess HF. Speed and thoroughness in washing off the acid is of primary importance.

All clothing must be removed. Continue under water until calcium gluconate gel is available. Calcium gluconate gel can be massaged into skin while flushing with water.

2. Summon medical personnel and continue with first aid.
3. Apply calcium gluconate 2.5% gel every 15 minutes and massage continuously until the pain disappears. Remember, rubber gloves must be worn while touching the victim. If pain recurs, apply calcium gluconate gel and massage while transporting the injured worker to an emergency room.
4. An alternate procedure is to soak the affected areas in an iced 0.13% water solution (1:750) of Zephiran® chloride (benzalkonium chloride solution, NF). Use ice cubes, not shaved ice, to prevent frostbite. If soaking is impractical, soaks or compresses may be used. Compresses should be changed every 2-4 minutes. Total immersion for areas such as fingers, hands, and feet is desirable. Do not use Zephiran solution for burns of the eyes. Zephiran is an eye irritant.

5. Continue procedure in #3 or #4 while transporting to a medical facility.
6. For deep burns, infiltration of 2.5% aqueous calcium gluconate solution with a small-gauge (#27-#30) needle around the affected area and intralesionally may be necessary. Initially use no more than 0.5cc per square centimeter of burned skin. Do not distort skin appearance. Caution must be observed to avoid calcium overdosing. Administration should be performed by a physician only.
7. Do NOT use local anesthetics. Resolution of pain is the means to determine effective medical treatment.
8. In some cases, it may be necessary to surgically remove damaged tissue and then apply calcium gluconate (2.5% aqueous solution) to the affected area.
9. The person with HF burns covering greater than four (4) square inches should be admitted immediately to an intensive care unit and monitored carefully for 24 to 48 hours. Serum calcium, potassium, and magnesium levels should be monitored. The QT interval should be followed for signs of hypocalcemia. Hypocalcemia results in prolonged QT intervals.

Eye burns

1. Flush immediately with water for at least 5 minutes while holding eyelids open.
2. Do not use oils, salves, ointments, or HF skin burn treatments.
3. If available, apply a few drops of aqueous topical ophthalmic anesthetic solution to the eyes (proparacaine hydrochloride 0.5%). Do not delay treatment if ophthalmic anesthetic solution is not readily available.
4. If sterile 1% calcium gluconate solution is available, flushing may be limited to 5 minutes. Place a Morgan's lens or the Eye Irrigator® on patient and irrigate eye intermittently for 20 minutes with an aqueous calcium gluconate 1% solution.
5. Transport patient to eye specialist for further treatment. Continue treatment as outlined in Step 4 during transportation.
6. Instill aqueous calcium gluconate 1% solution every two to four hours for the next two to three days.

Inhalation

1. Remove victim from source of HF fumes.
2. If not breathing, begin artificial respiration immediately.

***NOTE: Mouth-to-mouth resuscitation is not recommended.**

3. Give 100% oxygen by mask.
4. As soon as possible, give a 2.5% to 3% calcium gluconate solution by inhalation by Intermittent Positive Pressure Breathing (IPPB) using a nebulizer or by nebulizer alone.
5. Refer patient to a pulmonologist for further care.
6. Carefully watch the patient for edema of the upper airway with respiratory obstruction. The airway may be maintained by either endotracheal intubation or tracheotomy if necessary.
7. Pulmonary edema should be treated by placing the patient on IPPB with Positive End Expiratory Pressure (PEEP). Close supervision and continued use of a 2.5% to 3% calcium gluconate solution by inhalation is necessary.
8. Patients with neck, chest, or head burns should be watched for delayed pulmonary edema.
9. Hemodialysis must be considered for fluoride removal and to avoid or correct hyperkalemia and recurrent hypocalcemia not responsive to replacement therapy.
10. A patient with a history of recent exposure who is experiencing respiratory irritation should be admitted immediately to an intensive care unit and observed closely for 24 to 48 hours. Administration of nebulized calcium gluconate should be considered.
11. Do not give stimulants. Patient must remain inactive for at least 24 hours.

Oral Ingestion

1. Do not induce vomiting. Do not give patient any baking soda or emetics.
2. Give one (1) to three (3) glasses of water.
3. Administer several vials of 10% aqueous calcium gluconate orally. (Calcium carbonate, Maalox, Mylanta, or Milk of Magnesia may also be used.)
4. Gastric lavage with lime water may be performed by a physician. Extreme caution must be observed when passing the Levin tube.
5. Extreme throat swelling may occur that may require a tracheotomy.
6. Patient should be admitted to a hospital intensive care unit.
7. Hemodialysis may be necessary for fluoride removal and to avoid or correct hyperkalemia and recurrent hypocalcemia not responsive to replacement therapy.

Nail Burns

1. Immediately soak the nail in an iced solution of calcium gluconate. In the past, a 0.13% water solution (1:750) of Zephiran Chloride (benzalkonium chloride solution, NF) was used successfully.
2. If pain does not completely cease, 2 to 3 holes should be drilled in the nail using an 18 gauge needle. Continue soaking.
3. If pain still does not subside, the nail must be removed by a physician. The nail bed should be massaged with 2.5% calcium gluconate gel. Infiltration of 2.5% aqueous calcium gluconate solution with a small-gauge (#27-#30) needle around the burn and intralesionally must be used only in severe cases due to the risk of obstruction of the microcirculation.
4. Do not use calcium gluconate 2.5% injections without first removing the nail.
5. The use of 0.5% calcium gluconate given intraarterially has also been reported.

Hypocalcemia

Significant fluoride exposure via large burns, inhalation, or ingestion will require observation for hypocalcemia.

An important way to monitor the necessity for and effectiveness of treatment is EKG monitoring (for example, prolongation of the Q-T interval may indicate hypocalcemia).

Calcium gluconate infusion (using 2 to 3 ampules of 10% calcium gluconate in one liter of 5% dextrose solution or NSS to pass at the rate of 100 milliliters per hour) may be administered. CAUTION must be taken. Excess calcium can produce ventricular arrhythmias, vagal bradycardia, and ventricular fibrillation. Repeat infusions until EKG abnormalities or symptoms disappear.

Serum calcium, magnesium, and potassium levels must be monitored. Electrolyte monitoring should indicate if and when magnesium should be replaced intravenously.

In cases of extreme fluoride absorption, a potentially therapeutic maneuver is the use of bicarbonate/acetazolamide infusion to control metabolic alkalosis and to enhance fluoride excretion by the kidneys. The efficacy of this intervention has not been determined conclusively.

Calcium gluconate 1% eye irrigation solution

1. To obtain 100cc of a 1% calcium gluconate solution, mix 90 cc of normal saline with 10cc calcium gluconate 10%.
2. To obtain 1000cc of a 1% calcium gluconate solution, mix 900 cc of normal saline with 100cc calcium gluconate 10%.

Calcium gluconate 2.5 % solution for nebulizer or for injection

1. To obtain 100cc of a 2.5% calcium gluconate solution, mix 75 cc of normal saline with 25cc calcium gluconate 10%.
2. To obtain 1000cc of a 2.5% calcium gluconate solution, mix 750 cc of normal saline with 250cc calcium gluconate 10%.

Table 1: Medical Treatment Options

Zephiran® (0.13% Benzalkonium chloride)

The solutions should be cooled with ice cubes. Shaved or crushed ice may cause excessive cooling, with danger of frostbite. If immersion in the solution is not practical, soaked compresses of the same iced solution should be applied to the burned area. The immersion or compresses should be used for at least two hours. Compresses should be changed or soaked with additional solution approximately every two to four minutes. If blisters are present, they should be open and drained and necrotic tissue should be debrided by a physician or qualified health care practitioner as soon as possible. However, immersion in 0.13% benzalkonium chloride (Zephiran) or use of compresses should not be delayed if debridement cannot be accomplished immediately. Prolonged immersion in the iced Zephiran bath may result in discomfort due to excess chilling; relief may be obtained by removing the part from the bath every 10 to 15 minutes for a few minutes and then reimmersing it. After the initial 30-60 minutes of treatment, less ice can be used so that the bath is cool rather than cold. The success of this treatment is indicated by relief of the severe pain in the burned area. If there is no significant relief of pain within 30 to 40 minutes, the use of 2.5% calcium gluconate injections may be necessary. If pain recurs when the treatment is stopped at the end of the first two hours, immersion or compresses should be resumed until pain is relieved. A total of four to six hours immersion or use of compresses of Zephiran is usually required for the treatment of most burns. No further treatment will be required in many instances. The use of iced quaternary ammonium compound solutions offers several advantages: reduction of local pain, possible slowing of the rate of tissue destruction, possible slowing of the passage of the fluoride ion into tissues and into the bloodstream. Large burns, serious burns due to concentrated HF, or burns with delayed treatment will probably require the use of calcium gluconate injections in addition to or instead of Zephiran soaks. Zephiran should not be used for burns on the face, ears, or other sensitive areas due to its irritating nature. It is preferable to use calcium gluconate gel or calcium gluconate injections in these areas.

Calcium Gluconate Gel

Calcium gluconate gel, consisting of 2.5% USP calcium gluconate in a surgical water soluble lubricant, is widely used for first aid and/or primary treatment of HF burns of the skin. The gel is convenient to carry and can be used to initially treat small burns that might occur away from medical care. The gel is not recommended for burns with concentrated HF except as a first aid measure. The gel is used by massaging it promptly and repeatedly into the burned area until pain is relieved. Neoprene, nitrile or PVC gloves must be worn during initial application of the gel so that the person providing the treatment will not receive a secondary burn. This treatment can be started without waiting for medical direction. If used as the only method of treatment, liberal quantities of calcium gluconate gel must be massaged into the burned area continuously for up to several hours. Relief of pain can be used to assess the efficacy of this treatment. If good relief of pain is not obtained after 30-40 minutes, alternate methods of treatment such as calcium gluconate injections or Zephiran soaks should be considered. The gel is especially useful for burns on the face, particularly near the mouth and eyes or on the ears. It may be convenient to use the gel for very small burns where the victim can easily apply and massage the gel into

the burned area. Use of the gel may be more convenient for dilute acid burns such as those that occur with commercial products like rust removers, aluminum cleaners, or etching solutions.

Calcium Gluconate Injections

After first aid measures have been taken, injection of 2.5% calcium gluconate solution is indicated as the primary medical treatment for large burns (over 25 square inches or 160 square centimeters). For smaller burns, if Zephiran soaks or calcium gluconate gel does not result in significant relief of pain within 30 to 40 minutes, injection of calcium gluconate solution is indicated. Injection of calcium gluconate solution may also be indicated for burns in which treatment has been delayed. The physician should inject sterile 2.5% aqueous calcium gluconate beneath, around, and into the burned area. Do not use calcium chloride, which is corrosive and may result in additional damage. If subcutaneous calcium gluconate injections are used, the amount injected initially is small and should not exceed 0.5 cc per square centimeter of affected skin. The injections should not distort the appearance of the skin. A small-gauge needle (#27-#30) should be used and the burned area should be injected through multiple sites. With successful treatment, pain relief following injection of 2.5% calcium gluconate is very rapid. The patient can usually indicate when the pain stops, which is an indicator of adequate treatment. Multiple injections in the skin that has compromised integrity may increase the risk of infection, and the use of antibiotic creams such as Silvadene or Garamycin should be considered following such treatment. Local anesthetics should not be used since they mask pain relief, which is an important indication of adequacy of treatment.

Calcium Gluconate Solution

In some instances, a 5% or 10% calcium gluconate solution may be used in compresses or for irrigation. For example, irrigating with a calcium gluconate solution may be the best treatment should HF enter the external ear canal. In this instance, referral to an otolaryngologist may also be needed.

Medical Supplies

It is extremely important that medical supplies be acquired and kept on hand in sufficient quantities at all times.

Some of these supplies are difficult to acquire and must be ordered. Others must be prepared by a pharmacist, and a few require a doctor's prescription. The immediate application of first aid using HF-specific medical supplies is the key to a rapid and successful recovery from HF absorption.

1. Calcium gluconate 2.5% gel.

Your pharmacist can prepare this gel by mixing 2.84 grams of USP calcium gluconate powder with a 4 ounce tube of K-Y Lubricating Jelly (Johnson & Johnson). Once mixed, the calcium gluconate 2.5% gel can be repackaged by the pharmacist in the K-Y tube and resealed.

2. Calcium gluconate 10% aqueous, USP (standard ampule), is available in 10ml ampules and requires a doctor's prescription.

3. Proparacaine hydrochloride 0.5% solution for anesthetizing the eyes. This requires a doctor's prescription.

4. Aqueous solution of benzalkonium chloride—0.13%. (Note: This is less practical and infrequently used.) This can be prepared by purchasing "Zephiran" chloride 15% concentrate and diluting by mixing one (1) fluid ounce of concentrate and 127 fluid ounces of water to make a gallon of "Zephiran" solution 0.13%.

5. Syringes—5cc #27g to #30g gauge needles.
6. Oxygen—99% pure USP medical.
7. Morgan's lens or the Eye Irrigator®—to irrigate the eyes.
8. Ice cubes.
9. Towels for use as wet compresses.
10. Basins of assorted sizes for immersion.
11. Gauze, compression dressing, eye patches.
12. Eye wash fountain.
13. Safety showers.
14. Nebulizer.
15. Sterile 0.9% saline: vials 10cc, 30cc, or 100cc and 500cc IV bag.
16. Neoprene/Nitrile/Rubber/PVC gloves.

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