The treatment of hydrofluoric acid burns

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Hydrofluoric acid is a colourless or almost colourless, fuming liquid having a highly caustic and corrosive effect on organic tissue. Many kinds of hydrofluoric acid in concentrations are used in industrial processes and laboratory uses because of its useful chemical properties. Hydrofluoric acid causes severe and painful burns to the skin and eyes. In this paper, the immediate symptoms, the typical treatments in the literature, first aid and therapy of hydrofluoric acid burns are reviewed.

Key words: Burns; first aid; hydrofluoric acid; therapy; treatment.

General properties and uses of hydrogen fluoride and hydrofluoric acid

Hydrofluoric acid is an aqueous solution of hydrogen fluoride. Hydrogen fluoride is a colorless, fuming liquid or gas with a strong and irritating odor, and is corrosive. The chemical properties are listed in Table 1.

The 38.2 w/w% solution is a binary azeotrope and its boiling point is 112.2°C. Hydrofluoric acid is usually marketed in concentrations of about 46% and 53% for laboratory uses. Many kinds of hydrofluoric acid in concentrations of less than 20%, intermediate solutions, and concentrated solutions of more than 70% are used in industrial processes because of its useful chemical properties. Hydrofluoric acid attacks glass or stone and dissolves silica, and must be kept in plastic, lead, wax or paraffin paper bottles. It is a strong acid having a highly caustic and corrosive effect on organic tissue.

Hydrofluoric acid is used for frosting, etching and polishing glass, for removing sand from metal castings, and for etching silicon wafers in many industrial processes, especially in the manufacture of semiconductors (Table 2). Hydrofluoric acid may be used as a dilute 3% solution at the etch-station, or a 50% solution in a quartz furnace cleaning operation.
Table 1. Chemical properties of hydrogen fluoride

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molecular weight</td>
<td>20.01</td>
</tr>
<tr>
<td>F</td>
<td>94.96%</td>
</tr>
<tr>
<td>H</td>
<td>5.04%</td>
</tr>
<tr>
<td>Boiling point</td>
<td>19–20°C</td>
</tr>
<tr>
<td>Hazardous substance (EPA)</td>
<td></td>
</tr>
<tr>
<td>Hazardous waste (EPA)</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Uses of hydrofluoric acid

- Cleaning cast iron, copper or brass
- Removing efflorescence from brick and stone
- Removing sand particles from metallic castings
- Frosting and etching glass or enamel
- Polishing crystal glass
- Decomposing cellulose
- Enameling and galvanizing iron
- Increasing the porosity of ceramics
- Analytical work to determine SiO₂

Table 3. Immediate symptoms in an hydrofluoric acid accident

<table>
<thead>
<tr>
<th>Symptom</th>
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</thead>
<tbody>
<tr>
<td>1. Burning sensation and inflammation</td>
</tr>
<tr>
<td>2. Irreparable damage to skin, which gradually turns white and become very painful</td>
</tr>
<tr>
<td>3. Blisters</td>
</tr>
<tr>
<td>4. Profound damage to the tissues</td>
</tr>
<tr>
<td>5. Shock may occur as a result of pain</td>
</tr>
<tr>
<td>a. weak and rapid pulse</td>
</tr>
<tr>
<td>b. cold sweat—pale complexion</td>
</tr>
<tr>
<td>c. tendency to fainting</td>
</tr>
<tr>
<td>d. cold hands and feet</td>
</tr>
</tbody>
</table>

Eye contact

1. Intense stinging and burning sensation
2. Watering of eyes
3. Conjunctivitis (inflammation of eyes)
4. Burning sensation in eyelids and eyes, with ulceration of the tissues
5. Irreparable damage to cornea
6. Loss of vision

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Hydrofluoric acid burns in the literature. 3,4,10-19

Traditionally, hydrogen fluoride paste containing magnesium oxide had been used for the treatment of hydrofluoric acid burns, but today it is rarely used. The topical application of a magnesium oxide paste 19 or an injection of magnesium compounds, such as magnesium sulfate, magnesium acetate 12 was applied to the skin.

The quaternary ammonium compounds, 4 benzethonium chloride (Hyamine) solution, 3,4 or benzalkonium chloride (Zephiran), 3,4 are also used for the treatment of hydrofluoric acid burns. The quaternary ammonium compounds may have the effect of replacing fluoride ion and the chloride moiety in the ammonium complex, but the protection mechanism is not well known. The solutions are often used as an iced solution to decrease lymphatic spread of the hydrofluoric acid. The hyamine might cause the alteration of cellular permeability of the fluoride ion. The disadvantage of hyamine therapy is that it requires a prolonged period of saturation of the burn area. 2 Iced alcohol is also often coadministered to withdraw some of the fluoride from the tissues.

It has long been recognized that the infiltration of calcium gluconate 3,10,11,13,15,16 is effective for the treatment of hydrofluoric acid burns. This therapy restrains the degree of edema or necrosis by hydrofluoric acid and prevents the penetration of fluoride ion to deeper tissues. Depending on the case, the intra-arterial infusion of calcium gluconate 10 can be used to deliver the calcium to the tissues without some of the deleterious local effects.

Recently, calcium gluconate gel 14-17-18,19 has been used widely in first aid for hydrofluoric acid burns. After washing off the exposed area, the gel is applied to the skin to keep the injury minimal.

There is no clear evidence which treatment is best, because the majority of the literature has been anecdotal or retrospective studies.

FIRST AID AND THERAPY

In the treatment of hydrofluoric acid burns, to prevent the hydrofluoric acid from fully reacting on tissue components and causing toxicity to the cell, the immediate dilution and decontamination of the
Table 5. Treatment for hydrofluoric acid burns in the literature

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jones (1939)</td>
<td>Immediate washing with a warm solution of sodium bicarbonate&lt;br&gt; + Infiltration with calcium gluconate&lt;br&gt; + Topical application of a magnesium oxide paste&lt;br&gt; Intravenous calcium gluconate</td>
</tr>
<tr>
<td>Paley and Seifter (1941)</td>
<td>3% calcium gluconate infiltration (experiments with rats)</td>
</tr>
<tr>
<td>Reinhardt et al. (1965)</td>
<td>Quaternary ammonium compounds: Hyamine solution, Benzalkonium chloride (Zephiran)</td>
</tr>
<tr>
<td>Scharnweber (1969)</td>
<td>Immediate excision of the wound and closure</td>
</tr>
<tr>
<td>Dibbell et al. (1970)</td>
<td>Hyamine solution for exposures to solutions of less than 20%,&lt;br&gt;Benzalkonium chloride (Zephiran) for exposures to solutions of less than 20%,&lt;br&gt;Calcium gluconate infiltration for exposures to solutions of 20% or greater</td>
</tr>
<tr>
<td>Iverson et al. (1971)</td>
<td>Infiltration of the burn area with calcium gluconate</td>
</tr>
<tr>
<td>Browne (1974)</td>
<td>Gel containing 2.5% calcium gluconate</td>
</tr>
<tr>
<td>Harris et al. (1981)</td>
<td>Injection of calcium gluconate, magnesium sulfate, magnesium acetate</td>
</tr>
<tr>
<td>Velvert (1983)</td>
<td>Intra-arterial regional perfusion,&lt;br&gt;Infiltration of the calcium gluconate</td>
</tr>
<tr>
<td>Bracken (1985)</td>
<td>Calcium gluconate gel</td>
</tr>
<tr>
<td>Kodama et al. (1988)</td>
<td>2.5% calcium gluconate gel</td>
</tr>
<tr>
<td>Kono et al. (1994)</td>
<td>Calcium gluconate jelly</td>
</tr>
</tbody>
</table>

exposed area is most important. The cytotoxic reaction of hydrofluoric acid is critical. A patient exposed to a concentrated solution of more than 50% and with a burn area of over 1-2% of the body surface should be monitored carefully.

If a worker has come in contact with hydrofluoric acid, it is essential that the exposed area be washed immediately with large quantities of water for a sufficient period of time, that is, at least 10-15 minutes. After the initial decontamination, a topical modality is applied. The topical therapy is usually adequate for minor exposure of the skin to a diluted solution of less than 20% without calcium gluconate infiltration. If there is erythema, discoloration, severe pain or a delay of decontamination, calcium gluconate infiltration will be needed in addition to the topical therapy. However, this is not a fixed rule.

Topical modality

Topical modality should be applied as soon as possible after washing. A delay may cause the diminishment of the effect of the topical agent.

There is still a controversy as to the agent of choice for topical application. Iced solutions of the quaternary ammonium compounds, 0.13% benzalkonium chloride (Zephiran) or 0.2% benzethonium chloride (Hyamine), a solution of 25% magnesium sulfate (Epsom salts) or a solution of calcium gluconate may be applied to the exposed area in topical therapy. However, calcium gluconate has been the most widely used among them. Calcium gluconate gel is also acceptable for topical therapy. The 2.5% calcium gluconate gel is easily massaged into the burned area. A patient may take the gel with him and repeat the application as needed at home. The burned area should be dressed in a soft and bulky dressing and observed carefully for the next 2 days. If the concentration of hydrofluoric acid is less than 20% and the pain is not too severe, iced topical treatments need not be applied beyond 1-4 hours.27

Calcium gluconate infiltration

If the above topical therapy fails to reduce the pain caused by the hydrofluoric acid burn within 0.5-1 hour, an injection of 5-10% calcium gluconate should be considered. Similarly, if the injury appears to be severe and there is acute pain, this treatment should be applied to the painful area. The smallest effective amount of calcium gluconate injected can be determined by monitoring the patient’s pain, as the relief of pain is often a good indication of the end point of the infiltration. An effective dose of calcium gluconate is about 0.5 mL/cm² of the burned surface area, and repeated injections are preferable. More than 0.5 mL/phalanx of calcium gluconate should not be injected for finger burns. Basically, local anesthesia should be avoided in this therapy, to allow the patient to accurately recognize the areas requiring treatment. The calcium gluconate should be directly infiltrated by a 25- to 30-gauge needle into the affected derma or subcutaneous tissue using a similar technique to a local anesthesia. The infiltration should be carried out 0.5cm away from the margin of the injured area into the surrounding normal area. If the pain recurs, additional calcium gluconate should be injected. However, the use of large amounts of calcium gluconate may result in hypercalcemia. After the calcium gluconate infiltration, the injured area may be carefully debrided. The
**Table 6. First aid manual for hydrofluoric acid accident**²⁰

**SKIN CONTACT**

1. Remove the victim from the source of contamination and take him immediately to the nearest shower.
2. First aiders, wearing rubber gloves and air-tight safety goggles, should remove the clothing from affected area under the shower (clothing should be cut away, if necessary). Care should be taken not to contaminate healthy skin or eyes. If the victim is already wearing air-tight safety goggles, do not remove them.
3. Wash him down with cold water for 15 minutes or longer.
4. Dry the skin very gently with a clean, soft towel.
5. Apply 2.5% of calcium gluconate gel on the affected skin.
6. Massage the gel gently into every burnt area with clean fingers.
7. Dress the victim in clean clothes.

In the case of burns (inflammation, blisters, or painful lesions) and in the absence of a physician:

8. If there is no calcium gluconate gel on hand, rub a clean tube of ice on the painful area and apply a dry, sterile dressing.
9. Take the victim, wrapped in a blanket, to the hospital as soon as possible.

If the victim shows signs of shock:

10. Cover him with a blanket.
11. Make him lie down in a quiet place on his back with his head down and legs raised until physician arrives.

**Notes**

a. It is vital to apply first aid without delay.
b. In the case of extensive splashing of the hydrofluoric acid, wash the victim down under a cold shower or a hand-held hose, at the same time protecting his eyes.
c. First aider must take precautions for their own safety when handling contaminated clothing.
d. Notify a physician and inform him of the nature of the hydrofluoric acid of the accident.
e. Never apply an oily substance on the affected area without medical advice.
f. Oral administration of 6 tablets of effervescent calcium gluconate (Calciofon, Calglucon, Ebucim, Glucal, and Glubiogen tablets) dissolved in water is recommended in cases of large burns.

**EYE CONTACT** (Splashing of liquid in or contact of vapor with eyes)

1. Remove the victim from the source of contamination and take him to the nearest eye wash basin or shower.
2. Immediately wipe away any excess chemical very gently and quickly.
3. Wash affected eye or eyes under slowly running water for 15 minutes or longer, making sure that victim's eyelids are held wide apart and he moves his eyes slowly in every direction.
4. If great pain persists after washing, the nurse can put 1 to 2 drops of anesthetizing eye salve, or better still, 1 drop of benoxinate (novesine) at 0.4%, into the eye.
5. If the pain still persists, repeat washing the eye for 15 minutes or until the pain is relieved or the pH of the eye returns to normal (touch the white of the eye with litmus paper).

**Notes**

a. It is imperative to bathe the eyes as soon as possible.
b. Never introduce oil or ointment into the eyes without medical advice.
c. Notify a physician and inform him of the name of the chemical and nature of the accident.
d. The medical service will refer the victim to an ophthalmologist and inform him of the nature of the accident and hydrofluoric acid.

Patient who has to receive a debridgement should be hospitalized. In case of serious subungual exposure, the fingernails may be removed.

**Intra-arterial infusion of calcium gluconate**

Regional intra-arterial infusion of calcium gluconate is used for serious hydrofluoric burns as an investigational therapy. This therapy can avoid local tissue distention by subcutaneous infiltration, however, it should be done only by expert physicians of hydrofluoric acid burns. There is no clear protocol because of too few cases in which it has been applied. Vervart¹⁶ reported a 4-hour infusion of 20% calcium gluconate for injuries to the hand. Hypercalcemia may occur when calcium gluconate therapy is used.

Finally, Table 6 shows the First Aid Manual for Hydrofluoric Acid Accident as summarized by M. J. Lefevre.²⁰

**REFERENCES**

1. Proctor NH, Hughes JR, Fischman ML, Hathaway GW. The
K. Matsuno: The treatment of hydrofluoric acid burns


