
Information and recommendations for doctors at hospitals/emergency departments

- Patients whose clothing or skin is contaminated with hydrofluoric acid can secondarily contaminate rescue and medical personnel, by direct contact or through evaporation of hydrofluoric acid.
 - Hydrofluoric acid is a highly corrosive chemical causing extremely painful burns.
 - Fluoride ions are very well and rapidly absorbed by all exposure routes which can lead to hypocalcemia and other metabolic changes. Systemic poisoning may result in central nervous system disturbances, cardiovascular, renal, and respiratory failure.
 - Rapid decontamination by immediate extensive irrigation - even before removing clothing - with copious amount of water is the most critical measure after dermal exposure.
 - The early administration of calcium and/or magnesium can counteract the systemic effects of hydrofluoric acid. Depending on route and severity of exposure calcium gluconate can be applied locally as a gel, its solution may be used as irrigant, injected (subcutaneously, intravenously, or intraarterially), or inhaled.
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1. Substance information

Hydrogen fluoride (HF), liquid or gas (CAS 7664-39-3), is clear and colorless with a strong and irritating odor.

The boiling point of hydrogen fluoride is 19-20°C, 292-293 K. Hydrogen fluoride is miscible in water and forms a clear and colorless aqueous solution, hydrofluoric acid (boiling point of the azeotrope 112°C, 385 K).

When exposed to air, hydrogen fluoride and its solutions may produce pungent dangerous fumes. Significant vapor concentrations may occur when concentrations of hydrofluoric acid of >40% in water are heated.

The substance is a strong acid and reacts violently with many compounds causing fire and explosion hazard. It attacks metals, glass and stone and dissolves silica, and must be kept in plastic, lead, wax, or paraffin paper bottles. Hydrofluoric acid is used in solutions of various concentrations (concentrated - >50%, e.g. in industrial processes; intermediate - 20-50%, e.g. in the electronics industry; dilute - less than 20%, e.g. in industrial and consumer cleaning compounds). Typical uses are frosting, etching and polishing of glass, removing sand from metal castings, enameling and galvanizing iron, and etching silicon wafers, especially in the semiconductor industry.

2. Routes of exposure

Inhalation

Significant absorption of fluoride ions leading to systemic toxicity may occur by inhalation of hydrofluoric acid fumes or vapors.

Hydrofluoric acid's strong irritant properties usually provide an adequate warning of acutely hazardous concentrations.

Skin/eye contact

Skin contact is the major route of toxic hydrofluoric acid exposures. Fluoride ions are absorbed very well and rapidly through the skin and eyes and cause systemic toxicity. If more than 160 square cm (25 square inches) of skin are affected, there is risk of serious systemic toxicity. Even dilute solutions (<2%) may cause severe eye or skin burns if contact is prolonged.

Ingestion

Accidental ingestion of hydrofluoric acid may occur and rapidly lead to severe systemic toxicity. Deaths in adults have been described after ingestion of 1.5 g or more.

3. Acute health effects

<i>Local effects</i>	At all sites of oral, gastroesophageal, dermal, or ocular contact hydrofluoric acid can cause severe painful burns.
<i>Dermal</i>	<p>Initially redness, edema, and blistering are usually observed. With concentrated hydrofluoric acid white discoloration of the skin can occur, and, due to liquefaction necrosis a granular exudate may form under blisters. When treatment is delayed, deep tissue necroses, tendinitis, tenosynovitis, or decalcification of bones may result.</p> <p>Clinical signs or symptoms might not be present up to 8 or 24 hours, respectively, after exposure to intermediate or low concentrations of hydrofluoric acid or its vapors or fumes, which may result in the danger of delayed recognition of fluoride ion-related effects. A hallmark of dermal exposure to low concentrations of hydrofluoric acid (<20%) is pain that is out of proportion to the physical examination. Severe pain may be reported, while only erythema of the exposed skin is observed.</p>
<i>Ocular</i>	Eye exposure may result in destruction of the eye or opacification of the cornea. Burning sensations in the eyelids with tissue ulcerations can occur as well.
<i>Respiratory</i>	Inhalation of hydrofluoric acid usually causes sore throat and coughing. Rapid development of respiratory distress with chest pain, dyspnea, and laryngospasm may occur. In symptomatic patients, onset of pulmonary edema may be delayed up to 24 hours.
<i>Gastrointestinal</i>	In case of ingestion, diffuse corrosive mucosal injury can involve the mouth, esophagus and stomach. Vomiting, in particular hematemesis, is common.
<i>Systemic effects</i>	Reaction of fluoride with body calcium may occur by any route of exposure to hydrofluoric acid. This can cause a marked hypocalcemia, hypomagnesemia and other metabolic changes that may result in a fatal outcome.
<i>Cardiovascular</i>	Due to binding of calcium and magnesium and changes in potassium levels myocardial irritability and subsequent life-threatening cardiac arrhythmias, especially ventricular fibrillation, and asystole may result.
<i>CNS</i>	Fluoride ions may have a direct toxic effect on the central nervous system leading to stupor, coma, and respiratory failure.
<i>Others</i>	Metabolic acidosis, renal failure as well as coagulation defects may develop.
<i>Potential sequelae</i>	Skin, deep tissue and eye damage caused by chemical burns may be irreversible; e.g. necrosis and destruction can occur.
4. Actions	
<i>Rescuer self-protection</i>	Patients whose clothing or skin is contaminated with hydrofluoric acid may secondarily contaminate rescue and medical personnel, by direct contact or through evaporation of hydrofluoric acid. Exposure to high concentrations of hydrofluoric acid vapor or fumes may cause absorption of hydrofluoric acid onto clothing; caution should be exercised in decontamination.
<i>Decontamination and Initial treatment</i>	All patients exposed to hydrofluoric acid require immediate decontamination. Patients who are able and cooperative may assist with their own decontamination. If the exposure involved liquid hydrofluoric acid and if clothing is contaminated, remove and double-bag the clothing.
<i>Eyes</i>	If the hydrofluoric acid concentration was intermediate or high,

assure that 1 or 2 anesthetic eye drops (e.g. 0.5% tetracain hydrochloride) have been administered. With a syringe, continue irrigating the eye with the 1% calcium gluconate solution until an ophthalmologist is available, but not longer than 2 hours. Continue other basic care during flushing.

If the hydrofluoric acid concentration was low, assure that the eye is irrigated, with a syringe, with the 1% calcium gluconate solution until relief of pain occurs or until an ophthalmologist is available, but not longer than 30 minutes.

Skin

Assure that exposed skin and hair have been flushed for at least 5 minutes with copious amounts of plain water and continue flushing until calcium gluconate is available. Protect eyes during flushing of skin and hair.

If the exposed area is larger than 160 square cm (25 square inches) and the hydrofluoric acid concentration >20%, injection of a sterile 5-10% calcium gluconate solution beneath, around and into the burned area is indicated as primary medical treatment. A small (25-30) gauge needle should be used and the burned area injected through multiple sites. The amount injected initially should not exceed 0.5 ml/cm² of affected skin surface. Since pain relief is usually a good indicator of adequate treatment, local anesthesia should be avoided. Calcium gluconate injections may be repeated if pain is not markedly diminished.

Note: DO NOT use calcium chloride instead of calcium gluconate.

If the exposed area is smaller or the hydrofluoric acid concentration low, start massaging the calcium gluconate 2.5% gel into the burn site, wearing protective (e.g. surgical) gloves. Apply new gel every 15 minutes flushing the skin in between with water. If good relief of pain is obtained within 45 minutes, these patients do not need to be transferred to a hospital.

Note: If calcium gluconate gel is not available, iced benzalkonium chloride 0.13% soaks or compresses can be used as an alternative.

In case of burns of fingers and the nails, after a first application of calcium gluconate gel as described above, partially fill an oversize surgical glove with calcium gluconate gel, insert the hand into the glove, and immerse the gloved hand in ice water.

Inhalation

Start or continue administration of an aqueous solution of 2.5% calcium gluconate by nebulizer with 100% oxygen under close control of calcium serum levels. 100% humidified oxygen should be administered to patients with abnormal respiratory signs or symptoms.

- Administration of oxygen

- Administration of 8 puffs of beclomethasone (800 µg beclomethasone dipropionate) from a metered dose inhaler.

Patients with severe clinical respiratory symptoms (e.g. bronchospasms, stridor) should be treated as follows:

a) Nebulization of adrenaline (epinephrine): 2 mg adrenaline (2 ml) with 3 ml NaCl 0.9% and inhale through a nebulizer mask.

b) Administration of a β_2 -selective adrenoceptor agonist, e.g., four strokes of terbutaline or salbutamol or fenoterol (one stroke usually contains 0.25 mg of terbutaline sulfate; or 0.1 mg of salbutamol; or 0.2 mg of fenoterol); this may be repeated once after 10 minutes. Alternatively, 2.5 mg salbutamol and 0.5 mg atrovent may be administered by nebulizer mask.

If inhalation is not possible, administration of terbutaline sulfate (0.25 mg to 0.5 mg) subcutaneously or salbutamol (0.2 mg to 0.4 mg over 15 minutes) intravenously.

c) Intravenous administration of 250 mg methylprednisolone (or equivalent steroid dose).

Patients with clinical signs of a toxic lung edema (e.g. foamy sputum, wet crackles) should be treated as follows:

- a) Start CPAP-therapy (Continuous Positive Airway Pressure Ventilation).
- b) Intravenous administration of 1000 mg methylprednisolone (or an equivalent steroid dose) is recommended.

Intubation of the trachea or an alternative airway management should be considered in cases of respiratory compromise. When the patient's condition precludes this, consider cricothyrotomy if equipped and trained to do so.

Ingestion

In case of hydrofluoric acid ingestion, do not induce emesis. The vomitus may contain hydrofluoric acid and result in secondary contamination. **If not already done, patients who are conscious and able to swallow should be given immediately 1-2 glasses of milk and/or 12 antacid (magnesium hydroxide, calcium carbonate) tablets/suspensions. If possible, within 60 minutes after exposure, immediately perform a gastric lavage with calcium chloride solution (20 ml CaCl₂ diluted with 1000 ml saline) via a small-bore tube.** The benefit usually outweighs the risk of perforation.

Further evaluation and treatment

All exposed patients - except those with skin exposure to a low concentrated solution of hydrofluoric acid, an exposed area < 160 square cm (25 square inches) and complete relief of pain after 45 minutes - **should be examined and treated as follows:**

Systemic treatment

Immediately start monitoring closely serum calcium, magnesium, potassium, and fluoride levels. Correction of reduced calcium levels by slow intravenous infusion of calcium gluconate as a 10% solution is of highest priority. Magnesium may also be replaced intravenously.

In cases with a supposed severe exposure, administer calcium and magnesium intravenously without previous laboratory testing. Constant monitoring of cardiac and vital signs is essential.

Adults:

1-2 g calcium gluconate IV infused over 5 minutes

2-4 g magnesium sulfate IV infused over 15-20 minutes

Children:

25 mg/kg bodyweight calcium gluconate IV infused over 5 minutes

25-50 mg/kg bodyweight magnesium sulfate IV infused over 15-20 minutes

To the standard intake history, physical examination, and vital signs add monitoring of complete blood count, hemoglobin, blood glucose, other electrolytes, prothrombin and partial thromboplastin time (PT and PTT) and urinalysis.

Arterial blood gas measurements should be performed and guide administration of sodium bicarbonate for correction of systemic acidosis.

Continuous electrocardiographic monitoring is strongly advised for recognition of signs of electrolyte imbalance (in particular prolonged QT interval as sign of hypocalcemia and hyperkalemia-induced arrhythmias).

Serum fluoride levels (normal <0.1 mg/l) may confirm overexposure.

Inhalation

Hemodialysis with fluoride-free water (and normal to low potassium and slightly higher calcium concentrations) can be considered in life-threatening cases.

Evidence of pulmonary edema - hilar enlargement and ill-defined, central-patch infiltrates on chest radiography - **is a late finding that may occur 6 to 8 hours or later after exposure. The chest X-ray is typically normal on first presentation to the emergency department even with severe exposures.**

Patients who develop serious signs or symptoms should be observed for a minimum of 24 hours and reexamined frequently before confirming the absence of toxic effects. Delayed effects are unlikely in patients who have minor upper respiratory symptoms (mild burning or a slight cough) that resolve quickly.

Spirometry should be performed.

If oxygen saturation is less than 90% or if it appears to drop, immediately check arterial blood gasses and repeat the chest X-ray.

If blood gasses begin to show deterioration and/or if the chest X-ray begins to show pulmonary edema start oxygen supplementation.

In case of worsening clinical signs (especially tachypnea >30/min with a simultaneous decrease of the partial pressure of carbon dioxide) CPAP-therapy (Continuous Positive Airway Pressure Ventilation) should be started within the first 24 hours after exposure.

In case of a pulmonary edema fluid intake/output and electrolytes should be monitored closely. Avoid net positive fluid balance. Central line or Swan-Ganz catheterization might be considered, to optimize fluid management.

As long as signs of pulmonary edema are present, intravenous administration of methylprednisolone (or an equivalent steroid) should be continued in intervals of 8-12 hours.

Prophylactic antibiotics are not routinely recommended, but antibiotics may be used based on clinical signs of infection. Pneumonia can complicate severe pulmonary edema.

Skin

In case of burns to feet, hands and digits which do not respond within 45 min to the therapy described above or where treatment has been delayed intraarterial or intravenous calcium gluconate infusion should be considered:

For intraarterial therapy insert a 20-gauge, 4 or 5 French arterial catheter percutaneously into the brachial or femoral artery. Perform arterial pressure wave monitoring and consider digital subtraction arteriography. Infuse a dilute calcium gluconate preparation (e.g. 10 ml of a 10% solution mixed with 40 ml 5% dextrose) with a perfusion pump over 4 hours; depending on serum calcium levels and pain relief during the subsequent 4 hours, continue intraarterial therapy for another 4 hours. If during the following 4 hours pain returns, repeat the whole procedure until continuous pain relief. 500 Units of heparin may be added to the infusion mixture.

For intravenous therapy (only for hand, digit, or foot burns if hydrofluoric acid concentration is not >20%) place the catheter on the dorsum of the affected hand or in an appropriate vena of the affected leg; exsanguinate superficial veins by elevation. After application of a pneumatic tourniquet (inflated above the systolic blood pressure) above the elbow or on the thigh, infuse 10 ml of a 10% calcium gluconate solution diluted with 40 ml saline. After 20 minutes of ischemia release the tourniquet.

In general, where blistering or necrosis occurs, early debridement may be recommended.

Patients should be observed for a minimum of 6 hours after pain relief and reexamined frequently.

Clinically asymptomatic patients **as well as patients who have a normal clinical examination and no signs or symptoms of toxicity may be discharged after an appropriate observation period in the following circumstances:**

- a) The evaluating physician is experienced in the evaluation of individuals with hydrofluoric acid exposure.
- b) Information and recommendations for patients with follow-up instructions are provided verbally and in writing. Patients are advised to seek medical care promptly if symptoms develop or recur.
- c) The physician is comfortable that the patient understands the health effects of hydrofluoric acid.
- d) Site medical is notified, so that the patient may be contacted at regular intervals in the 24-hour period following release from the emergency department.
- e) Heavy physical work should be precluded for 24 hours.
- f) Exposure to cigarette smoke should be avoided for 72 hours for patients who have had an inhalation exposure; the smoke may worsen the condition of the lungs.

Patients who required systemic treatment should not be discharged before a minimum 24 hour period free of symptoms and pain.

All patients with skin or eye burns should be reexamined after 24 hours.

In this document BASF has made a diligent effort to ensure the accuracy and currency of the information presented but makes no claim that the document comprehensively addresses all possible situations related to this topic. This document is intended as an additional resource for doctors at hospitals/emergency departments in assessing the condition and managing the treatment of patients exposed to hydrofluoric acid. It is not, however, a substitute for the professional judgement of a doctor and must be interpreted in the light of specific information regarding the patient available to such a doctor and in conjunction with other sources of authority.

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