

Chemical Emergency Medical Guideline

Information and recommendations for healthcare professionals

Hydrogen fluoride / hydrofluoric acid

CAS No.: 7664-39-3

GHS symbols:



GHS05
Corrosive



GHS06
Acute toxicity

Signal word: Danger

Hazard statements:

- H310 Fatal if in contact with skin.
- H314 Causes severe skin burns and serious eye damage.
- H301+H331 Toxic if swallowed or inhaled.

Overview

- Patients who have hydrofluoric acid on themselves or their clothing may endanger rescue workers and other persons through direct contact or hydrofluoric acid vapors.
- Hydrofluoric acid is a highly corrosive chemical that can cause extremely painful wounds.
- Fluoride ions are absorbed very well and quickly via all routes of exposure. This can result in hypocalcemia and other metabolic changes.
- Systemic poisoning can result in disorders of the cardiovascular system (especially cardiac arrhythmia), the central nervous system and kidney failure, and even respiratory and circulatory arrest.
- Immediate cleaning, taking personal protection into account, is the most important measure: before removing clothing, carefully rinse the affected eyes, skin and hair with plenty of water.
- Early intravenous administration of calcium and/or magnesium can counteract the systemic effects of hydrofluoric acid. Depending on the type and severity of exposure, calcium gluconate can be applied locally as a gel, used as a solution for rinsing the eyes, injected (subcutaneously, intravenously) or inhaled.

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1. Information about the substance

Hydrogen fluoride / hydrofluoric acid (HF) CAS 7664-39-3.

Aqueous solutions of hydrogen fluoride are referred to as hydrofluoric acid.

Hydrogen fluoride is a pungent-smelling, colorless, clear liquid that boils at 19-20°C and emits thick smoke in moist air. The vapors of hydrofluoric acid are also toxic. Hydrofluoric acid boils as an azeotropic mixture at 112°C. When hydrofluoric acid with a concentration > 40% is heated, hydrogen fluoride is released.

Hydrogen fluoride is also produced during the hydrolysis of various fluorides (cobalt fluoride, phosphorus pentafluoride, silicon tetrafluoride, sulfur tetrafluoride). Hydrofluoric acid is a very strong acid that reacts with many compounds to produce intense heat and can form highly flammable and explosive substances. It attacks metal, glass and stone and dissolves silicon, and must therefore be stored in plastic, lead, wax or paraffin bottles. Hydrofluoric acid is used in the production of inorganic fluorides and in the surface treatment of glass and metals (cleaning, etching, enameling). As a diluted solution, it is used as an industrial and household cleaner and as auxiliary material in the electronics and semiconductor industries.

2. Exposition

2.1. Inhalation

The absorption of large quantities of fluoride ions through inhalation of hydrofluoric acid vapors can lead to systemic poisoning. The strong irritant effect of hydrofluoric acid serves as a clear warning of dangerous concentrations.

2.2. Skin/eye contact

Exposure to hydrofluoric acid occurs mainly through skin contact. Fluoride ions are absorbed very easily and quickly through the skin and eyes and can thus lead to systemic poisoning. If more than 160cm² of skin is affected (an area of approx. 1-2 palms), there is a risk of severe systemic effects. Even low concentrations (<2%) can cause severe skin and eye burns if exposure is prolonged.

2.3. Ingestion

Accidental ingestion of hydrofluoric acid quickly leads to severe burns of the mucous membranes in the throat, esophagus and gastrointestinal tract, as well as systemic poisoning symptoms upon absorption. In adults, fatalities have been reported after ingestion of 1500 mg of hydrofluoric acid or more.

3. Acute health effects

3.1. Local effects

Contact with hydrofluoric acid can cause very painful burns to the eyes, skin and gastrointestinal tract.

3.2. Systemic effects

Contact with hydrofluoric acid can cause fluorine to react with the body's own calcium and other electrolytes. This can result in a significant drop in calcium levels, as well as other electrolytes, and consequent metabolic changes, including fatal cardiovascular arrest.

3.3. Cardiovascular system

The binding of calcium and magnesium and changes in potassium levels can lead to life-threatening cardiac arrhythmias, in particular ventricular fibrillation and asystole.

3.4. Central Nervous System

Fluoride ions can cause coma and respiratory arrest through a direct toxic effect on the central nervous system.

3.5. Eye contact

Exposure of the eye can have serious consequences, ranging from corneal opacity to complete destruction of the eye. In addition, burning sensations in the eyelids and ulceration may occur.

3.6. Respiratory System

Inhalation usually causes throat irritation and coughing. Respiratory problems with chest pain, shortness of breath and laryngospasm can develop rapidly. After inhalation exposure with corresponding symptoms, pulmonary edema may occur up to 24 hours later.

3.7. Skin contact

Skin contact usually causes redness, edema and blistering. Exposure to higher concentrations (>10%) may cause the skin to turn white; exudate may form under the blisters due to colliquative necrosis. Delayed treatment may result in deep tissue damage, tendonitis, tenosynovitis or even bone decalcification.

Clinical signs or symptoms may also occur with a delay after exposure to low to medium concentrations (<10%) of hydrofluoric acid or its vapors. Effects attributable to fluoride ions may therefore only be recognized after a delay. Dermal exposure to low concentrations of hydrofluoric acid can cause pain to a much greater extent than would be expected based on the examination findings. Severe pain can also occur with only reddened skin.

3.8. Gastrointestinal tract

Swallowing hydrofluoric acid causes severe burns to the mucous membranes of the throat, esophagus and gastrointestinal tract. Vomiting, especially hematemesis, is possible.

3.9. Other systemic health effects

Metabolic acidosis, renal failure and blood clotting disorders may occur.

3.10. Possible consequences

Irreversible burns may be caused to the skin, tissue and eyes, e.g. deep necrosis.

4. Measures

4.1. Self-protection for first aiders

If there is a suspicion that the area the helper must enter contains hydrofluoric acid like vapor or liquid, a self-contained breathing apparatus and a chemical protection suit must be worn. Contaminated equipment must not be used.

A patient whose clothing or skin is contaminated with hydrofluoric acid may endanger other people or medical personnel through direct contact or through hydrofluoric acid vapor. The release of high concentrations of hydrofluoric acid vapor/smoke can lead to the absorption of hydrofluoric acid on clothing; appropriate care must be taken during cleaning.

4.2. Rescue

Patients should be rescued from the danger zone immediately. If they are unable to walk unaided, they should be removed from the danger zone quickly using appropriate means, taking care to protect yourself. The "A, B, C procedure" has absolute priority.

- A) Clear the airways** (check for blockages caused by the tongue or foreign objects)
- B) Ventilation** (check the patient's breathing, if necessary, begin ventilation with adequate self-protection, e.g. breathing mask)
- C) Circulation** (begin resuscitation on any person who does not respond to verbal commands and is not breathing normally)

"CRASH" decontamination

- Patients contaminated with hydrofluoric acid who are unconscious or unable to move (critically ill/injured patients according to the ABCDE scheme) must be rescued with self-protection using suitable personal protective equipment
- If necessary, perform emergency measures ("Basic Life Support"; e.g. bleeding control using a tourniquet, chest compressions, etc.)
- At a suitable location outside the danger zone, completely undress the contaminated patient using an emergency rescue knife, taking care to protect yourself (duration: approx. 1 minute)
- Shower/rinse with plenty of water (duration: approx. 1 minute)
- Transfer to a clean stretcher. Ensure body heat is maintained.
- Transport/handover to the emergency services/emergency doctor (duration: approx. 1 minute)

4.3. Cleaning

If possible, patients should help with their own cleaning. If liquid hydrofluoric acid has come into contact with clothing, it must be removed and securely wrapped.

If the eyes have been exposed to hydrofluoric acid or if there is eye irritation, rinse thoroughly with water, neutral saline solution or, if available, a 1% calcium gluconate solution. Remove any contact lenses, if possible, without causing further injury to the eye. Continue other important first aid measures during this time.

Rinse affected skin and hair with water for at least 15 minutes. Continue other important first aid measures during this time. Protect eyes while rinsing.

4.4. Initial treatment (pre-clinical or clinical)

Eyes

If the eyes have been exposed to hydrofluoric acid or if there is eye irritation, rinse immediately with clean water or neutral saline solution. If eye rinsing is impeded by spasmodic eyelid closure, the use of a local anesthetic solution (e.g. lidocaine, oxybuprocaine) may be considered. Remove any contact lenses, if possible, without causing additional danger to the eye. Other important measures must be continued in the meantime.

Until an ophthalmologist is available, the eye can be rinsed (e.g. carefully with the aid of a syringe) with a 1% calcium gluconate solution.

Skin

Rinse affected skin areas and hair thoroughly under plenty of running water for at least 5 minutes. Continue rinsing until 2.5% calcium gluconate gel is available. Protect eyes during treatment.

For large-area burns (>160cm²; corresponds to an area of approx. 1-2 palms) and hydrofluoric acid concentrations >20%, the following measures are recommended: Subcutaneous injection of 10% calcium gluconate solution into and around the affected area as primary medical treatment.

A thin needle (25-30 G) should be used, and the burned tissue should be injected into several places. The amount applied should not exceed 0.5ml/cm² of the affected skin surface.

As the reduction in pain is usually a good indicator of adequate treatment, local anesthesia should be avoided. Subcutaneous injections with 10% calcium gluconate should be repeated until the pain subsides significantly.

*Note: **DO NOT** use calcium chloride instead of calcium gluconate for injection.*

To treat minor chemical burns or lower concentrations of hydrofluoric acid, massage calcium gluconate gel (2.5%) into the affected areas of skin. It is essential to wear suitable gloves (e.g. made of butyl rubber) when doing so.

Reapply the gel every 10 minutes and rinse the skin areas with water in between. If the pain has not subsided 45 minutes after the start of treatment, it is recommended to inject 10% calcium gluconate subcutaneously as described above.

In the case of isolated exposure of the fingers or nails to hydrofluoric acid, after initial application of calcium gluconate gel (see above), the hand should be placed in a rubber glove filled with calcium gluconate gel for further treatment and the hand should be cooled.

Inhalation

The following measures are recommended if, after inhaling hydrofluoric acid vapors, respiratory complaints or symptoms (sore throat, cough, shortness of breath) occur, hydrofluoric acid has affected the head, chest or throat area, or systemic toxic effects are present:

- Nebulization of 6ml of an aqueous solution of calcium gluconate (2.5%) via a mask
- Oxygen administration
- Administration of 8 sprays of beclomethasone (800µg beclomethasone dipropionate) from a metered dose inhaler.

If there are signs of airway constriction (e.g. bronchospasm or stridor)

- Nebulization of adrenalin (epinephrine): mix 2ml of adrenalin (2ml) with 3ml of 0.9% NaCl and administer via a nebulizer mask
- Administration of a β_2 -selective adrenoceptor agonist, e.g. four puffs of terbutaline or salbutamol or fenoterol (one puff usually contains 0.25mg terbutaline sulphate; or 0.1mg salbutamol; or 0.2mg fenoterol); this can be repeated once after 10 minutes.

Alternatively, 2.5mg salbutamol and 0.5mg ipratropium bromide can be administered via a nebuliser mask.

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

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

If there are signs of toxic pulmonary oedema (e.g. frothy sputum, moist rales)

- CPAP therapy
- Intravenous administration of 1000mg methylprednisolone (or an equivalent steroid dose)
In case of (increasing) respiratory insufficiency, advanced airway management, e.g. endotracheal intubation or coniotomy if necessary.

Note: The efficacy of corticosteroid administration has not yet been proven in controlled clinical trials.

Ingestion

If swallowed, do not induce vomiting under any circumstances.

Vomit may contain hydrofluoric acid and may therefore be dangerous. Anyone contaminated with hydrofluoric acid should immediately drink 200-300ml of water or, if available, milk and/or, if available in a timely manner, take stomach acid neutralizing agents – e.g. magnesium hydroxide, calcium carbonate – in tablet/suspension form.

If there are signs or symptoms of esophageal irritation or burns, the patient should be taken to an endoscopy center as soon as possible. An endoscopy to determine the extent of the damage (suspected gastrointestinal necrosis or perforation) should be considered.

Only if a significant dose was swallowed less than 60 minutes before the patient's endoscopic examination and perforation has been ruled out can gastric lavage with calcium chloride (20ml CaCl₂ per 1000ml water) or calcium gluconate via a gastric tube be considered within 60 minutes of ingestion.

4.5. Further procedure and treatment

Patients who have been exposed to high concentrations of hydrofluoric acid or who have swallowed hydrofluoric acid, as well as patients, should be transported immediately to a hospital with intensive care facilities.

All exposed patients with hydrofluoric acid exposure of the skin covering an area greater than 160 cm² should be examined and treated as follows:

Systemic treatment

In cases of severe exposure, administer calcium and magnesium intravenously at an early stage without prior laboratory diagnosis. Closely monitor vital signs and continuously monitor circulatory functions and respiration.

Adults:

1-2g calcium gluconate intravenously over 5 minutes
2-4g magnesium sulphate intravenously as a short infusion

Children

25mg/kg body weight calcium gluconate intravenously over 5 minutes
25-50mg/kg body weight magnesium sulphate intravenously as a short infusion

In addition to taking a medical history, performing a physical examination and analyzing urine, vital signs, blood count, hemoglobin, glucose, electrolytes, prothrombin and partial thromboplastin time (PT and PTT) must be monitored. Arterial blood gas analysis is recommended.

Continuous ECG monitoring is strongly recommended so that signs of electrolyte imbalance can be detected in good time (especially prolonged QT intervals as a sign of hypocalcemia or hyperkalemia-induced arrhythmias).

Serum fluoride concentrations (normal <0.1mg/l) may also indicate high exposure. Hemodialysis with fluoride-free water (and normal to low potassium and slightly higher calcium concentrations) may be considered in life-threatening cases.

Inhalation

The X-ray image is typically normal at the initial presentation at the hospital, even after inhalation of a larger dose. Radiological signs of pulmonary edema may only appear several hours after exposure.

If oxygen saturation drops while treatment, arterial blood gas concentrations should be determined immediately, and a follow-up chest X-ray should be performed.

If there are signs of pulmonary oedema, oxygen should be administered via a mask. If the findings worsen, ventilation therapy with positive end-expiratory pressure (PEEP) or continuous positive airway pressure therapy should be considered within the first 24 hours after exposure. An early indication for PEEP therapy or CPAP therapy is tachypnoea (>30/min) with a simultaneous decrease in carbon dioxide partial pressure. An insufficient increase or a relative decrease in oxygen partial pressure despite hyperventilation indicates the development of pulmonary oedema.

Fluid intake and excretion as well as electrolytes should be closely monitored. A positive balance should be avoided. To optimize fluid management, invasive volume monitoring and the insertion of a central venous catheter should be considered.

If signs of pulmonary edema are present, intravenous administration of 1.0g methylprednisolone (or an equivalent steroid dose) every 12 hours may be continued.

Pneumonia can occur as a complication of severe pulmonary edema. Prophylactic antibiotic administration is not routinely recommended but may be indicated based on the results of sputum cultures.

Skin

In the event of chemical burns to the hands, feet, fingers or toes that do not respond to the above treatment within 45 minutes, intra-arterial calcium gluconate therapy may be considered as a last resort.

Intravenous therapy (only for burns to the hands, fingers, toes or feet with hydrofluoric acid concentrations not exceeding 20%) should also be considered as a last resort. A catheter should be placed on the back of the hand or in a suitable vein in the affected leg; empty the superficial veins by elevating the limb. After applying a pneumatic tourniquet (above systolic blood pressure) above the elbow or on the thigh, infuse 10 ml of a 10% calcium gluconate solution with 40ml of saline solution. Release the tourniquet after 20 minutes of ischemia.

In cases of skin necrosis and extensive chemical burns, dermatological surgery or plastic wound revision may be performed to remove all necrotic and irreversibly damaged skin areas.

4.6. Biomonitoring

Biomonitoring with determination of the fluoride concentration in urine can be performed to estimate the systemic dose absorbed after exposure.

4.7. Discharge of the patient / instructions for further rules of conduct

Clinically asymptomatic patients who show unremarkable examination findings and no signs of toxic effects of hydrofluoric acid after an appropriate follow-up period may be discharged under the following circumstances:

- Information and recommendations for patients with instructions for further action have been provided verbally and in writing.
- The patient has been fully informed about the possible effects and symptoms following hydrofluoric acid exposure and has understood this information.
- The patient is aware of and understands the toxic effects of hydrofluoric acid.
- The attending physician has been informed that regular contact between the patient and the physician is possible in the following 24 hours.
- Avoid physical exertion and do not smoke.
- All patients who have skin or eye contact with hydrofluoric acid should be examined by a doctor after 24 hours at the latest.

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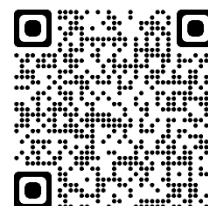
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