# ORIGINAL RESEARCH

## Efficacy of Hexafluorine for Emergent Decontamination of Hydrofluoric Acid Eye and Skin Splashes*

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**ABSTRACT.** Hexafluorine is an amphoteric, hypertonic, polyvalent compound for decontaminating hydrofluoric acid (HF) eye and skin splashes. In a German metallurgy facility during the period of 1994-1998, all eye or skin splashes with 40% HF alone or with a 6% HF/15% HNO3 mixture were initially decontaminated with Hexafluorine within 2 min following the splash at the accident site by the victims themselves or co-workers who witnessed the accident. Eleven workers using 40% HF or a 6% HF/15% HNO3 mixture sustained eye (2 cases) or skin (10 cases) splashes (1 combined) during 1994-1998. Hexafluorine was used within 2 min, and a second Hexafluorine decontamination was done on arrival at the plant infirmary. No further medical or surgical treatment was needed, no workers developed chemical burns, and none lost work time. These 11 cases demonstrate the efficacy of Hexafluorine in decontaminating HF or combined HF/HNO3 splashes.

Hydrofluoric acid (HF) is a corrosive and toxic chemical, and splashes cause physical and psychological sequelae (1-3) and sometimes fatalities (4-9). The corrosive lesions are caused by penetration of $H^+$ and $F^-$ ions into tissues; chelation of calcium leads to toxic systemic hypocalemia (10, 11) and other electrolyte imbalances (hypomagnesemia, hyperkalemia) may occur (12-13). Because of the risks presented by HF and its widespread usage in industry (6), numerous publications have described a variety of treatment modalities for HF burns in both experimental animals (14-23) and in human accidental exposures (4,13,24).

Hexafluorine is a novel amphoteric, hypertonic, polyvalent compound specifically developed for decontamination of hydrofluoric acid eye and skin splashes. The cases reported here demonstrate the ability of Hexafluorine to decontaminate HF eye/skin splashes and to prevent the expected development of HF burns and their sequelae.

### CASE REVIEWS

#### Methods

Mannesmann is a German metallurgical facility in which 40% HF is diluted and then mixed with nitric acid (HNO3) to produce a mixture of 6% HF/15% HNO3 for treatment of stainless steel tubing used in the automobile industry for manufacturing luxury car exhaust pipes. Eye or skin splashes occurred with 40% HF or during maintenance operations.

In 1994, after experience with attempted decontamination of eye or skin splashes with 6% HF/15% HNO3 with water lavage followed by topical application of 2.5% calcium gluconate gel (skin splashes only) without complete success, the Mannesmann Medical and Health and Safety Services decided to train workers about the hazards of these chemicals and the use of Hexafluorine decontamination and various application devices situated throughout the workplace.

During 1994-1998, all eye or skin splashes with 40% HF alone or the 6% HF/15% HNO3 mixture were initially decontaminated with Hexafluorine within the first 2 min (between 30 and 120 sec following the splash) at the accident site by the victims themselves or co-workers who witnessed the accident. Workers with skin splashes were undressed prior to decontamination.

The amount of Hexafluorine used depended on the duration of contact and the extent of total body surface area involved. For initial decontamination of eye splashes, 500 ml of Hexafluorine was applied within the first 2 min (30-120 sec) following exposure. For skin splashes an automatic portable 5 L Hexafluorine shower was used to decontaminate each exposed worker's entire body within 2 min (30-120 sec) following exposure. In each instance, a second Hexafluorine decontamination was carried out when the exposed worker arrived at the plant infirmary, after which clean work clothing was provided.

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Table 1. Emergency Decontamination of 40% HF or 6% HF/15% HNO(3) Eye Splashes with Hexafluorine(R)

| No Cases | Exposure | Splash Area Involved | Initial Decontamination | Second Decontamination | Sequelae | Requirement for Further Treatment | Lost Work Time |
|---|---|---|---|---|---|---|---|
| 1 | 40% HF | Eye | Hexalfluorine® | Hexafluorine® | None | None | None |
| 1 | 6% HF/ 15% HNO3 | Eye | Hexafluorine® | Hexafluorine® | None | None | None |

## Results

During 1994-1998, 11 workers sustained eye or skin splashes, 6 of which involved the 6% HF/15% HNO3 mixture and 5 of which were with 40% HF. Exposed workers were all males aged 35 +/- 11 y. One worker sustained both eye and skin splashes with 40% HF, and 1 worker had only an eye splash with the 6% HF/15 % HNO3 mixture (Table 1).

The 10 skin splashes involved from 0.2% (1 finger) to 16.5% of the total body surface area (Table 2). In 6 cases, the total body surface area involved was equal to or greater than 4%. In 1 case each, splashes with either the 6% HF/15% HNO3 mixture or 40% HF involved greater than 10% of the total body surface area, ie 10.5% and 16.5% respectively. Exposed areas included the hands, upper or lower extremities, face, eyes, and thorax.

No chemical burns or sequelae of any sort were observed in these 11 exposed workers. There was no requirement for any type of medical or surgical treatment other than Hexafluorine decontamination, and none of the workers lost work time.

## DISCUSSION

Numerous methods for decontamination and treating HF dermal burns can be found in the published literature (2, 5,12, 26-29). Splashes with concentrated HF (40-70%, anhydrous) rapidly produce very painful lesions (30), requiring that decontamination and treatment be undertaken immediately following exposure. In spite of early decontamination with water followed by repeated topical inunction or sc injection of calcium gluconate, development of burns often cannot be prevented. The risk of developing systemic HF toxicity (hypocalcemia, hypomagnesemia, hyperkalemia and their attendant risks) is greatest with concentrated HF splashes involving 2.5% or more of the total body surface area, which can sometimes be fatal (4).

Splashes with dilute HF have been successfully decontaminated with water followed by topical application of calcium gluconate gel. In such cases, the difficulty lies in perceiving the need to immediately undertake these measures in the absence of pain, which may be delayed in onset for as much as 24-48 h after exposure (30-32). The duration of HF contact with the tissues may be prolonged in such situations, although the $F^-$ ion is initially bound to the calcium ion derived from calcium gluconate, it may later be released and can then initiate a burn. With dermal exposure to either dilute or concentrate HF, in some cases surgical debridement, excision, or even amputation of necrotic areas may be required (33-36).

The relatively short duration of this study (1994-1998) plus the utilization of safety goggles resulted in inclusion of only 2 cases of HF eye splashes. In both cases, rapid decontamination with Hexafluorine prevented ocular burns in 1 case each of eye splashes with concentrated or dilute HF.

In the cases reported here, a combined program of worker training on the hazards encountered during the use of 40% HF or 6% HF/15% HNO3 together with the use of Hexafluorine for emergent decontamination within the first 2 min following eye or skin exposure allowed avoidance of the development of chemical burns and their sequelae. Hexafluorine has thus been demonstrated to be efficacious for decontamination of eye or skin splashes with either concentrated or dilute HF solutions in the workplace.

Hexafluorine is an HF decontamination compound which acts through a combination of physical and chemical mechanisms. It is hypertonic and can thus osmotically recover a portion of the HF which penetrated into the tissues. Its amphoteric properties allow it to bind both $H^+$ and $F^-$ ions, thus acting both against the acidity of HF and the tissue toxicity of the $F^-$ ion (37-39). In vitro, Hexafluorine has 100 times the affinity of calcium gluconate for the $F^-$ ion (38).

The various treatment modalities found in the medical literature are focused on the toxic potential of HF and are based on chelation or binding of the $F^-$ ion, while not addressing the potential contribution of the hydrogen ion in the development of burns. Calcium gluconate has only a very weak action on the acidity of HF, making multiple topical applications or injections necessary. Treatment following splashes with HF when water decontamination is followed by calcium gluconate must be repetitive, of long duration, and sometimes dependent on the reoccurrence of the sensation of pain, which may be unnecessarily uncomfortable for the patient (40, 41).

Table 2. Emergency Decontamination of 40% HF or 6% HF/15% HNO(3) Skin Splashes with Hexafluorine(R)

| No Cases | Exposure | Splash Area Involved (% Total body surface area) | Initial Decontamination | Second Decontamination | Sequelae | Requirement for Further Treatment | Lost Work Time |
|---|---|---|---|---|---|---|---|
| 5 | 40% HF | 0.2; 1; 4.5; 4.5; 16.5 | Hexalfluorine® | Hexafluorine® | None | None | None |
| 5 | 6% HF/ 15% HNO3 | 0.2; 2.25; 4; 4.5; 10.5 | Hexafluorine® | Hexafluorine® | None | None | None |

By acting on all the toxic mechanisms of HF, Hexafluorine allows rapid decontamination of splashes, prevention of burns and their sequelae, rapid resolution of pain, and avoidance of the need for further medical or surgical treatment. The excellent clinical outcomes in the cases reported here demonstrate both the efficacy of Hexafluorine for decontamination of HF splashes and the value of a training program for workers about the hazards of the chemical and first aid procedures (42). When workers are familiar with emergency protocols for HF splash response, the duration of chemical contact can be significantly decreased.

*In vitro* studies, *in vivo* experimental animal studies, and results from 5 previously-reported human HF eye or skin splash cases, as well as the 11 cases reported here, demonstrate that Hexafluorine is efficacious for HF decontamination (38, 39).

When workers have been trained about the hazards of HF splashes and rapidly utilize a decontamination compound, such as Hexafluorine which acts to neutralize all of the toxic mechanisms of this chemical, it is possible to prevent the development of eye or skin burns and their sequelae, as demonstrated in the cases presented here. The particular value of Hexafluorine for emergent decontamination of HF eye or skin splashes is that, unlike other decontamination measures, it can prevent the development of burns and the necessity for further medical or surgical treatment, potential serious or even fatal systemic toxicity, sequelae, and lost work time. It can rapidly and easily be used by the victim or co-worker(s) directly at the accident site.

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