EFFICACY OF HEXAFLUORINE® FOR EMERGENT DECONTAMINATION OF HYDROFLUORIC ACID EYE AND SKIN SPLASHES

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ABSTRACT

Introduction: Hexafluorine® is an amphoteric, hypertonic, polyvalent compound for decontaminating hydrofluoric acid (HF) eye and skin splashes. **Methods:** 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% HNO_3 mixture were initially decontaminated with Hexafluorine® within the first 2 minutes following the splash at the accident site by the victims themselves or co-workers who witnessed the accident. **Results:** Eleven workers using 40% HF or a 6%HF/15% HNO_3 mixture sustained eye (2 cases) or skin (10 cases) splashes (1 combined) during 1994-1998. Hexafluorine® was used within the first 2 minutes, 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 had lost work time. **Discussion:** Amphoteric Hexafluorine® binds both hydrogen and fluoride ions and has an affinity for fluoride 100 times greater than that of calcium gluconate. In experimental animals, Hexafluorine® prevented 70%

HF skin burns, while water decontamination alone or followed by 2.5% calcium gluconate gel inunction did not. **Conclusion:** These 11 cases demonstrate the efficacy of Hexafluorine® in decontaminating HF or combined HF/HNO_3 splashes.

Key Words: Hydrofluoric acid; Hydrofluoric acid, burns; Hydrogen fluoride; Hydrogen fluoride, burns; Skin decontamination; Eye decontamination; Hexafluorine®

INTRODUCTION

Hydrofluoric acid (HF) is a corrosive and toxic chemical and splashes can cause physical and psychological sequelae (Dayal et al 1994; Beaudouin et al 1989; Camarasa 1983) and sometimes fatalities (Muriale et al 1996; Tepperman 1980; Sheridan et al 1995; Kirkpatrick et al 1995; Chataigner et al 1992; Mullett et al 1987; Chan et al 1987). The corrosive lesions are caused by penetration of H^+ and F^- ions into the tissues; chelation of calcium leading to toxic systemic hypocalcemia (Noonan et al 1994; McCulley et al 1983) and other electrolyte imbalances (hypomagnesemia, hyperkalemia) may occur (Upfal and Doyle, 1990; El Saadi et al 1989). Because of the risks presented by hydrofluoric acid and its widespread usage in industry (Kirkpatrick et al, 1995), numerous publications have described a variety of treatment modalities for HF burns in both experimental animals (Beiran et al 1997; Dunn et al 1996; Boink and Meulenbelt 1995; St. Noordhoek et al 1995; Cox and Osgood 1994; Dowback et al 1994; Burkhart et al 1994; Kono et al 1992; Bracken et al 1985; Carney et al 1974) and in human accidental exposures (Tepperman 1980; El Saadi et al 1989; Rubinfeld et al 1992).

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.

METHODS

Mannesmann is a German metallurgical facility in which 40% HF is diluted and then mixed with nitric acid (HNO_3) to produce a mixture of 6% HF/15% HNO_3 utilized for treatment of stainless steel tubing used in the automobile industry for manufacturing luxury car exhaust

pipes. Eye or skin splashes with 40% HF or the 6% HF/15% HNO_3 mixture can occur during stainless steel tubing stripping, decanting and dilution of 40% HF, or during maintenance operations.

In 1994, after experience with attempting decontamination of eye or skin splashes with 6% HF/15% HNO_3 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 the various application devices which had been previously situated throughout the workplace.

During the period of 1994-1998, all eye or skin splashes with 40% HF alone or the 6% HF/15% HNO_3 mixture were initially decontaminated with Hexafluorine® within the first 2 minutes (between 30 and 120 seconds 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 the total body surface area involved. For initial decontamination of eye splashes, 500 mL of Hexafluorine® was applied within the first 2 minutes (30-120 seconds) following exposure. For skin splashes, an automatic portable 5 L Hexafluorine® shower was used to decontaminate each exposed worker's entire body and utilized within 2 minutes (30-120 seconds) 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.

RESULTS

During the period of 1994-1998, 11 workers sustained eye or skin splashes, 6 of which involved the 6% HF/15% HNO_3 mixture and 5 of which were with 40% HF. Exposed workers were all males aged 35 ∀ 11 years. One worker sustained both eye and skin splashes with 40% HF and one worker had only an eye splash with the 6% HF/15% HNO_3 mixture (Table 1).

The 10 skin splashes involved from 0.2% (one 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 one case each, splashes with either the 6% HF/15% HNO_3 mixture or 40% HF involved greater than 10% of the total body surface area, 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 these workers had any lost work time.

DISCUSSION

Numerous methods for decontaminating and treating HF dermal burns can be found in the published literature (Matsuno 1996; Bentur et al 1993; Upfal and Doyle 1990; Greco et al 1988; Trevino et al 1983; Browne 1974; Wetherhold and Sheperd 1965). Splashes with concentrated HF (40-70%, anhydrous) rapidly produce very painful lesions (Griffith 1987), requiring that decontamination and treatment be undertaken immediately following exposure. In spite of early decontamination with water followed by repeated topical inunction or subcutaneous 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 (Tepperman 1980).

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 hours after exposure (Griffith 1987; Saada et al 1995; Henry and Hla 1992). The duration of the HF contact with the tissues may be prolonged in such situations; although the fluoride 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 concentrated HF, in some cases surgical debridement, excision, or even amputation of necrotic areas may be required (Chick and Borah 1990; Buckingham 1988; Barbier et al 1987; Saada et al 1974).

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 one 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% HNO_3 together with the use of Hexafluorine® for emergent decontamination within the first 2 minutes 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 has already 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 fluoride ion (Burgher et al 1996; Josset et al 1992; Hall et al 1999). In vitro, Hexafluorine® has 100 times the affinity of calcium gluconate for the fluoride ion (Josset et al 1992).

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 fluoride 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 hydrofluoric acid when water decontamination is followed by calcium gluconate must be repetitive, of long duration, and sometimes dependent on the re-occurrence of the sensation of pain, which may be unnecessarily uncomfortable for the patient (Lheureux et al 1991; White 1984).

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 (Perrotte et al 1993). 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 (Josset et al 1992; Hall et al 1999).

CONCLUSION

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-workers directly at the accident site.

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Table 1

Emergency Decontamination of 40% HF or 6% HF/15% HNO_3 Eye Splashes with Hexafluorine®

No. Cases	Exposure	Splash Area Involved	Initial Decontam-ination	Second Decontam-ination	Sequelae	Require-ment for Further Treatment	Lost Work Time

1	40% HF	Eye	Hexafluor-ine7	Hexafluor-ine7	None	None	None
1	6% HF/ 15% HNO_3	Eye	Hexafluor-ine7	Hexafluor-ine7	None	None	None

Table 2

Emergency Decontamination of 40% HF or 6% HF/15% HNO_3 Skin Splashes with Hexafluorine®

No. Cases	Exposure	Splash Area Involved (% Total Body Surface Area	Initial Decontam-ination	Second Decontam ination	Sequelae	Require-ment for Further Treatment	Lost Work Time

5	40% HF	0.2; 1; 4.5; 4.5 16.5	Hexafluor-ine7	Hexafluor-ine7	None	None	None
5	6% HF/ 15% HNO_3	0.2; 2.25; 4; 4.5; 10.5	Hexafluor-ine7	Hexafluor-ine7	None	None	None