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Epidemiology of Work-Related Hydrofluoric Acid Exposure in Western Zhejiang Province, China

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Abstract

Background: Hydrofluoric acid (HF) burns are one of the most frequent chemical burns in western Zhejiang province of China, and most of them are work-related. This study documents the epidemiology of HF burns in the region using burn data from a local specialized hospital. Results from this survey will assist in the planning of prevention strategies for high-risk occupations and groups.

Methods: A 13 y retrospective analysis was conducted including all patients with work-related HF exposure admitted to the Department of Burns and Plastic Surgery, Zhejiang Quhua Hospital, Zhejiang Province, China, between January 2004 and December 2016. Information obtained from eligible patients included sex, age, education, season distribution, type and nature of enterprise, cause of HF injury, and HF concentration. Data regarding time lag from injury to medical treatment, burn sites and sizes, accompanying injuries, treatments, and prognosis were also assessed.

Results: A total of 316 patients (294 males, 22 females; average age: 39.5 ± 10.31 y) were admitted for work-related HF burns. These patients were divided into the FI group (170 patients) and the NFI group (146 patients). The incidence of HF burn injury has increased gradually over the last 13 y period, although several slight fluctuations were observed in several years. There was a significant difference in education level between the FI and NFI groups. Compared to the state-owned enterprises, private enterprises seemed to contribute most of the work-related HF injuries. These HF injuries were caused by varying concentrations of HF solution. The average concentration of HF in the FI group was significantly higher than that in the NFI group. However, the time lag from injury to medical treatment in the FI group was shorter than that in the NFI group. The most common burn sites in the FI group were the head, neck, arms, and legs, while the hand was the most frequently involved site in the NFI group. The average burn area was significantly larger in the FI group than the NFI group. In terms of accompanying injuries, there were higher rates of morbidity in the FI group than the NFI group. Accordingly, the FI group showed a higher poisoning severity score than the NFI group. Fifty-two patients underwent surgery, including 31 from the NFI group and 21 from the FI group. Most of the surgeries involved early eschar excision and skin grafting performed in the ER, while most surgeries, including amputation and flaps, were performed in patients in the NFI group. More sequelae were observed in the NFI group.

Conclusions: Work-related HF burns are preventable. The high morbidity of HF burns in western Zhejiang Province is related to the industrial structure of the area. The related enterprises and local authorities are encouraged to launch and upgrade their safety policies, as well as to provide the necessary occupational education and training to high-risk populations based on the differences in characteristics of the FI and NFI groups. Strategies focusing on the production, transportation, and usage of HF should be enhanced immediately.

Introduction

Hydrofluoric acid (HF) is a dangerous acid that is widely used in many industrial and domestic settings [1]. HF is an important industrial material used for refrigerants, fluoropolymers, pesticides, and dyes [2,3]. HF is also used extensively in non-chemical industries, such as electronics manufacturing, metal polishing, glass etching, smelting, cleaning, and denture manufacturing [4-6]. With its widespread applications, the incidences of HF-related injuries are increasing in the workplace and even in domestic settings [1,7].

HF has protoplasmic toxicity, causing not only local tissue corrosion, but also systemic poisoning by ongoing absorption into the human body [1]. It has been reported that HF burns over small areas can result in death [8,9]. Previous epidemiological investigations of HF exposure were mostly conducted by regional poison centres [10-13],

partly due to the low morbidity of HF injuries worldwide. HF injuries have been shown to occur more frequently in some regions [3,14], however, there have been few HF-related surveys or data analyses from clinical institutes. Zhejiang Quhua Hospital is a medical institute focusing on the treatment and management of chemical burns in western Zhejiang Province, China. This study was conducted to analyse the occupational distribution and clinical features of work-related HF exposure in patients admitted to Zhejiang Quhua Hospital between January 2004 and December 2016 to provide evidence in support of upgrading safety measures and for the formulation of preventive strategies.

Materials and Methods

Data collection

A 13 y retrospective analysis was conducted including all patients with work-related HF exposure admitted to the Department of Burns and Plastic Surgery, Zhejiang Quhua Hospital, Zhejiang Province, China, between January 2004 and December 2016. Work-related HF exposure was strictly defined, indicating workers with a positive history of HF exposure. Information obtained from eligible patients included sex, age, education, season distribution, type and nature of enterprise, cause of HF injury, and HF concentration. Data regarding time lag from injury to medical treatment, burn sites and sizes, accompanying injuries, treatments, and prognosis were also assessed. Here, the accompanying injuries included inhalation injury and ocular burns. After collecting the above information, clinical severity of poisoning was divided into asymptomatic, mild, moderate, severe, and death according to Zhejiang Criteria [15].

Based on the types of enterprises where work-related HF exposure occurred, the eligible patients were divided into two groups, i.e., fluoride industry (FI) group and non-fluoride industry (NFI) group. The FI group included patients working in industries where HF was produced or regarded as a main raw material. The NFI group included all other patients engaging in transporting or using HF in their daily work.

Statistical analysis

Numerical variables are presented as the mean and standard deviation or median and interquartile range, and categorical variables are summarised as frequency and percentage. Differences in the distributions of categorical variables between FI and NFI groups were examined using Pearson's chi-square test. Student's t-test was used to examine differences in means, and Wilcoxon's test was used to examine differences in medians. Statistical significance was considered as two-tailed $p < 0.05$. All analyses were performed using SAS 9.4 statistical software (SAS Institute Inc., Cary, NC, USA).

Results

The 5552 burn patients admitted to the Department of Burns, Zhejiang Quhua Hospital, Zhejiang Province, China, between January 2004 and December 2016 included 963 patients with chemical burns, accounting for 17.3% of all burn patients. Of these, 319 patients had been exposed to HF solution, which accounted for 33.1% of all chemical burn patients during the study period (Figure 1). Among all of cases of HF burns, 99.1% (316 patients) were work-related, and were eligible for inclusion in this study. These patients were divided into two

groups, i.e., the FI group (170 patients) and the NFI group (146 patients) (Figure 1).
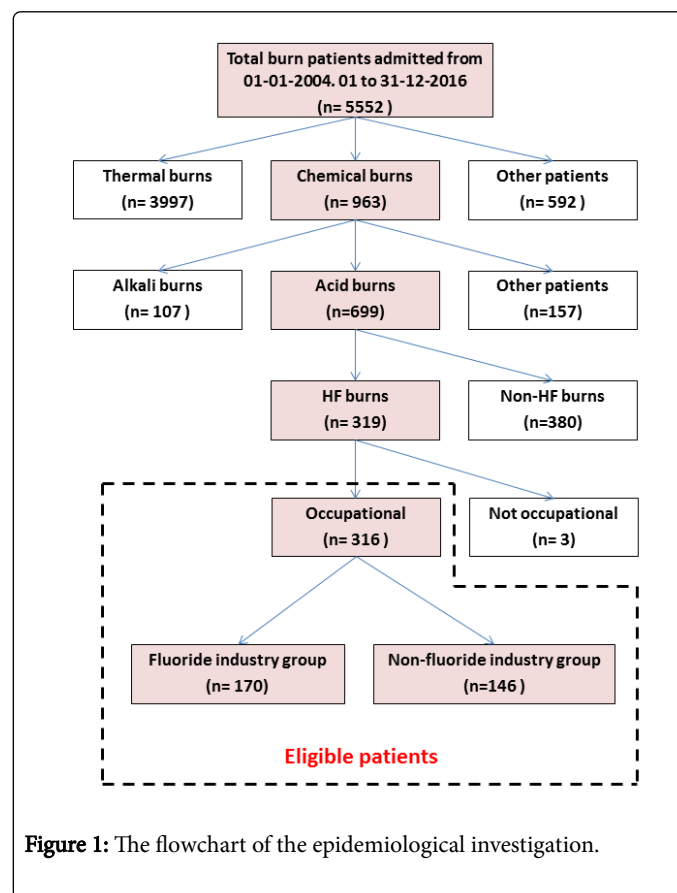

Figure 1: The flowchart of the epidemiological investigation.

Tendency of work-related HF exposure

Figure 2 shows the number of work-related HF exposures each year. The incidence increased gradually over the 13 y period in both the FI and NFI groups, although several slight fluctuations in this trend were observed in 2006, 2014, and 2015.
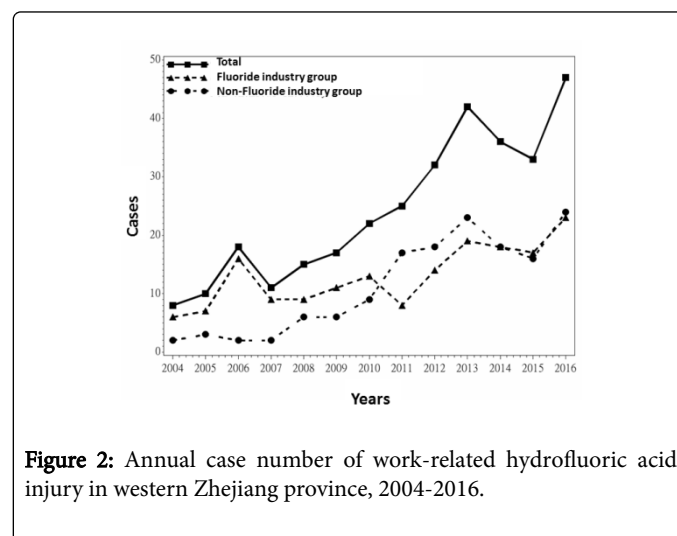

Figure 2: Annual case number of work-related hydrofluoric acid injury in western Zhejiang province, 2004-2016.

Basic demographic characteristics

Of the 316 patients, 294 were male and only 22 were female (ratio, 13.4:1). The average age was (39.5 ± 10.31 y), ranging from 17 to 69 y. For all patients, chemical burns occurred most frequently in patients aged 31-50 y (64.9%), followed by that aged 41-50 y and 21-30 y (Table 1). The average age of the FI group was 38.5 ± 10.5 y, while that of the NFI group was 40.7 ± 10.1 y.

There were significant differences in education level between the two groups. The FI group had a lower ratio of patients with primary or below education level and a higher ratio of patients with senior or above education level compared with the NFI group (p<0.0001).

Seasonal distribution

For all 316 patients, the seasonal distribution of HF burns was relatively uniform: spring, 62 patients (19.6%); summer, 91 patients (28.8%); autumn, 89 patients (28.2%); and winter, 74 patients (23.4%).

In the FI group, the seasonal distribution was as follows: spring, 28 patients; summer, 52 patients; autumn, 49 patients; and winter, 41 patients. Those in the NFI group were 34, 39, 40, and 33 patients, respectively.

Sources of work-related HF exposure

In addition to the 170 patients (53.8%) working in fluoride industries, the other 146 patients were distributed in different types of industries, including stevedoring and transportation (52 patients, 16.4%), metal casting (29 patients, 9.2%), semiconductor manufacturing (24 patients, 7.6%), glass and crystal etching (16 patients, 5.1%), waste disposal services (10 patients, 3.1%), electroplating (4 patients, 1.3%), and other industries (11 patients, 3.5%) (Figure 2).

In the FI group, 48.2% of patients were from state-owned enterprises, and 37.1% were from private enterprises. Meanwhile, most patients in the NFI group (95.9%) were from private enterprises (Table 1).

Causes of HF injury and HF concentrations

All of the work-related HF injuries involved exposure to varied concentrations of HF solution. (Table 2) presents the concentrations of HF to which the patients were exposed. The average concentration of HF in the FI group was 58.6 ± 34.65%, which was significantly higher than the average of 39.8 ± 19.01% in the NFI group. Furthermore, more patients in the FI group were exposed to HF solution with a concentration>50% (Table 2).

Time lag from injury to medical treatment

For all 316 patients, the median time lag from injury to medical treatment was 7.0 h. However, the time lag in the FI group (3.0 h) was significantly shorter than that in the NFI group (21 h) (p<0.0001).

Burn sites and sizes

HF burns were observed at 430 total sites among the 316 patients (Table 2). The most common sites of injury were head and neck (133 cases, 30.9%), hand (128 cases, 29.8%), and arm and leg (109 cases, 25.4%). The incidences of HF burns involving the head and neck and the arm and leg were higher in the FI group (84 and 120 cases,

respectively) than in the NFI group (13 and 25 cases, respectively). However, chemical burns of the hand were more common in the NFI group (103 cases) than the FI group (25 cases) (Table 2).

The average area of burn injury in all 316 patients was 2.8 ± 5.7% of total body surface area (% TBSA). The average burn area was significantly larger in the FI group (3.6 ± 6.8% TBSA) than the NFI group (1.8 ± 3.8% TBSA) (p=0.003).

Accompanying injuries

Of the 316 patients, 15 patients (4.8%) had inhalation injury, including 12 patients from the FI group and three patients from the NFI group. Twenty-nine patients (9.2%) had ocular injuries, and most (26 patients) were from the FI group.

Poisoning severity score

As shown in (Table 2), poisoning severity score was significantly different between the two groups. There were more patients with light poisoning in the NFI group (86 patients) compared with the FI group (50 patients). Patients in the FI group suffered more severe poisoning situations than those in the NFI group (Table 2).

Treatments, hospitalisation stay, and prognosis

Most of the total population of 316 patients (264 patients) were treated using conservative therapies. Fifty-two patients underwent surgery, and most were from the NFI group (31 patients) compared with the FI group (21 patients). Eighteen patients from the NFI group and 15 patients from the FI group underwent eschar excision and skin grafting in the ER. Amputation and flaps were performed in 22 patients, and most (20 patients) belonged to the NFI group. Skin grafting in the later stage was performed in 12 patients, consisting of four from the FI group and eight from the NFI group (Table 3).

The average hospitalisation stay was 8.7 ± 11.4 d for all patients. There was no significant difference in the length of hospitalisation stay between the FI group (9.1 ± 12.1 d) and the NFI group (8.2 ± 10.6 d) (p=0.49).

With regard to sequelae, scar formation occurred in 126 patients, consisting of 39 patients from the FI group and 87 from the NFI group. Ten patients underwent surgery to shorten the injured finger(s), and they were all from the NFI group. Three deaths occurred, all of which were in the FI group.

Discussion

The morbidities of chemical burns vary worldwide, but are mostly influenced by the local population structure, industry distribution, and geographical and social environments [16,17]. Zhejiang Province, located in the southeast coast of China, is well known for its rapid economic development and high industrialisation level following the reform and opening-up of China [14]. Particularly in the western part of the province, there has been a great deal of chemical industrial development. There are rich fluorite (CaF_2) sources in this area, and fluorite mines have been overexploited. CaF_2 in combination with concentrated sulphuric acid can be used to produce HF, an important industrial raw material [18]. Over the past several decades, the large-scale state-owned fluoride industries have continued to expand their plants and increase production. Some other enterprises, including private and joint venture enterprises, have also emerged. This region

has become a large base for fluoride-based industries. It has been estimated that the region produces 400,000 tons of HF annually, accounting for approximately a quarter of the annual output from China [3,19]. Furthermore, some other related industries, such as semiconductor manufacturing, electroplating, and glass and crystal etching enterprises, where HF is widely and heavily used have accumulated in the surrounding areas. Chemical burns caused by HF have occurred as sporadic cases or as group events injuring multiple people in this region [20,21]. Our previous study investigating chemical burns in Zhejiang Province between September 2008 and August 2009 found HF to be the cause of 27.44% of burn injuries; HF was listed as the top cause for all chemical burns [14].

This epidemiological survey showed that the morbidity of HF burns in western Zhejiang Province reached up to 33.1% of all chemical burns (Figure 1), which is much higher than the rates reported by other investigators [22,23]. The frequency of HF burns has increased over the past several decades. Our study revealed similar incidences of chemical burns in western Zhejiang Province between January 2004 and December 2016, although small fluctuations were observed in 2006, 2014, and 2015. As described above, the fluoride and derivative industries have shown a great deal of growth over the past several decades. Consequently, the incidence of chemical burns has gradually increased in this region [20,24].

The majority of chemical burns are work-related, and working-age individuals are affected most frequently [2,23,25]. In this study, most HF burns (316 patients, 99.1%) were occupational, and more than half (53.8%) came from the fluoride industries, with 46.2% from non-fluoride industries. In both the FI and NFI groups, most individuals with HF burns were between the ages of 21 and 60 y (Table 1). There were more patients with senior, college or above education, and less with primary or below education in the FI group than in the NFI group (Table 1). This suggested that educational level could be related to the morbidity of HF burns.

For all 316 patients, the incidence of HF burns in our study revealed seasonal variability. More than half of all HF burn injuries (57.0%) occurred in summer and autumn compared with the spring and winter. This may be partly because people tend to wear less clothing during the warmer summer and autumn seasons [26]. However, chemical burns still occurred in winter and spring at a moderate rate (43.0%). As most of the chemical burns were reported as work-related, season likely plays only a minor role in chemical burn incidence in both the FI and NFI groups.

There were 82 patients (48.2%) from state-owned enterprises and 63 patients (37.1%) from private enterprises in the FI group, while most patients (140 patients, 95.9%) were from private enterprises in the NFI group. Workers have opportunities to receive better occupational education and protective equipment in state-owned and joint venture or overseas-funded enterprises. In other enterprises, especially in the private sector, related occupational education and safety training are lacking, and therefore workers may fail to follow safety rules and regulations, leading to a high frequency of chemical injuries [3]. Patients in the NFI group were distributed in stevedoring and transportation (52 patients, 16.4%), metal casting (29 patients, 9.2%), semiconductor manufacturing (24 patients, 7.6%), glass and crystal etching (16 patients, 5.1%), waste and disposal services (10 patients, 3.1%), electroplating (4 patients, 1.3%), and other industries (11 patients, 3.5%) (Table 4). A recent study investigated cases of acute HF exposure occurring from 1991-2010 using data collected from the Taiwan Poison Control Centre [10]. A total of 324 cases were identified, of which 80% were caused by occupational exposure, including that occurring in the semiconductor industry (61%), cleaning industry (15%), chemical and metal industries (13%), and other industries (11%). There were some obvious differences in the occupational distribution of HF burns between these data and those listed in this survey.

Varied concentrations of HF solution have the potential to cause injuries. In the FI group, patients had greater incidences of exposure to higher concentrations of HF solutions compared with those in the NFI group (Table 4). Generally, due to early onset of symptoms and timely treatment, the prognosis actually tends to be more favourable in those exposed to high concentrations of HF. The lack of apparent symptoms in those exposed to lower concentrations of HF may delay the receipt of treatment, leading to more severe systemic damage when symptoms do become apparent [1]. This partly explains why patients in the FI group had a shorter time lag from injury to medical service than those in the NFI group (Table 4).

Small burn areas were common in patients with HF burns. However, the average burn area in the FI group was significantly larger than that in the NFI group (Table 4). In the FI group, the head and neck (30.9%) were the most common involved sites, followed by the hands (29.8%) and the arms and legs (25.4%). The most frequently involved sites in the NFI group were the hands (64.2%). In addition, accompanying injuries as well as poisoning rated as moderate or above occurred more frequently in the FI group (Table 4). However, the patients in the NFI group showed higher proportions of receiving surgery and having more sequelae, such as scar formation and finger shortening (Table 3). There were a total of three deaths in this study population, all of which were in the FI group. For patients working in fluoride industries, exposure to HF mainly occurred in two ways. First, when workers were operating machines, filling containers, or overhauling equipment, highly concentrated or anhydrous HF solution spilled or splashed out from the machines or pipes. Burns located on the head and neck was common, and some other sites, such as the trunk, upper extremities, eyes, and respiratory tract, were sometimes involved. Poisoning occurred frequently, and required timely treatment. Second, workers were exposed to HF solution due to broken gloves, or their hands came into contact with surfaces contaminated by HF solution. In this situation, the concentrations of HF solution were usually low, and the hands were most commonly involved.

Variable	Total (n=316)	Fluoride industry group (n=170)	Non-fluoride industry group (n=146)	p-value
Age (y)	39.5 ± 10.31	38.5 ± 10.45	40.7 ± 10.07	0.07
≤ 20	8 (2.5)	5 (2.9)	3 (2.1)	0.39
21-30	55 (17.4)	36 (21.2)	19 (13.0)	

31-40	110 (34.8)	58 (34.1)	52 (35.6)	
41-50	95 (30.1)	49 (28.8)	46 (31.5)	
51-60	43 (13.6)	19 (11.2)	24 (16.4)	
>60	5 (1.6)	3 (1.8)	2 (1.4)	
Gender				0.42
Male	294 (93.0)	160 (94.1)	134 (91.8)	
Female	22 (7.0)	10 (5.9)	12 (8.2)	
Education				<0.0001
Primary or below	61 (19.3)	19 (11.2)	42 (28.7)	
Junior	147 (46.5)	73 (42.9)	74 (50.7)	
Senior	99 (31.3)	71 (41.8)	28 (19.2)	
College or above	9 (2.9)	7 (4.1)	2 (1.4)	
Type of enterprise				<0.0001
State-owned	85 (26.9)	82 (48.2)	3 (2.1)	
Joint venture or overseas-funded	28 (8.9)	25 (14.7)	3 (2.1)	
Private	203 (64.2)	63 (37.1)	140 (95.9)	

Table 1: Demographic and occupational characteristics of patients with work-related hydrofluoric acid exposure.

Variable	Total (n=316)	Fluoride industry (n=170)	Non-fluoride industry (n=146)	p-value
Hydrofluoric acid concentration, %	50.1 ± 30.09	58.6 ± 34.65	39.8 ± 19.01	<0.0001
<20	33 (10.4)	17 (10.0)	16 (11.0)	0.15
20-50	72 (22.8)	33 (19.4)	39 (26.7)	
>50	83 (26.3)	53 (31.2)	30 (20.6)	
Unknown	128 (40.5)	67 (39.4)	61 (41.8)	
Time lag from injury to medical treatment, median (Q1-Q3)	7.0 (1.5-23.0)	3.0 (0.5-9.0)	21.0 (6.0-32.0)	<0.0001
% TBSA	2.8 ± 5.7	3.6 ± 6.8	1.8 ± 3.8	0.003
Burn sites (n=430)				<0.0001
Head and neck	133 (30.9)	120 (45.3)	13 (7.9)	
Hand	128 (29.8)	25 (9.4)	103 (62.4)	
Arm and leg	109 (25.4)	84 (31.7)	25 (15.2)	
Foot	36 (8.4)	19 (7.2)	17 (10.3)	
Other	24 (5.6)	17 (6.4)	7 (4.2)	
Inhalation injury				0.04
No	301 (95.2)	158 (92.9)	143 (98.0)	
Yes	15 (4.8)	12 (7.1)	3 (2.0)	
Eye burn				<0.0001

No	287 (90.8)	144 (84.7)	143 (98.0)	
Yes	29 (9.2)	26 (15.3)	3 (2.0)	
Poisoning severity score				<0.0001
No	21 (6.7)	0	21 (14.4)	
Light	136 (43.0)	50 (29.4)	86 (58.9)	
Moderate	120 (38.0)	92 (54.1)	28 (19.2)	
Severe	36 (11.4)	25 (14.7)	11 (7.5)	
Lethal	3 (1.0)	3 (1.8)	0	

Table 2: Injury level in patients with work-related hydrofluoric acid exposure.

Variable	Total (n=316)	Fluoride industry (n=170)	Non-fluoride industry (n=146)	p-value
Operation				0.03
No	264 (83.5)	149 (87.6)	115 (78.8)	
Yes	52 (16.5)	21 (12.4)	31 (21.2)	
Operation type				<0.0001
Eschar excision, skin grafting in the ER*	18 (34.6)	15 (71.4)	3 (9.7)	
Finger flap, amputation at later stage	22 (42.3)	2 (9.5)	20 (64.5)	
Skin grafting at later stage	12 (23.1)	4 (19.1)	8 (25.8)	
Hospitalisation days	8.7 ± 11.42	9.1 ± 12.13	8.2 ± 10.56	0.49
Sequelae				
Scar	126 (39.9)	39 (22.9)	87 (59.6)	<0.0001
Finger shortening	10 (3.2)	0	10 (6.9)	0.0004
Death	3 (0.9)	3 (1.8)	0	0.5

*ER: Emergency Room.

Table 3: Treatment and sequelae in patients with work-related hydrofluoric acid exposure.

Sources	Cases	Percent (%)
Fluorine industry	170	53.8
Stevedoring and transportation	52	16.46
Metal rust removal	29	9.18
Semiconductor manufacturing	24	7.59
Glass and crystal etching	16	5.06
Waste and disposal services	10	3.16
Electroplating	4	1.27
Others	11	3.48

Table 4: Sources of work-related hydrofluoric acid exposure.

For other patients working in non-fluoride industries, hands were the most common site of HF exposure. Due to exposure to a low concentration of HF solution, the lack of apparent symptoms, such as pain or erythema at the early stage after exposure, may prolong the time lag from injury to medical treatment. In some situations, exposure to a low concentration of HF solution has the potential to cause massive HF burn injury [27]. Moreover, during stevedoring and transportation, HF leakage may occur and has the potential to cause massive and/or severe chemical burns or poisoning [21,28]. The results described above emphasise the importance of safety management and protective equipment for workers in both fluoride and non-fluoride industries. Most cases of work-related HF injury can be prevented.

The severity of HF burns is closely associated with the type and duration of contact, concentration of the acid, and the characteristics of the topical tissues involved [29,30]. The critical measure for HF burns is to block the ongoing HF absorption and the progressive destruction caused by fluoride ions [1]. Later fluoride ion blockade is

associated with a higher rate of surgical intervention [20]. In this study, the patients in the FI group exposed to higher concentrations of HF solution were characterised by larger burn area and greater morbidity of accompanying injuries. However, their rate of surgery was lower than those in the NFI group. This difference may be explained by the better occupational education and safety management in industries related to fluoride use. When patients in the FI group were exposed to chemicals, they tended to show more timely and effective prehospital treatments in the workplace, followed by medical treatment. The patients in the NFI group usually failed to recognise the situation of chemical exposure, and delayed first aid without treating the exposure as an emergency. The ongoing absorption of HF, as well as the progressive destruction caused by fluoride ions, resulted in more severe tissue damage, delayed wound healing, and a higher rate of surgery in the NFI group [20]. Furthermore, the purposes of surgeries differed between the two groups. The surgeries for patients in the FI group were usually performed in the early stage after exposure, with the aim of reducing the absorption of fluoride ions and relieving the chemical poisoning by removing the damaged tissues or eschar. The operations in the NFI group were usually performed in the later stage after exposure, with the aim of repairing the wounds by debridement, skin grafting, and flap transplantation, as the exposed sites mostly on the hands were often complicated by the exposure of bone, tendons, and ligaments. Amputation was performed more frequently in the NFI group than the FI group.

This survey had some limitations. Briefly, all data were collected from one hospital in western Zhejiang Province, and only inpatients were included. Therefore, the estimation of morbidity based on these data may be different from the real situation. However, the data presented here remain valuable; Quhua Hospital is the main medical centre focusing on the care of HF burns, and it receives the majority of patients with HF burns in this region. Therefore, the epidemiological characteristics of the FI and NFI groups described here have the potential to provide valuable information to update clinical guidelines, encourage the upgrading of safety measurements and formulation of preventive strategies.

In summary, this epidemiological study presented characteristic findings related to work-related HF burns in western Zhejiang Province, China. As shown in this study, there were 319 patients with HF injuries, and most (316 patients, 99.1%) were work-related. Of the 316 patients, 170 patients were from industries where HF is produced or is regarded as a major raw material (FI group), while the other 146 patients came from other types of industry (NFI group). The incidence of HF burn injury has increased gradually over the last 13 y period regardless of the FI or NFI groups, although several slight fluctuations were observed in several years. Most patients were working-age males (20-60 y). There was a significant difference in education level between the FI and NFI groups, indicating that low education level could be a risk factor for HF injury. Compared to the state-owned enterprises, private enterprises seemed to contribute most of the work-related HF injuries. The work-related HF injuries were caused by varying concentrations of HF solution. The average concentration of HF in the FI group was significantly higher than that in the NFI group (Table 4). However, the time lag from injury to medical treatment in the FI group was shorter than that in the NFI group.

The most common burn sites in the FI group were the head, neck, arms, and legs, while the hand was the most frequently involved site in the NFI group. The average burn area was significantly larger in the FI group than the NFI group. In terms of accompanying injuries, such as inhalation injury and ocular injury, there were higher rates of morbidity in the FI group than the NFI group. Accordingly, the FI group showed a higher poisoning severity score than the NFI group. Fifty-two patients underwent surgery, including 31 from the NFI group and 21 from the FI group. Most of the surgeries involved early eschar excision and skin grafting performed in the ER, while most surgeries, including amputation and flaps, were performed in patients in the NFI group. More sequelae were observed in the NFI group. Based on these results, the related enterprises and local authorities are encouraged to launch and upgrade their safety policies, as well as to provide the necessary occupational education and training to high-risk populations based on the differences in characteristics of the FI and NFI groups. Strategies focusing on the production, transportation, and usage of HF should be enhanced immediately.

Acknowledgements

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