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Ten-year epidemiology of chemical burns in western Zhejiang Province, China

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ABSTRACT

Background: Chemical burns occur frequently in western Zhejiang Province. This study documents the epidemiology of chemical burns in the region using burn data from a local specialized hospital. Results from this analysis will assist in the planning of prevention strategies for high-risk occupations and groups.

Methods: A 10-year retrospective analysis was conducted for all patients with chemical burns admitted to the Department of Burn and Plastic Surgery from January 2004 to December 2013. Information obtained for each patient included demographics (gender, age, occupation and education), location of the burn, cause of the burn, and categories of chemicals. Data regarding the season of admittance, prehospital treatment, wound site/size (area, region, and depth), accompanying injuries, operations, length of hospital stay and mortality were also assessed.

Results: A total of 690 patients (619 males, 71 females; average age: 30.6 ± 12.4 years) were admitted to the department for chemical burns. Over the 10-year period, the incidence of chemical burns showed an increasing tendency. Chemical burns occurred most frequently in patients aged 20–59 years (94.79%). Most of the chemical burns were work-related, primarily in private enterprises (47.97%) and state-owned enterprises (24.93%). Operations (68.99%) and machine problems (17.26%) were the main causes of chemical burns in the workplace. With regard to burns caused by chemicals, most were caused by acids (72.01%), with hydrofluoric acid and sulphuric acid causing 51.45%. Most chemical burns occurred in the summer and autumn seasons (61.02%). The burn size was <10% of the total body surface area (TBSA) for 445 patients (64.49%), while only 26 patients (3.76%) had burns covering >40% TBSA. The most common burn sites were the upper extremities (31.57%), lower extremities (19.86%), and head and neck (28.83%). Most patients (581 (84.20%)) received water washing treatment on site immediately after exposure. The most common accompanying injuries included inhalation injury, ocular burns and digestive tract injury. The average hospital stay was 17.0 ± 23.1 days (range 1–333 days). Surgery was performed in 146 patients (21.16%), and the overall mortality rate was 0.58%.

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Conclusions: Chemical burns are preventable. The high morbidity of chemical burns in western Zhejiang Province is related to the industrial structure of the area. Governmental management in the fields of production, transportation, and utilization of chemicals could be improved. Workplaces have the responsibility to provide safe work environments and equipment, as well as occupational education and safety training for high-risk work groups.
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1. Introduction

Chemical burns, after thermal burns, are the second most common cause of burns in China [1,2]. A wide variety of chemicals have the potential to cause tissue injuries and systemic effects [3,4]. Although many strategies have been developed for prehospital decontamination [5,6], wound management and systemic support [3,7], prevention remains the best way to avoid recurrence of these accidents and injuries.

The etiology and morbidity of chemical burns varies around the world, influenced by the local population structure, industry distribution, and geographical and social environments [8,9]. Epidemiologic studies can provide reliable data to help with the initiation and assessment of effective preventive approaches. Zhejiang province, located in the southeast coast of China, is well-known for its rapid economic development and industrialization level [10]. The chemical industry is considered an important pillar industry in the area, particularly in the western part of the province. In recent years, large chemical corporations, as well as private enterprises and sole proprietorships, have continued to expand their plants and increase production. The usage of chemicals is high in the production industry, transportation and domestic life, partly due to the thriving development of private and collective enterprises. The related occupational education and safety training are lacking, and thus, workers may fail to follow safety rules and regulations. This lack of safety education combined with the high usage of chemicals leads to a high frequency of chemical injuries, which may occur as sporadic cases or as group events injuring multiple people [11]. The Quhua Hospital is a medical institute focusing on the treatment and management of chemical burns in western Zhejiang Province. This study presents the epidemiologic characteristics of 690 patients with chemical burns admitted to the Quhua Hospital between January 2004 and December 2013.

2. Materials and methods

The Quhua Hospital is the largest chemical burn center in western Zhejiang Province, with 38 beds and eight ICU beds. The burn center provides high-quality medical care for patients with chemical burns, thermal burns, and other types of burns and trauma. Clinical data were collected from 3702 consecutive patients with burns admitted to the Quhua Hospital from January 2004 to December 2013. Of these, 690 patients (18.64%) suffered from chemical burns. This study retrospectively analyzed the 690 chemical burn cases with regard to patient demographics (gender, age, occupation and education), location of burn, cause of burn, and chemical category. The season of admittance, prehospital treatment, wound site/size (area, region, and depth), accompanying injuries, operations, length of hospital stay and mortality were also assessed.

3. Results

3.1. Tendency of chemical burns

Fig. 1 presents the number of patients admitted each year for chemical burns. The incidence increased gradually over the 10-year period, although a slight fluctuation in this trend was observed in 2010.

3.2. Basic demographic characteristics

Of the 690 patients, 619 were male and 71 female (a ratio of 8.72:1). The average age was 30.6 ± 12.4 years, ranging from 6 months to 79 years. Chemical burns occurred most frequently in patients aged 30–49 years (67.25%), followed by those aged 50–59 years and 20–29 years (Table 1). The occupations of the patients are listed in Table 2. Workers accounted for the majority (76.23%), followed by farmers (11.30%), citizens (6.23%), and students (1.59%). Workers were more often from private enterprises (47.97%) and state-owned enterprises (24.93%) than from joint venture or overseas-funded enterprises (3.33%). In terms of education level, most patients had

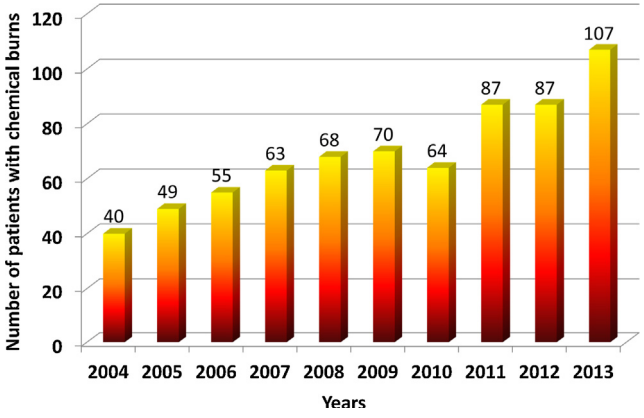

Fig. 1 – The number of chemical burns from January 2004 to December 2013.

Table 1 – Age distribution of patients with chemical burns.

Age	Cases	
	N	Percentage (%)
<10	8	1.16
10–19	14	2.03
20–29	89	12.9
30–39	225	32.61
40–49	239	34.64
50–59	101	14.64
60–69	13	1.88
≥70	1	0.14
Total	690	100

Table 2 – Occupations of patients with chemical burns.

Occupations	Cases	
	N	Percentage (%)
Worker		
State-owned enterprises	172	24.93
Joint venture/overseas-funded enterprises	23	3.33
Private enterprises	331	47.97
Farmer	78	11.30
Citizen	43	6.23
Student	11	1.59
Others	32	4.64

low educational attainment (illiteracy/primary school: 27.68%; junior middle school: 53.48%), 17.39% had high middle school attainment, and only 1.45% had a college degree or higher (Fig. 2).

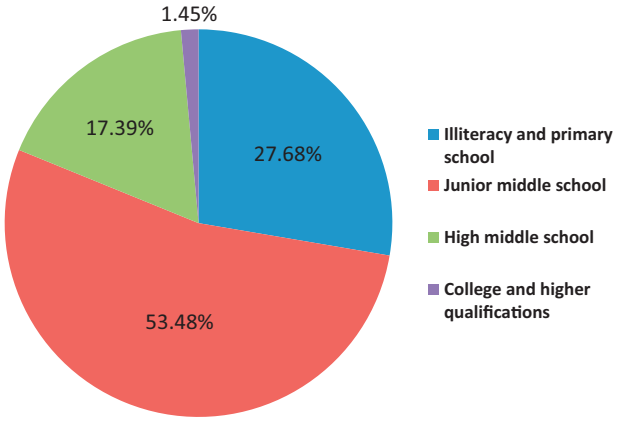

Fig. 2 – Educational background of patients with chemical burns.

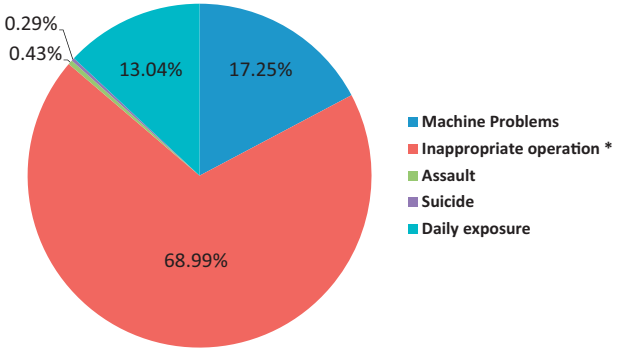

Fig. 3 – Causes of chemical burns. * indicates inappropriate operation of machines or handling of chemicals.

3.3. *Location and causes of chemical burns*

Most chemical burns (595 cases (86.24%)) occurred in the workplace; 119 (17.26%) were caused by machine problems and 476 (68.99%) by inappropriate operation during the production process (Fig. 3). There were 90 cases caused by daily exposure (13.04%), 3 caused by assault, and 2 caused by suicide. Table 3 further presented the distribution of inappropriate operations, machine problems and education status among the private enterprises, state-owned enterprises, and joint venture/over-sea enterprises. On machine problems, a higher incidence rate (19.64%) happened in the private enterprises showed rather than those in the state-owned enterprises (16.28%), and joint venture/over-sea enterprises (17.39%). For operations, state-owned enterprises led a rate of 83.14%, which was higher than the other both types of enterprises (Table 3).

Table 3 – The distribution of operations, machine problems and education status among the main enterprise types.

Enterprises qualifications	Machine problems		Operations		Illiteracy and primary school		Junior middle school		Senior middle school		College and higher	
	N	Percent (%)	N	Percent (%)	N	Percent (%)	N	Percent (%)	N	Percent (%)	N	Percent (%)
State-owned enterprises	28	16.28	143	83.14	46	26.74	74	43.02	47	27.33	5	2.91
Joint venture/ overseas-funded enterprises	4	17.39	19	82.61	2	8.7	12	52.17	8	34.78	1	4.35
Private enterprises	65	19.64	261	78.85	63	19.03	202	61.03	62	18.73	4	1.21

The causative agents included acids (497 cases (72.01%)), alkalis (74 cases (10.71%)), phosphors, aminobenzene and derivatives, nitrobenzene and derivatives, mixed chemicals and other organic chemicals (Table 4). Of the acid-related burns, 201 (29.13%) were caused by hydrofluoric acid (HF) and 154 (22.32%) by sulphuric acid; burns caused by phenol (6.23%), hydrochloric acid (5.51%) and nitric acid (2.90%) were less common (Table 4).

3.4. *Season distribution*

Fig. 4 displays the distribution of chemical burns by season. Chemical burns occurred more frequently in the autumn (32.90%) and summer (28.12%) than in the spring (22.75%) or winter (16.23%).

3.5. *Extent of chemical burns*

Burn areas were calculated by estimating the sizes of degree II and III burns. The average burn area was 30.7 ± 25.5% of the total body surface area (TBSA), with a range of 0.5–85% TBSA. There were 445 patients (64.49%) with burns <10% of TBSA, while only 26 patients (3.76%) had burns covering >40% TBSA (Table 5). Regarding burn thickness, 395 (57.25%) had deep partial thickness burns, 174 (25.22%) had full thickness burns, and 121 (17.53%) had superficial burns.

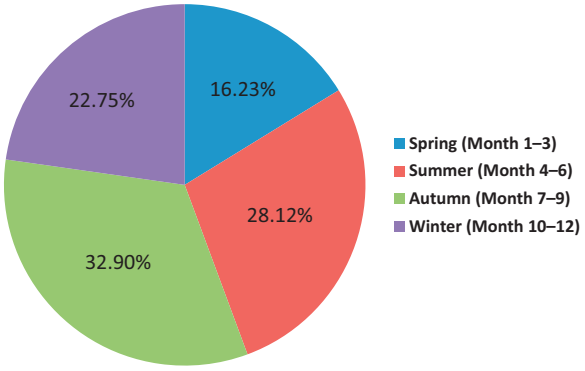

Fig. 4 – The seasonal distribution of chemical burns.

Table 4 – Categories of chemicals for burns.

Chemicals		Cases	
		N	Percentage (%)
Acids			
	Sulphuric acid	154	22.32
	Nitric acid	20	2.90
	Hydrofluoric acid	201	29.13
	Hydrochloric acid	38	5.51
	Phenol	43	6.23
	Formic acid	5	0.72
	Acetic acid	3	0.43
	Liquid bromine	6	0.87
	phosphoric acid	9	1.30
	Chlorosulphonic acid	9	1.30
	Acidic mixture	8	1.16
	Ice boric acid	1	0.14
		497	72.01
Alkalis			
	Sodium hydroxide	17	2.46
	Potassium hydroxide	3	0.43
	Sodium carbonate	2	0.29
	Calcined lime	19	2.75
	Ammonia water	5	0.72
	Unknown alkali	28	4.06
		74	10.71
Phosphors		7	1.01
Aminobenzene, nitrobenzene and derivatives		23	3.33
Dimethyl sulfate		2	0.29
m-Cresol		1	0.14
Pesticide		3	0.43
Other organic chemicals		83	12.03

Table 5 – TBSA distribution for patients with chemical burns.

TBSA (%)	Cases	
	N	Percentage (%)
<10	445	64.49
10–19	143	20.72
20–29	40	5.80
30–39	36	5.22
40–49	8	1.16
50–59	7	1.01
60–69	6	0.87
70–79	3	0.43
80–90	2	0.29

Table 6 – Sites of chemical burns in patient.

Region	Cases	
	N	Percentage (%)
Head and face	308	17.94
Neck	187	10.89
Hand	198	11.53
Forearm	182	10.60
Upper arm	162	9.44
Anterior trunk	160	9.32
Posterior trunk	105	6.12
Buttock	55	3.20
Perineum	19	1.11
Lower limb	341	19.86

3.6. *Sites of chemical burns and accompanying injuries*

Chemical burns were observed at 1717 total sites among the 690 patients (Table 6). The most common sites of injury were the upper extremities (542 cases (31.57%)), lower extremities (341 cases (19.86%)), head and neck (495 cases (28.83%)), and trunk (265 cases (15.43%)).

Table 7 lists the injuries accompanying the chemical burns; inhalation injuries and ocular burns occurred more frequently than did digestive tract injuries.

Table 7 – Accompanying injuries for patients with chemical burns.

Accompany injuries	Cases	
	N	Percentage (%)
Inhalation injury	94	13.62
Ocular burns	68	9.86
Digestive tract injury	4	0.58

3.7. *Prehospital treatment*

Most patients (581 (84.20%)) received water rinsing treatment at the scene immediately after exposure (Fig. 5). The rinsing time varied greatly.

3.8. *Number of operations*

A total of 179 operations, such as skin grafting and flap repair, were performed in 146 patients (21.16%).

3.9. *Length of hospital stays*

The average hospital stay was 17.0 ± 23.1 days, with a range of 1–333 days (Table 8).

3.10. *Mortality*

Four patients died of severe inhalation injury, chemical poisoning and/or multiple organ failure. The overall mortality rate was 0.58%.

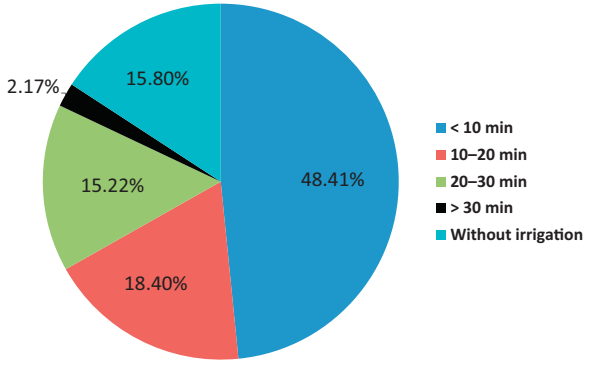

Fig. 5 – The prehospital water irrigation for chemical burns.

Table 8 – Length of hospital stays for patients with chemical burns.

Hospital stay (days)	Cases	
	N	Percentage (%)
<10	344	49.86
10–19	139	20.14
20–29	95	13.77
30–39	43	6.23
40–49	28	4.06
50–59	14	2.03
60–69	10	1.45
70–79	3	0.43
80–89	3	0.43
≥90	11	1.59

4. Discussion

Chemical burns are not uncommon in some areas of the world, and their frequency has increased over the past several decades [12]. Our study revealed similar incidences of chemical burns in western Zhejiang Province between 2004 and 2013, although a small decrease was observed in 2010. There were 690 patients who were admitted for chemical burns, accounting for 18.6% of the 3702 patients admitted for burns during the 10-year survey period. A study published ~25 years ago found the rate of chemical burns to be 6.6%, based on data collected from 14 large burn treatment centers in mainland China [13]. Large-scale epidemiologic surveys of this nature have not typically been conducted, and local or regional data are more often reported. For example, Xie et al. reported that 377 patients with chemical burns were admitted to Guangzhou Red Cross Hospital from 1987 to 2001, and the rate of chemical burns was 8.5% [2]. Li et al. indicated that 615 patients were admitted for chemical burns over a 10-year period; however, the rate of chemical burns was not provided [1]. Compared with developed countries, the incidence of chemical burns in China remains high. According to the 2015 National Burn Repository published by the American Burn Association, chemical burns represent 3.4% of all burns in the United States [14]. In an assessment of burns occurring in South Australia from July 2009 to June 2014, Greenwood et al. reported 6.5% of burns to be caused by chemicals [15].

Chemical burns are typically reported as work-related and occur predominantly in working-age individuals [1,2,16]. Our study showed similar demographic characteristics, with most chemical burns resulting from work-related activities (87.53%) in patients aged 20–59 years (94.79%). Further analyses indicated that nearly half of the chemical burns occurred in private enterprises, while a quarter occurred in state-owned enterprises. Chemical burns occurred less frequently in employees of joint venture and overseas-funded enterprises; this may be attributed to a better working environment and more occupational education provided by such enterprises. Furthermore, advanced management principles and experiences lead to improved safety consciousness and risk awareness among workers. Our survey showed that most patients had low educational attainment (primary and middle school education), while only a small minority received college education or higher. This low level of education may partly explain the higher incidence of chemical burns in western Zhejiang.

Workplace protection against chemical burns requires the use of personal protective equipment, such as protective masks and gear while operating equipment or handling chemicals [10]. Our study found that 86.24% of chemical burns occurred in the workplace, as a result of inappropriate machine operation, inappropriate chemical handling or machine problems. These data emphasize the importance of safety in the workplace and highlight the shortcomings of many enterprises in occupational education and training, machine maintenance, and production management.

In this survey, chemical burns were most commonly caused by acidic substances, primarily HF and sulphuric acid. This could be a result of the industrial nature of the area.

Western Zhejiang Province is rich in fluorite (CaF_2), and in recent decades, this region became a large base for fluoride industries. CaF_2, in combination with concentrated sulphuric acid, can be used to produce HF, an important industrial raw material [17]. It was estimated that the region produced 400,000 tons of HF annually, accounting for approximately a quarter of the annual output from China. Chemical injuries caused by sulphuric acid are not uncommon, while chemical burns by HF vary among different regions [7,18,19]. In China, burns caused by HF occur more frequently, and HF has been listed as one of the top three substances responsible for chemical burns [2]. Our previous study evaluating chemical burns in Zhejiang Province between September 2008 and August 2009 found HF to be the cause of 27.44% of burns; HF was listed as the top cause for all chemical burns [10]. Because of the high incidence of HF burns, specific measures and strategies have been developed, such as special training to prevent HF burns and algorithms for HF burn management. Some patients with HF burns have received appropriate treatments [11,20–23]. Chemical burns caused by alkalis accounted for only 10.71% of burns in this study, which differed from that of other publications [2,24]. Strong alkalis have the potential to cause aggressive tissue damage by fat saponification, cell dehydration and protein liquefaction [15]. Thus, immediate and prompt diagnoses and treatments for alkali burns should also be highlighted.

The incidence of chemical burns in our study revealed seasonal variability. More cases of chemical burns occurred in summer and autumn compared with the spring and winter; this may be partly due to less clothing worn during the warmer summer and autumn seasons [1]. However, chemical burns in winter and spring still occurred at a moderate rate (38%). As most of the chemical burns were reported as work-related (caused by machine problems and inappropriate operations), season likely plays only a minor role in chemical burn incidence. The related trainings and occupational education should be further enhanced, and necessary equipment for protection should become mandatory for some enterprises.

Chemical burns typically involve a small scattered area and are not usually extensive [2]. Our study revealed similar characteristics, with the majority of patients (64.49%) having a burn area <10% of TBSA. Less than 4% of patients had a burn area >40% of TBSA. We also found chemical burns to occur more frequently on commonly exposed sites, such as the head and neck (28.83%), upper extremities (31.57%) and lower extremities (19.86%), as many chemical burns are caused by spilled or splashed chemicals. Appropriate use of protective equipment for the head, neck and extremities could prevent a significant number of this type of injury. Regarding burn depth, most patients experienced superficial and partial thickness burns (74.78%), while a quarter of the patients had full thickness burns. In addition, chemical liquids or gases have the potential to damage the organic tissues, leading to accompanying injuries such as inhalation injury or ocular burns. For certain chemicals, such as HF, continuous absorption of fluoride could cause systemic poisoning and even death [4,7].

The severity of chemical burns is determined primarily by factors such as the type and duration of contact, chemical concentration, and characteristics of the topical tissues. Correct diagnoses and prompt treatments are especially emphasized for chemical burns. The basic principles to treat chemical burns include removal of the chemical, treatment of systemic toxicity, systemic supportive treatments, defined treatments for specific chemicals, and management of the topical chemical burn [3]. Appropriate prehospital treatment is especially crucial. To date, immediate and copious water lavage is the best decontamination method for on-site treatment of chemical burns [5,25]. In this study, 84.20% of patients received or conducted water irrigation immediately after exposure. Despite this, 21.16% of patients still underwent surgery for wound closure. Thus, the methods for washing and the washing time should be further improved, as inappropriate rinsing may be one of important causes for progressive deepening of burned wounds. Our result is significantly lower than the surgical rates of 42.2% reported by Xie and co-workers in Guangdong [2] and 34.5% observed in Shanghai [1]. Thus, the average length of hospital stay was shorter than those reported abroad [8]. Our Department also provides rehabilitation for burn patients, resulting in prolonged hospital stays; for example, many patients with severe burns continued to be involved in the later recovery plans without being discharged. Less than 1% patients died from the burn injuries and complications.

There are several limitations to note in this study. The data were obtained from only one hospital in this area, and only patients admitted to the hospital were included. Many other patients in the clinic were excluded due to undefined clinical data. Hence, there may be errors in the estimation of morbidity in this area. Further, chemical poisoning is one of the most severe complications for chemical injuries, and this was not addressed in the study. There are thousands of chemicals causing chemical burns or poisoning by different mechanisms [3], and there are no universal standards to evaluate the severity of poisoning effectively. Although some acute poisoning grading system can be selected [26], the evaluation process, as well as the involved content, is very complicated and will likely not contribute to emergency care for patients with poisoning.

A number of interesting findings were observed regarding chemical burns in western Zhejiang Province. Firstly, the morbidity of chemical burns in the past 10 years showed an increasing tendency. Secondly, most of chemical burns were work-related and occurred in private and state-owned enterprises; more than 94% of chemical burns occurred in working-age patients. Thirdly, operations and machine problems were identified as the main causes of chemical burns in the workplace, indicating a need to further improve occupational education and technical training. Fourthly, more than 51% of chemical burns were caused by HF and sulphuric acid, which were intimately associated with the industrial structure of this area. Finally, small-area burns occurred more frequently, and the most common burn sites were the head, neck and extremities, and approximately one-fifth of patients underwent surgery. Based on these findings, the local government would benefit from establishing a long-term strategic plan to improve education of the population and enhance the management of hazardous chemicals. Private and state-owned enterprises should be encouraged to learn advanced management methods from joint venture and/or overseas-funded enterprises, and provide safety knowledge and protective equipment for workers. More attention should

also be paid on improvement of medical treatment for chemical burns.

Conflict of interest

None of the authors has any financial interest with the information presented.

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