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2.1 Introduction

Ocular chemical burns are a significant problem [1] because they may destroy the entire corneal epithelium and extend into the fornices [2]. More than 25,000 chemical products – oxidizers, reducing agents, corrosives, etc. – have the potential to cause chemical burns [3]. Because serious eye burns can result in loss of sight or require corneal transplants, such chemical burns must be taken seriously.

2.2 Data Limitations and Scope of the Problem

No international or national databases were found that specifically collect data on ocular chemical injuries. There are individual publications detailing burns in general or chemical burns (including eye and/or skin burns) in a region or country and case series from burn centers, hospitals, or groups of hospitals. Occupational burn data are usually regional in nature or are case series. National Poison Center databases such as the US American Association of Poison Centers' National Poison Data System (NPDS) collect data on the annual number of eye exposures, but do not contain specific information

regarding the specific chemical substance(s) involved, the type of initial decontamination, the time from exposure to initial decontamination, and clinical outcomes. National occupational exposure databases such as the US Department of Labor Statistics (BLS) also contain only nonspecific data and also do not collect specific information regarding the specific chemical substance(s) involved, the type of initial decontamination, the time from exposure to initial decontamination, and clinical outcomes. Information such as the number of lost work days, number of eye injuries, industry segment, and rates of injury per 10,000 full-time workers from the US BLS data do provide some insights into the scope of the problem.

2.2.1 Individual Publications/Case Series

Josset et al. [4] found that there were approximately 7,000 serious chemical splash injuries in France per year, with about half of these cases involving the eyes [4]. Chemical eye splashes made up about 9.9% of ocular trauma in the USA and 7.2% in a UK casualty department; however, most were with rather innocuous substances such as hairsprays and shampoos [5]. Acid and base eye burns were 1.6% and 0.6%, respectively, of total eye injuries [5].

Ocular burns comprise about 7–18% of ocular trauma presenting to emergency departments in the USA and eye injuries account for about 3–4% of total occupational injuries [6]. Most of these (approximately 84%) are chemical burns. About 15–20% of patients with facial burns also have ocular burns. The ratio of acid/alkali chemical ocular burns is 1:1–1:4 [6].

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In a 5-year retrospective study of 383 patients with eye injuries (397 eyes involved) in Croatia, 13.6% sustained chemical injuries [7]. Of the total patients with burned eyes, 54 required hospital admission [7]. A 7-year retrospective study of 60 hospitalized cases of pediatric eye injuries in Hong Kong found that 10% were ocular chemical burns [8].

In a US study of compensable work-related ocular injuries, the incidence of eye burns was 23.4 per 10,000 employees [9]. The majority of these were associated with chemical exposures.

In a retrospective study of 148 cases of occupational eye injuries in Germany, ocular burns (not specified as chemical or other etiology) comprised 15.5% of the total [10]. In another German study of 101 patients with 131 severely burned eyes, 72.3% of the injuries were work-related, 84.2% were chemical injuries, and 79.8% of these were due to alkalis [11]. Of the 42 cases of alkali ocular burns admitted to a German eye clinic between 1985 and 1992, 73.8% involved industrial accidents [11]. In Finland in 1973, 11.9% of all industrial accidents were ocular injuries and burns comprised 3.6% of these (chemical or other injury mechanism not specified) [12].

A 7-year retrospective Australian study of 182 industrial burns found that 5.5% were ocular burns due to chemicals, gas explosions, and electric flashes (percentages not specified) [13]. In another Australian study of 159 cases of hospital-admitted alkali ocular burn patients from 1972–1981, the majority of burns were Grade 1 or 2 and none of these resulted in vision loss [14].

In contrast, in a US Poison Center study of a random sampling of 500 cases of chemical eye exposure over a 6-month period in 1986, the majority (84.4%) occurred in the home and involved household products [15]. These most commonly involved accidental exposures in children [15].

2.2.2 American Association of Poison Centers National Poison Data System (NPDS)

Data on poison exposures reported to US Poison Centers are collected on a daily basis and published yearly in the American Association of Poison Centers National Poison Data System (NPDS) Annual Report [16]. In the latest published report for the year 2006, there were

2,403,539 human poison exposure cases, including 136,534 eye exposures (5.4%), with 2 deaths [16].

2.2.3 US Bureau of Labor Statistics Data

The US Bureau of Labor Statistics collects data annually regarding workplace injuries. The latest data at the time of this writing are from 2006. While these data are quite nonspecific and difficult to relate directly to the epidemiology of ocular chemical injuries, they do provide some insight into the scope of the problem. All of the following data refer to *private industry* and *cases of nonfatal injuries or illnesses resulting in lost work days*.

The incidence rate in 2006 for chemical burns (not specified as to eye and/or skin) was 1 per 10,000 full-time workers and the median number of lost work days was 3 [17]. There were 7,490 chemical burns (also not specified as to eye and/or skin). Eye injuries and illness totaled 35,970 with the largest number, 17,760 (49%), occurring in the Total Goods industry segment [17]. The industry segment, Chemicals and Chemical Products, accounted for 19,480 occupational injuries or illnesses, with the largest number, 19,480 (65%), occurring in the Total Service Providing industry segment.

Overall, chemical burns comprised 0.6% of total occupational injuries and illnesses resulting in lost work time and chemicals and chemical products accounted for 1.6 % of such injuries or illnesses [17]. The incidence of chemical burns (not specified as to eye and/or skin) was 0.8 per 10,000 full-time workers. The incidence rate for the Chemicals and Chemical Products industry segment was 2.1 per 10,000 full-time workers.

The percent distribution of lost work days in the Chemicals or Chemical Products industry segment was as follows [17]:

Lost work days	Percent
1 day	28.8%
2 days	19.0%
3–5 days	24.7%
4–20 days	7.6%
21–30 days	2.4%
31 days or more	7.8%

2.3 Etiology

2.3.1 Work-Related Injury

Of 1,720 persons with occupational burn injuries in the US State of North Carolina, the most common event was exposure to corrosive substances [18]. Of burn injury patients from all causes, 361 patients (69.6%) also had eye burns [18]. Ocular burns comprise about 7–18% of ocular trauma presenting to emergency departments in the USA and eye injuries account for about 3–4% of total occupational injuries [6]. Most of these (approximately 84%) are chemical burns. About 15–20% of patients with facial burns also have ocular burns. The ratio of acid/alkali chemical ocular burns is 1:1–1:4 [6].

In a retrospective study of 148 cases of occupational eye injuries in Germany, ocular burns (not specified as chemical or other etiology) comprised 15.5% of the total [10]. In another German study of 101 patients with 131 severely burned eyes, 72.3% of the injuries were work-related, 84.2% were chemical injuries, and 79.8% of these were due to alkalis [11]. Of 42 cases of alkali ocular burns admitted to a German eye clinic between 1985 and 1992, 73.8% involved industrial accidents [19]. In Finland in 1973, 11.9% of all industrial accidents were ocular injuries and burns comprised 3.6% of these (chemical or other injury mechanism not specified) [12]. A 7-year retrospective Australian study of 182 industrial burns found that 5.5% were ocular burns due to chemicals, gas explosions, and electric flashes (percentages not specified) [30]. In a 4-year hospital-based study in Taiwan, of 486 patients with eye injuries, 39.9% were work-related [20]. Chemical ocular burns accounted for 19.6% of these injuries [20].

2.3.2 Deliberate Chemical Assault

“The challenge in such cases is to save the eyes...” [21]. Beare [22] reported a series of 64 patients with eye injuries from chemical assaults treated in a specialty eye hospital in London with 20,333 Accident and Emergency Department visits and 29,853 outpatient visits during a 12-month period in 1988 [22]. In 17 eyes of 16 patients, there was a total loss of corneal

epithelium with varying degrees of limbal ischemia. Nine eyes were essentially blinded and two eyes had less severe but permanent vision loss.

There had been a marked increase in the number of patients presenting to this hospital with chemical eye injuries from assaults over a 6-year period beginning in 1984, when only 1 case was seen [22]. There were 3 cases in 1985, 15 cases in 1986, 37 cases in 1987, and 40 cases in 1988. Of the 64 reported patients, 55 were male and 9 were female. Six patients also had significant facial or eyelid burns, although none became necrotic. Assaults were often gangs of male youths in their teens to twenties, and racial bias was a likely precipitant in certain cases.

Thirty-seven patients (58%) had a unilateral eye injury and 27 (42%) had bilateral injuries, for a total of 91 injured eyes [22]. The chemical agent involved was generally unknown, although 6 patients reported smelling ammonia. The time between exposure and initial water irrigation ranged from 5 s to 2 h, with irrigation usually on three separate occasions: first by the victim with tap water, second with normal saline in the Accident and Emergency Department, and third with potassium dehydrogenate orthophosphate buffered solution in distilled water at the specialty eye hospital.

The conjunctival sac pH was measured with test paper and was alkaline in 46 eyes (51%) (pH 7.0–9.0), neutral in 4 eyes (4%), acidic in one eye (1%) and was not recorded in the remaining 40 eyes [22]. In 16/91 (19%) of injured eyes, there were varying degrees of limbal ischemia. The majority of injured eyes (73%) were Grade I (minimal) on the Roper-Hall grading system. Six eyes (7%) were grade II injuries, two (2%) were Grade III injuries, and nine (10%) were Grade IV injuries. Marked conjunctival stromal edema was seen in all Grade III and IV injured eyes, and evidence of chemical damage to the anterior lens capsule was present in the nine most severely injured eyes. Hypopyon occurred in four eyes.

Thirty-one patients were admitted to hospital for an average of 3.3 days (range: 1–14 days) [22]. The approximate cost of treatment was £500.00 per patient.

The eight most severely injured patients (15%) with Grade IV injuries had gross scarring, vascularization, and a permanent severe reduction in vision, bilateral in one case [22]. There were two cases of infectious keratitis with *Staphylococcus aureus* in patients with persistent corneal epithelial defects; this progressed to globe perforation in one case. One patient underwent

corneal grafting 20 months post-injury. None of the 64 patients developed symblepharon, but 1 patient with severe injuries was registered as blind [22].

O'Driscoll et al. [23] briefly reported several patients with severe ocular injuries presenting to a specialty eye hospital in Birmingham, UK over a several week period [23]. These patients had been deliberately splashed with alkaline substances (not specified) during robberies or violent assaults. The assailants were most often children or young adults. These authors note that alkali eye injuries involve massive corneal and conjunctival epithelial loss and that necrosis of the corneal stem cells can develop, resulting in delayed healing with scarring. Secondary glaucoma may develop. The alkali injured eye may be irreversibly damaged and a painful, blind eye may result [23].

In his discussion, Beare [22] compared the above UK series to a series reported from the USA by Klein and Lobes (1984) [22]. In the US series, of 52 patients reported, assault was the cause in 35 cases with the assailants being women and the victims being men. Severe burns were frequently present, with 39% of 100 injured eyes being classified as very severely damaged on the Hughes scale. In this US series, 58% of injured eyes had a final visual acuity of less than 20/20. There was a globe perforation rate of 13/100 (13%) in these injured eyes. The incidence of symblepharon was 29% and that of secondary glaucoma was 18% in this US series [22].

Yeong et al. [24] reported 15 cases of facial mutilation from chemical assaults from 1991 to 1992 in Taiwan [24]. There were 10 women and 5 men and 10/15 (66%) identified the assailant. In 6/15 cases, the assailant was the spouse.

Ninety percent of victims claimed that sulfuric acid was the chemical involved [24]. Injured areas were confined to the head and neck. While most had their faces flushed with tap water, none had continuous effective flushing, especially of the eyes, before presentation to hospital. Most had half or more of their faces grossly disfigured by scars. Six patients (40%) had total bilateral blindness and one had partial loss of vision. Other common function sequelae were: lower eyelid ectropion (14/15), microstomia (12/15), cervical flexion contracture (10/15), ear deformity (8/15), and nostril stenosis (6/15). Victims had severe psychological and social effects, and most lived as recluses.

In their discussion, Yeong et al. [24] described four case series of chemical assaults from the USA, two from New York City, one from Washington DC, and

one from Dallas, Texas [24]. In New York City, Crikelair et al. [25] reported that 15 of the 145 patients admitted to the burn center of one hospital had sustained chemical assaults [24]. All 15 cases involved a mixture of household lye mixed with water. Permanent visual loss occurred in three victims.

Amongst a series of 38 victims of chemical assault (acids) in Bangladesh, 10 (26%) had injuries of the eyeballs and 18 (47%) had injury of the eyelids [26]. Merle et al. [27] studied 66 patients with alkali ocular burns (104 eyes) in Martinique (French West Indies) over a 4-year period, of which nearly half (45.5%) were due to deliberate chemical assault (the most frequently involved product was Alkali®; 15.3% ammonia, pH 12.8) [27].

Branday et al. [28] reported that 562 patients with acute chemical injuries were admitted to 8 regional hospitals in Jamaica during a 10-year period from 1981–1990 [28]. Chemical burns comprised 13.3% of all burn patients admitted during this time period. Nearly half (236 cases 42%) of these chemical burns resulted from deliberate assault, while only 10 of the total chemical burn cases (1.8%) were the result of work-related accidents. In one of the study hospitals, 38% of burn admissions were due to chemical burns and 2/3 of these were due to deliberate chemical assaults. Assailants were more likely to be female and victims were either male or other women over disputes involving a relationship with a male partner [28].

Of the overall chemical burn patients, the most common sites involved were the face, neck, and upper body (87%), and the eyes or eyelids were involved in 19% of overall cases [28]. In deliberate chemical assault victims, the face and neck were commonly injured, but the genital area was also involved in many victims. Acids, such as sulfuric acid, can be obtained at low cost in Jamaica. These authors note that many of the chemical assault injuries were devastating with facial destruction and blindness. Less than half of the victims decontaminated themselves with copious water irrigation before presenting to hospital [28].

Asaria et al. [29] reported a retrospective review of 125 burn patients admitted to a hospital in Kampala, Uganda over an 18-month period in 2001–2002 [29]. Of these, 15 patients (17%) were victims of deliberate acid assault. The male/female ratio was 1:1. The average total body surface area (TBSA) involved was 14.1% and the most common burn sites were the face (86.7%), head and neck (66.7%), chest (53.5%), and upper limbs (60%). The eyes were commonly involved

(33.3%) and victims experienced partial or complete blindness. Fourteen of the 15 patients (93.3%) had permanent scarring as sequelae and 7 (46.7%) of them developed cervical or axillary contractures. Other significant sequelae included ectropion (33.3%), nostril stenosis (13.3%), microstomia (20.0%), paraphimosis (6.7%), and Cushing's ulcers (6.7%) [29].

The circumstances of the acid assault involved attacks by unknown assailants during a robbery in 46.7% (26.7% during a car or motorcycle robbery and 20.0% in a house robbery). A known person was the assailant in 33% of these acid assaults, commonly in a setting of marital discord. Many of these patients ended up living as recluses and dependent on family members for daily support. The acid involved in most cases was sulfuric acid used to restore exhausted automobile batteries, which is readily available at low cost from garages in Uganda [29].

Saini and Sharma [30] reported 145 eye injuries amongst 102 Indian patients treated at a major referral center [30]. There were only seven chemical assault victims, but the authors noted that these patients had more severe injuries than patients with accidental injuries with 71.4% of the eyes of chemical assault victims developing phthis bulbi (a deformed eyeball with no light perception). In contrast, phthis bulbi developed in only 3.6% of patients with accidental chemical exposures [30].

Non-governmental organizations (NGOs) play an important role in the management of victims of deliberate chemical assaults. For example, in Bangladesh the Acid Survivors Foundation (ASF) provides assistance with medical and surgical treatment [37], legal aid, and rehabilitation through a social program of training and employment assistance. The NGO also works on programs for prevention and for decreasing the delay to decontamination and access to medical treatment by establishing new facilities in rural areas.

2.3.3 Complications of Face Peeling

Severe burning sensation, redness, epiphora of the left eye, mild upper eyelid edema of the right eye, severe edema of the left eyelids, left eye inferior ectropion, blepharoconjunctivitis with severe hyperemia, papillary reaction, and chemosis occurred in a patient undergoing a face peeling procedure with a trichloroacetic acid-containing mask [31].

A 47-year-old woman undergoing face peeling with 35% trichloroacetic acid developed left eye burning sensation, excessive tearing, marked conjunctival injection, conjunctival infection, and mild inferior superficial punctate keratitis involving 25% of the cornea [32].

2.3.4 Burn Center/Hospital Studies

Amongst 377 patients with chemical burns admitted to a burn center in Guangdong province, China from 1987–2001, 337 (88.5%) were accidental and 40 (10.5%) were from deliberate chemical assault [33]. Of the total number of chemically burned patients, ocular burns occurred in 55 (14.6%) [33].

Saini and Sharma [30] reported a series of 145 chemical eye injuries in 102 patients treated at a major referral center in India between 1984 and 1991 [30]. Bilateral injuries were seen in 42.1% of patients. Acids and alkalis accounted for 80% of chemical ocular injuries in this series. Two-thirds of the injuries occurred in young people working in laboratories and factories. Roper-Hall Grade III and IV injuries were seen in 52 eyes (35.9%). In total, 102 eyes (70.3%) recovered with a visual acuity of 6/60 or better. Ten eyes (6.9%) had no light perception. Phthis bulbi (a deformed eyeball with no light perception) occurred in 71.4% of the seven deliberate chemical assault victims but in only 3.6% of the accidental ocular chemical exposures. The final visual acuity was better in the eyes with less severe grades of chemical injuries on presentation [30].

Cartotto et al. [34] reported a series of patients treated at the burn center in Toronto, Ontario, Canada [34]. Of the total 24 chemical burn cases, there were 8 chemical eye splashes. Five of these eight patients were decontaminated at the scene (presumably with water). The three chemical eye splash patients who did not receive immediate decontamination developed severe ocular injuries. However, three of the five who had immediate decontamination developed corneal erosions and one patient with eye exposure to “black liquor” developed a very deep corneal erosion leading to blindness [34].

Sawheny and Kaudish [35] reported a series of 27 patients with acid and alkali burns treated over a 5-year period in Chandigarh, India [35]. Eye involvement was present in 74% of these patients, with both eyes

involved in 15%. Severe conjunctivitis was present in all patients with eye burns, with 63% having keratitis and corneal ulcerations progressing to opacities. Corneal perforation progressing to panophthalmitis and vision loss occurred in two cases. Twelve patients developed severe eyelid ectropion [35].

Mozingo et al. [36] reported a series of 87 chemical burn patients treated at the US Army Institute of Surgical Research from 1969 through 1985 [36]. Associated injuries included chemical eye burns in

three patients. In an earlier report from this same institution, the authors noted: “The high incidence of peri-orbital and ocular complications is significant...”

In a retrospective study of patients admitted to the Royal Brisbane Hospital in Australia over a 7-year period, eye burns comprised 5.5% of the total (and included chemical exposures, gas explosions, and electric flashes) [13]. Eye burns were present in 4 (3.7%) patients and eyelid burns were present in 4.6% of patients [13].

Table 2.1 Some chemical substances reported to cause ocular chemical injury

Chemical substance	References
Acids (not further specified)	[28, 30, 35]
Alkalis (not further specified)	[23, 30]
Aluminum hydroxide	[30]
Ammonia	[22, 27]
Ammonium hydroxide	[30]
“Black liquor” (a heated mixture of sodium carbonate, sodium hydroxide, sodium thiosulfate, and sodium sulfate)	[34]
Calcium hydroxide	[30]
Chili powder	[30]
Corrosive substances	[18]
Cracker powder	[30]
Endoxan injection	[30]
Fish bile	[6]
Hydrochloric acid	[30]
Hydrofluoric acid	[30, 33]
Kerosene oil	[30]
Lye	[24, 25]
Methanol	[30]
Nitric acid	[30, 33]
Oxalic acid	[30]
Paint	[30]
Phenol	[30]
Savion	[30]
Sodium hydroxide	[30]
Sulfuric acid	[30]
Unknown	[30]

2.4 Involved Chemicals

Table 2.1 lists some chemical substances reported to cause ocular chemical injuries.

2.5 Conclusions

Ocular chemical injuries are a significant problem. Existing published data on the epidemiology of such injuries are incomplete. Currently recommended decontamination with water or other commonly available solutions such as normal saline cannot always prevent serious eye injuries. Alternative *active* eye decontamination solutions should continue to be investigated.

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Chemical Ocular Burns

New Understanding and Treatments

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