Taiwan Journal of Ophthalmology 6 (2016) 123–126

Contents lists available at ScienceDirect

Taiwan Journal of Ophthalmology

journal homepage: www.e-tjo.com

Original article

Colored corn starch dust explosion-related ocular injuries at a Taiwan water park: A preliminary report from a single medical center

Yi-Lin Liao [a, b], Lung-Kun Yeh [a, b], Yueh-Ju Tsai [a, b], Shin-Yi Chen [a, b, *]

[a] Department of Ophthalmology, Chang Gung Memorial Hospital, Taoyuan, Taiwan
[b] College of Medicine, Chang Gung University, Taoyuan, Taiwan

ARTICLE INFO

Article history:
Received 28 April 2016
Received in revised form
11 May 2016
Accepted 16 May 2016
Available online 21 June 2016

Keywords:
dust explosion
ocular injuries
thermal burn

ABSTRACT

Purpose: To elucidate the manifestations of ocular injuries in the colored corn starch dust explosion at a Taiwan water park.
Methods: This is a retrospective, non-comparative, consecutive-interventional case series. Fifty explosion-injury patients on 27 June 2015 treated at Chang-Gung Memorial Hospital, Linkou, were included. Thorough ophthalmic examinations were based on emergent triage and consecutive ophthalmological consultations. Multiple ocular and systemic parameters were assessed.
Results: Of the 100 eyes in the 50 cases reviewed, 22 cases were male and 28 cases were female. The mean age was 22.08 ± 4.64 years, and the mean burn total body surface area (TBSA) of patients was 45.92 ± 20.30%. Of the 50 patients, 20 had Grade 1 ocular burns, and the others were without ocular involvement. Two of the 20 cases that presented Grade 1 ocular burns died within 1 month due to other systemic complications. The most common ocular manifestations among those with ocular injuries included periocular swelling (75%), followed by conjunctival chemosis (65%), conjunctival hyperemia (50%), singed eyelashes (20%), cornea epithelial defects (10%), and punctate keratopathy (5%). It is worth mentioning that one patient developed herpes simplex keratitis due to stress 3 weeks after being burned. Half of the 50 patients had facial burns. Specifically, the patients with a greater TBSA presented more significant ocular-burn manifestations than those patients with lower TBSA.
Conclusion: Prompt ophthalmologic consultations are particularly necessary for mass burn-casualty patients with facial burns, inhalation injuries, and greater TBSA. The inspection and control of all ignition sources and the manipulation of dust with low concentrations and in an open space are crucial factors to prevent future dust explosions.

1. Introduction

On 27 June 2015, a large dust explosion happened at a “Color Play Asia” party that was held at a recreational water park in New Taipei City, Taiwan. The organizer sprayed colored corn starch powder from the stage with high-pressure bottles, and the tiny powder particles were repeatedly blown into the air of a drained pool by air blowers. A crowd of approximately 1000 people joined the party, but the colored powder ignited and induced a flaming chain reaction. Four hundred and ninety-eight victims suffered from second- to third-degree burns and were transferred to 43 hospitals across Taiwan. Of those injured, 202 required intensive care.

Most of the casualties were young people under 30-years old and just starting the next stage of life, and the severity of their ocular injuries will influence their subsequent rehabilitation, ability to work, and quality of life. The aim of our study was to investigate the spectrum of ocular injuries of these patients presenting to the tertiary medical center and to emphasize the differences in ocular injuries sustained from a dust explosion, a chemical burn, and a blast explosion. Furthermore, we shared our experiences in mass-casualty management after a dust explosion.

2. Methods

Patients who were victims of the dust explosion on 27 June 2015, and admitted to Chang Gung Memorial Hospital, Linkou Branch, between 27 June and 22 July, were all included in our study.

Conflicts of interest: The authors declare no conflicts of interest.

* Corresponding author. Department of Ophthalmology, Chang Gung Memorial Hospital, Chang Gung University, 5 Fuxing Street, Kuei-Shan District, Taoyuan City, Taiwan.

E-mail addresses: yilinliao@gmail.com, lemonkumquat@gmail.com (S.-Y. Chen).

http://dx.doi.org/10.1016/j.tjo.2016.05.004

This retrospective study to review the medical charts of these patients was approved by the Institutional Review Board of Chang Gung Memorial Hospital, Linkou, Taiwan. Immediate ophthalmological triage methods were carried out on the first day to provide each patient prompt treatment. Thorough ocular examinations noted in the consultations provided us information about the healing process and sequela of the ocular-burn patients in intensive care units and wards. The demographics of these patients, ocular manifestations, systemic conditions, and follow-up periods were recorded.

The ocular examinations were performed by slit-lamp microscopy and a hand-held tonometer (Tonopen, Mentor, Santa Barbara, CA, USA). Final presentation of visual acuity, intraocular pressure, periocular burn, singed eyelashes, conjunctival hyperemia, chemosis, limbal ischemia, corneal epithelial defect, and any retained foreign bodies in the anterior or posterior chambers were recorded. Systemic conditions of burn patients, including the percentage of the total body surface area (TBSA), overall burn-degree severity, presence or absence of facial burns, and presence or absence of inhalation injury, were analyzed. Ocular burns were classified from Grade 0 to Grade 4 according to the Roper-Hall ocular-burn grading system.[1] The grading system for thermal burns to the eyelids, similar to other areas of skin, was also adopted. An estimation of burn depth (first-degree with only epidermal involvement, second-degree with blistering affecting epidermal and dermal layers, and third-degree extending to subcutaneous tissues) was based on clinical experience.[2]

The data recorded in this study were analyzed by using SPSS version 18.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were used to outline the characteristics of the study patients and the severity of their ocular injuries. We undertook an independent *t* test to determine whether there were any significant differences in TBSA between groups presenting with ocular burns and those without ocular burns. A $p < 0.05$ was considered statistically significant.

3. Results

Fifty patients were admitted or transferred to the Chang Gung Memorial Hospital due to the dust explosion on 27 June 2015. Of the 100 eyes in 50 cases reviewed, 22 cases were male and 28 cases were female. The mean follow-up period was 59 ± 24.11 days (range: 4–116 days), and two patients with mild ocular burns had only one ophthalmological follow-up. The mean age was 22.08 ± 4.64 years (range: 15–38 years). The general information and clinical data of burn patients with ocular damage are listed in Table 1. The mean burn TBSA of patients was $45.92 \pm 20.30\%$ (range: 5–90%). Concerning the degree of TBSA burned in our patients, the majority of patients suffered burns between 25% and 66% TBSA. Six of 50 patients suffered from burns <20% TBSA, and three of 50 patients suffered from burns >80% TBSA (Figure 1).

According to Roper-Hall grading, we divided our patients into two groups. Twenty patients (40%) had Grade 1 ocular burns, and the remaining 30 cases (60%) were without ocular involvement. Two of the 20 patients who presented Grade 1 ocular burns died within 1 month due to other systemic complications. The percentage of ocular burns in each systemic variable is summarized in Figure 2. A higher percentage of ocular burns compared with the overall group was noted in two systemic factors, including facial burns and inhalation injury.

In the Grade 1 ocular-burn group, the most common clinical manifestations included periocular swelling, conjunctival chemosis and hyperemia, punctate keratopathy, cornea-epithelial defect, and singed eyelashes (Table 2). Occasionally, more than one manifestation was seen in a single patient. There were neither Grade 2 ocular burns nor open-globe injuries noticed in these patients, but it is worth mentioning case 18, who had only mild thermal burns

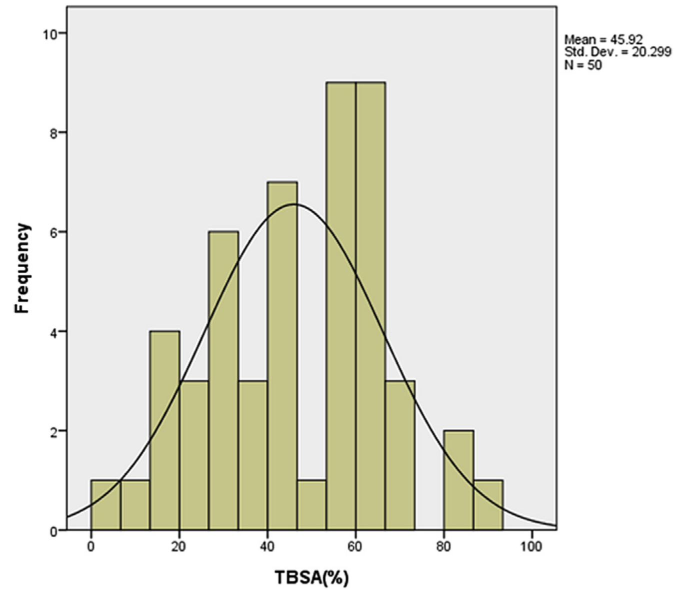

Figure 1. The distribution of the percentage of TBSA sustained among study patients. TBSA = total body surface area.

Table 1
Patient demographics and systemic conditions.

	Number	Percentage (%)	Mean ± SD	Range
Admissions	50			
Ocular burn (Grade 1)	20	40		
Facial burn	25	50		
Inhalation injury	28	56		
Age (y)			22.08 ± 4.64	15–38
TBSA (%)				
Overall	50		45.92 ± 20.30	5–90
No ocular burn	30		36.33 ± 16.61	5–65
Ocular burn	20		**60.3 ± 16.69**	21–90
Ocular burn follow-up (days)	20			
Multiple follow-ups	18		59 ± 24.11	4–116
One follow-up	2			

Bold represents significant values.
SD = standard deviation; TBSA = total body surface area.

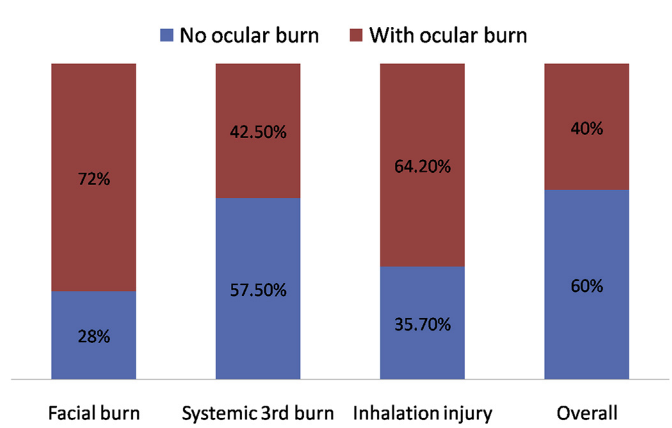

Figure 2. The percentage of ocular burn in systemic variables.

Table 2
Ocular injuries resulting from the dust explosion in the Taiwan water park.

Patient No.	Ocular injuries	Visual acuity	Systemic injuries		
		OD; OS	TBSA (%)	Facial burn	Inhalation injury
1	Periocular swelling Chemosis	20/20; 20/20	90	+	+
2	Periocular swelling Chemosis	20/20; 20/20	85	+	+
3	Periocular swelling Punctate keratopathy	20/20; 20/20	58	+	++
4	Periocular swelling Conjunctival hyperemia	—	72	+	+
5	Periocular swelling Chemosis Conjunctival hyperemia	20/20; 20/20	65	+	+
6	Cornea epithelial defect	20/20; 20/20	55	+	+
7	Conjunctival hyperemia	—	55	+	+
8	Periocular swelling Chemosis Conjunctival hyperemia	20/50; 20/50	65	+	++
9	Periocular swelling	20/20; 20/20	55	—	—
10	Conjunctival hyperemia	20/20; 20/20	55	+	+
11	Chemosis	20/20; 20/20	30	+	+
12	Periocular burn Singed eyelashes	20/20; 20/20	70	+	+
13	Periocular swelling Chemosis	—	60	+	+
14	Periocular swelling Chemosis	—	65	+	+
15	Periocular swelling Conjunctival hyperemia	20/20; 20/20	21	+	+
16	Periocular burn Singed eyelashes Chemosis	20/20; 20/20	80	+	+
17	Chemosis	—	40	—	—
18	Chemosis Conjunctival hyperemia HSV keratitis	20/20; 20/20	60	+	+
19	Periocular burn Singed eyelashes Chemosis	20/20; 20/20	55	+	+
20	Conjunctival hyperemia Chemosis Cornea epithelial defect	20/25, 20/20	70	+	++

— = no inhalation injury; + = Grade 1 inhalation injury; ++ = Grade 2 inhalation injury; OD = oculus dexter; OS = oculus sinister; TBSA = total body surface area.

(Roper-Hall Grade 1), but suffered from herpetic keratitis on her left eye 3 weeks after the event. The initial presentation was paracentral dendritic epitheliopathy in the 8 o'clock position without any sign of stromal infiltration, uveitis, or ocular hypertension. Acyclovir ointment administered five times daily and oral famciclovir (500 mg) taken three times daily were prescribed. After treatment, the dendritic lesion subsided in 1 week and resolved completely with clear cornea in 2 weeks. Two months after the event, her vision recovered to 20/20 bilaterally.

It was difficult to examine ocular conditions without lid retractors in two cases, with periocular burns resulting in tight and edematous lids. The depth of periocular burn ranged from first degree to second degree. Fortunately, all patients in this study could be managed by medical therapy, including eye ointment, preservative-free teardrops, and topical anti-inflammatory agents. No emergent ocular surgeries are required in our patients in the acute phase.

Specifically, 25 patients (50%) had facial burns, and 28 patients had inhalation injuries confirmed by bronchoscopy. There were two deaths within 1 month, for a mortality rate of 4%. Both suffered from not only facial burns with inhalation injuries, but also ocular burns and >60% TBSA burns. Of the 50 burn patients at this hospital, 40 had systemic third-degree burns mainly occurring on the limbs and trunk and underwent multiple debridement and surgical interventions.

After independent *t* test analysis, the ocular-burn group revealed greater TBSA (mean: 60.30 ± 3.73) as compared with the group having no ocular burns (mean: 36.33 ± 3.03). This difference was significant [$t(48) = -4.98$, $p < 0.05$]. We confirmed that "on average, there was a significantly greater TBSA in the ocular burn group than in the no ocular burn group".

4. Discussion

Dust explosions that have taken place in industrial settings are well documented[3]; however, mass-casualty dust explosions involving fire have seldom occurred at recreational parks. When the incident happened, the news media and journalists started to discuss the mechanism that caused the dust explosion from corn starch. A dust explosion becomes a potential hazard when fine particles are suspended in the atmosphere at high concentrations, followed by an ignition source causing the fire. It usually occurs in an enclosed location. When combustible dusts are ignited, the force of the explosion swirls up more dust and may trigger further explosions in a flaming chain reaction.

After analyzing the ocular injuries of our patients from the dust explosion at the Taiwan water park, we summarized that the ocular injuries caused by a dust explosion are different from other blast-related ocular traumas. Without a severe blast wave and debris, the injury is mainly related to flame burns of the ocular area, not a penetrating or blunt-force injury, which is common in a bomb explosion.[4]

Similar to chemical burns, the severity of thermal eye burns is related to the duration of exposure and the nature of the causative agent. The speed at which initial irrigation of the eye begins has the greatest influence on the prognosis and outcome of eye burns.[5] Fortunately, this explosion happened in a water park, where large volumes of water were readily available, enabling the trapped particles in the cul-de-sac of conjunctiva to be removed and patient ocular surfaces cooled following irrigation.

Unlike alkali chemical burns, the thermal energy of flame burns is less likely to penetrate into the cornea stroma and even the anterior chamber. Therefore, the ocular burns in 20 of the victims of this event were mild and rated as Grade 1 ocular burns in the Roper-Hall classification. Because the explosion of the rising colored powder originally precipitated to the bottom of the pool, more severe third-degree burns occurred on patient limbs rather than their faces and ocular areas. The severity of periocular burns should be evaluated precisely by the grading system for thermal burns to skin instead of the Roper-Hall classification.

Due to the rapidity of the lid-blinking reflex, the eyelid provides protection for the eye itself, and long-term visual acuity is preserved.[6] However, the eyelid takes on the majority of insult in a thermal injury, which may lead to an inordinately high rate of lid contractures. In our study, ocular burns involving severe periocular burn was thankfully rare. Only two patients with severe periocular burns had to undergo treatment to prevent further eyelid contracture, lagophthalmos, and exposure keratopathy.

Facial burns are a frequent component of the presentation of victims who have sustained thermal trauma, reportedly occurring in 20% of burn patients.[7] In our study, the percentage of facial burns was 50%, which was higher than the average observed in the tertiary burn center. The ocular involvement was 40%, also higher than the average observed in burn patients. Our study group had an average TBSA involved of nearly 46%, which was also far beyond the 22% average. The skewed data may be explained by this being a single thermal event from a dust explosion as compared with the prevalence of facial burns and ocular burns in a tertiary burn center. Moreover, mass casualties were transferred and admitted to Chang Gung Memorial Hospital, Linkou Branch, and all had been triaged as if having more severe burns. Prompt ophthalmological evaluations on the first day also helped to record more patients who had Grade 1 ocular involvement, but with self-limited clinical course.

However, diagnosis and treatment of thermal ocular injuries are often delayed, because facial burns are usually associated with life-threatening injuries requiring more immediate intervention.[8] In our study, there was a significantly greater TBSA involved in the ocular-burn group as compared with the group having no ocular burns. Ocular consultations may have been postponed until patient conditions become stable. We initiated immediate ophthalmological exams on the first day to triage each patient and offered continuous treatment to those patients with ocular burns in hopes of decreasing the ocular sequela due to the dust explosion.

Because the dust explosion involving fire occurred at a theme park during summer vacation, a large proportion of the victims were <30 years old. Rapid visual recovery from this disaster helps them to receive the necessary rehabilitation and enables them to quickly return to school and work. The limitation of our study was the outcome of cross-sectional observations among these young patients in a short-term review. Further investigation into their visual acuity, eyelid condition, and any ocular-burn sequela after long-term follow-up is necessary.

In conclusion, prompt ophthalmological consultations are preferred in patients with facial burns, inhalation injuries, and greater TBSA after a dust explosion. Prevention is better than cure, so care must be taken to control all ignition sources and to have dust manipulated under low concentrations in an open space. These are crucial factors to prevent dust explosion.

References

1. Roper-Hall MJ. Thermal and chemical burns. *Trans Ophthalmol Soc UK*. 1965;85:631–653.
2. Pham TN, Gibran NS. Thermal and electrical injuries. *Surg Clin North Am*. 2007;87:185–206.
3. Amyotte PR, Eckhoff RK. Dust explosion causation, prevention, and mitigation: an overview. *J Chem Health Saf*. 2010;17:15–28.
4. Yonekawa Y, Hacker HD, Lehman RE, et al. Ocular blast injuries in mass-casualty incidents. *Ophthalmology*. 2014;121:1670–1676.
5. Kuckelkorn R, Schrage N, Keller G, Redbrake C. Emergency treatment of chemical and thermal eye burns. *Acta Ophthalmol Scand*. 2002;80:4–10.
6. Spector J, Fernandez WG. Chemical, thermal, and biological ocular exposures. *Emerg Med Clin N Am*. 2008;26:125–136.
7. Stern JD, Goldfarb IW, Slater H. Ophthalmological complications as a manifestation of burn injury. *Burn*. 1996;22:135–136.
8. Bouchard CS, Morno K, Perkins J, McDonnell JF, Dicken R. Ocular complications of thermal injury: a 3-year retrospective. *J Trauma*. 2001;50:79–82.