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Corneoscleral Laceration and Ocular Burns Caused by Electronic Cigarette Explosions

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Purpose: To report cases of acute globe rupture and bilateral corneal burns from electronic cigarette (EC) explosions.

Methods: Case series.

Results: We describe a series of patients with corneal injury caused by EC explosions. Both patients suffered bilateral corneal burns and decreased visual acuity, and one patient sustained a unilateral corneoscleral laceration with prolapsed iris tissue and hyphema. A review of the scientific literature revealed no prior reported cases of ocular injury secondary to EC explosions; however, multiple media and government agency articles describe fires and explosions involving ECs, including at least 4 with ocular injuries.

Conclusions: Given these cases and the number of recent media reports, ECs pose a significant public health risk. Users should be warned regarding the possibility of severe injury, including sight-threatening ocular injuries ranging from corneal burns to full-thickness corneoscleral laceration.

Key Words: open-globe injury, ocular trauma, electronic cigarette, vaping, explosion

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Electronic cigarette (EC) usage is on the rise in the United States since being introduced to the market in 2006. An estimated 3.7% of Americans are regular users based on recent data from the Centers for Disease Control and Prevention.¹ ECs are battery-powered devices that vaporize a chemical mixture called “e-liquid” to simulate cigarette smoking. The Food and Drug Administration (FDA) does not currently regulate ECs, although new regulations have been proposed.² The proposal

includes the prohibition of sale to minors and a requirement that ECs carry a warning regarding nicotine content. Notably, the proposal does not include a warning regarding facial, oral, or sight-threatening ocular injuries. Among the safety concerns surrounding ECs, fires and explosions have been reported in various media outlets; in most of these cases, the presumed mechanism is battery malfunction.

Here, we describe 2 cases of patients who suffered multiple injuries from EC explosions. The first patient’s ocular injuries included a penetrating corneoscleral laceration with iris prolapse, hyphema, an additional partial-thickness corneal laceration, and bilateral thermal and/or chemical corneal burns. The second patient also suffered bilateral corneal burns. To our knowledge, these are the first cases of ocular injury from ECs to be reported in the scientific literature.

MATERIALS AND METHODS

The charts of 2 patients presenting with ocular injuries from EC explosions were reviewed in accordance with the Institutional Review Board and the Declaration of Helsinki.

Case 1

A 45-year-old man presented to the emergency department at Washington University after an EC exploded in his mouth. On external examination, the patient was found to have first-degree burns to his right hand and bilateral periocular and facial skin, and loss of 2 upper central incisors. The patient’s facial skin and tear lakes were dusted with numerous black particulate foreign bodies. His best-corrected near visual acuity was 20/400 pinholing to (PH) 20/100 (J10 equivalent) in the right eye and 20/30 PH 20/20 (J1+ equivalent) in the left eye. Intraocular pressure measurement was deferred in the right eye because of open-globe injury and was normal in the left eye. Slit-lamp examination with fluorescein stain revealed bilateral complete corneal epithelial defects, diffuse subconjunctival hemorrhages, and mild eyelid edema with singeing of his eyelashes. In the right eye, he had a 6-mm superior corneal laceration extending an additional 2 mm onto adjacent sclera with protruding iris tissue, and a 2-mm inferior partial-thickness corneal laceration. Seidel testing was briskly positive in the right eye, which also had a 1-mm hyphema. The remainder of the examination revealed trace nuclear sclerosis and a normal dilated fundoscopic examination in both eyes. Bilateral pH testing of the ocular surface was normal in all quadrants.

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An otolaryngology consult was obtained for his facial and oral injuries; no acute surgical intervention was recommended. A computed tomography (CT) scan was negative for radio-opaque intraocular or orbital foreign bodies. The patient underwent an emergent repair of his open globe with partial iridectomy and repositioning of the remaining prolapsed iris. Anterior chamber washout was not performed because of intraoperative concerns regarding wound integrity. He received moxifloxacin 400 mg intravenously and a tetanus booster. His left corneal burn was treated with a combined neomycin (3500 I.U./g), polymixin B (6000 I.U./g), and dexamethasone 0.1% ointment every 2 hours.

The next day, the patient's uncorrected distance visual acuity was 20/500 PH 20/200 in the right eye and 20/200 PH 20/100 in the left eye with normal intraocular pressures bilaterally. In the right eye, the repaired corneoscleral laceration was Seidel-negative and the anterior chamber had a persistent 1-mm hyphema. Diffuse mild-to-moderate corneal edema was present bilaterally with near-complete epithelial defects and no limbal ischemia (Figs. 1, 2). He was administered levofloxacin 500 mg orally daily and combined steroid-antibiotic ointment every 2 hours in both eyes. At subsequent postoperative visits, his uncorrected distance vision continued to improve, eventually attaining 20/100 PH 20/40-2 in the right eye and 20/70 PH 20/25 in the left eye by the 2 months follow-up. The right hyphema resolved within the first week, and the bilateral corneal epithelial defects slowly healed over the first month. His corneal sutures were removed after 2 months. He will eventually undergo a rigid gas-permeable contact lens trial in the right eye. This incident was reported to the Consumer Product Safety Commission and the FDA.

Case 2

A 16-year-old male presented to the emergency department at the University of Colorado Hospital with severe bilateral eye pain and diminished vision after his vapor pen



FIGURE 2. Case 1, extensive epithelial defect in left eye with fluorescein stain and diffuse conjunctival injection at 1 day after injury.

exploded at the chest level. He sustained burns to his face, neck, and hands. His uncorrected visual acuity at near was 20/20 (J1+ equivalent) in the right eye and count fingers at 1 foot with no improvement on pinhole in the left eye without an afferent pupillary defect. Intraocular pressures were normal in both eyes. His eyelids were mildly edematous and his lashes were singed and thickly matted with black particulate material (Fig. 3). Both conjunctivae were injected and littered with black particles but exhibited minimal fluorescein staining. The right cornea had a superotemporal epithelial burn sparing the central visual axis, with 1 mm of limbal blanching temporally. The left cornea had a greater than 90% surface burn with irregular, blackened epithelium diffusely except a small amount of sparing under the lower lid margin. The remainder of the examination including the posterior segment



FIGURE 1. Case 1, corneoscleral laceration of the right eye 1 day after repair (Seidel-negative), epithelial defect with fluorescein staining, persistent hyphema, and subconjunctival hemorrhage.



FIGURE 3. Case 2, right eye at presentation with superotemporal corneal burn sparing visual axis. Note the thick, matted black material along the lash line and partially coating the ocular surface.

was normal in both eyes. Bedside pH testing of the ocular surface was normal.

The patient was admitted to the burn intensive care unit for his face and neck injuries and for pain control. CT scan was negative for radio-opaque intraocular or orbital foreign bodies. Gentle debridement of the charred corneal epithelium was performed at the bedside with copious irrigation. There were small areas of blackened epithelium at the limbus bilaterally that did not clear with debridement (Fig. 4). The patient complained of a severe burning sensation with erythromycin ointment alone, so he was placed on topical moxifloxacin 0.5% 4 times daily with soft bandage contact lenses (BCLs) for pain relief.

The next day, the patient's uncorrected near visual acuity was 20/20 (J1+ equivalent) in the right eye and 20/40 (J3 equivalent) in the left eye. Mild corneal edema was present bilaterally with trace haze, diffuse epithelial defects, and resolution of limbal blanching. He was discharged from the hospital with BCLs and orders for topical moxifloxacin 0.5% 4 times daily and cyclopentolate 1.0% twice daily. On day 3, his uncorrected distance vision was 20/70 PH 20/50 in the right eye and 20/80 PH 20/60 in the left eye with normal intraocular pressures. Although the corneal epithelial defects had reduced in size, he had several new punctate foreign bodies embedded superficially in the cornea and conjunctiva beneath the BCLs bilaterally. These foreign bodies were thought to have migrated underneath the BCLs because of the placement of the BCLs after debridement. The foreign bodies were removed at the slit lamp and the BCLs replaced. Over the next 2 weeks, his uncorrected distance vision progressed to 20/20 in both eyes. The moxifloxacin drops were stopped, and topical prednisolone 1.0% was initiated. He had scattered anterior stromal scars that faded greatly during his course. He continued to have mild photophobia, but his pain was greatly improved and he no longer required the BCLs.



FIGURE 4. Case 2, right eye after bedside debridement. Note the areas of burned corneal and conjunctival epithelium with embedded black material that did not clear with gentle debridement, and the temporal limbal blanching.

DISCUSSION

ECs pose a number of health safety risks beyond nicotine content and gateway drug concerns. Explosion of ECs because of battery failure can cause serious injury to users, including mechanical injury and thermal and/or chemical burns. ECs may contain various materials, including metals, plastics, rubber, and ceramics, in addition to the battery and e-liquids ranging from nicotine to cannabis oil.^{3,4} It is difficult to ascertain which materials may have caused projectile damage to our patients resulting in corneal lacerations and dental trauma, and toxic and/or caustic burns of their ocular, mucosal, and skin surfaces. Both our patients had black particulate foreign bodies coating or even embedded into their ocular surfaces. Their ocular injuries from flying debris may have been prevented or minimized by protective eyewear, in keeping with the recommendations for high-risk activities like metalworking or setting off fireworks.

ECs are generally powered by lithium-ion batteries, which contain flammable and combustible liquids. ECs vary widely in design and often include end-user-modifiable parts. Defective or incorrectly matched electric currents can lead to thermal runaway, an uncontrolled positive feedback of increased temperature that can end in combustion.^{3,5} By avoiding the use of incorrectly matched chargers and ECs that can produce thermal runaway, some of the EC explosion-related injuries reported in the media may have been averted.⁵ In addition to the possibility of direct injury to person and bystanders, there is a serious risk of indirect injury and property damage through ignition of nearby combustible materials. The media have reported a number of EC explosions where individuals suffered burns, lost teeth and/or palate trauma, neck fractures, and battery acid exposure to the face, mouth, and eyes^{6,7}; moreover, one user died when his charging EC exploded and ignited adjacent oxygen equipment.⁸ At least 4 ocular injuries from EC explosions have been reported by the media, the U.S. Fire Association, or MedWatch, the FDA's voluntary reporting site.^{6,7} Unfortunately, the descriptions provided in these reports do not provide details on the scope and severity of those injuries.

At the time of this writing, there are no regulations or laws regarding the safety of electronics or batteries in ECs in any country with the exception of Croatia.⁹ In 2014, the FDA proposed regulating ECs like other tobacco products; however, this proposal does not mention the risk of fire, explosion, or injury from explosion.² Unlike most consumer products, ECs are not required to undergo independent product safety testing; hence, products may reach end-users without rigorous demonstration of safety features to prevent device overheating, thermal runaway, and battery failure including fire and explosions. There is a lack of product labeling to warn users of the potential of serious harm including mutilation and loss of vision. In fact, many EC products are missing ingredient labels, warnings besides nicotine content, and sometimes even instructions for use.⁵ Protective eyewear and even mouthguards may be advisable during EC use, although strict compliance is unlikely. Although the number of serious adverse events is small compared with the number of EC users worldwide, the consequences may be devastating to those involved in an EC-related blast. Because the FDA collects only voluntary reports,²

adverse events may be underreported. Further study is warranted to investigate the explosion hazard presented by these devices.

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