

Burns associated with e-cigarette batteries: A case series and literature review

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ABSTRACT

Electronic cigarettes, often referred to as *e-cigarettes*, have established a considerable market in North America over the last decade. In parallel to this trend, there has been a surge of e-cigarette battery explosions reported in the general media. Given the growing number of such events, acute care physicians should recognize the associated risks and injury patterns and initiate appropriate treatment. This report presents two cases of burn injuries from e-cigarette battery explosions requiring surgical management. The accompanying comprehensive literature review highlights the emerging importance of e-cigarettes as an aetiology of burn injury.

RÉSUMÉ

Les cigarettes électroniques ont gagné une place considérable sur le marché, en Amérique du Nord, au cours de la dernière décennie. Parallèlement à la tendance, il s'est produit une hausse importante du nombre d'explosions de piles, signalées dans les médias généralistes. Compte tenu du nombre croissant de pareils événements, les médecins en soins actifs devraient être informés des risques associés à ces explosions et des types de blessures qui en découlent, et appliquer le traitement approprié. L'article expose deux cas de brûlures causées par des explosions de piles de cigarette électronique, qui ont nécessité une intervention chirurgicale. L'examen exhaustif de la documentation qui accompagne cet exposé met en évidence l'importance croissante des cigarettes électroniques comme cause de brûlure.

Keywords: burns, e-cigarettes, lithium ion battery, vaping

INTRODUCTION

As of 2014, the e-cigarette industry in North America reported revenues of \$1.5 billion, compared to just \$20 million in 2008.¹ In Canada, 9% of adults have smoked e-cigarettes at least once in the last 5 years, and use is expected to rise further.² Despite the marketing of electronic cigarettes as safer, smoke-free counterparts to regular cigarettes, new consumer risks are being recognized and reported. Explosions of lithium ion batteries have been well documented in relation to their

use in laptop computers and cellular phones.³⁻⁵ The electrolyte liquid within the lithium ion battery cells is at risk for overheating, thus building pressure that may exceed the capacity of the battery casing. This “thermal runaway” can ultimately result in cell rupture or combustion.^{3,6}

The purpose of this publication is to review e-cigarette battery explosions as an emerging aetiology of burn injury and to describe two cases requiring admission to an American Burn Association verified regional burn centre.

CASE REPORT I

A 31-year-old, previously healthy male was driving a motor vehicle when an e-cigarette battery ignited spontaneously in the pocket of his pants. The battery had been placed with several coins in the pocket. He was able to steer safely off of the road, remove his pants, and extinguish the flames with his hands. He was transported directly from the scene to the regional burn centre by Emergency Medical Services.

The patient sustained mixed partial thickness and full-thickness flame burns to his right anterolateral thigh, buttock and leg, as well as his left inner thigh (Figure 1, A and B). These findings were consistent on reassessment of possible progression after 24 hours. The total body surface area (TBSA) of the burn injury was calculated to be 10%, according to the Lund and Browder chart. The burn wounds were thoroughly irrigated with water on presentation to remove debris and to cool the burned surface area. The patient was sedated with ketamine, fentanyl, and midazolam during this procedure. The thigh wounds were dressed with silver sulfadiazine cream in sterile gauze and wrapped

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with cling. He received a tetanus vaccination. His burns were debrided and successfully covered with autologous split thickness skin grafts on Day 3 of a 7-day

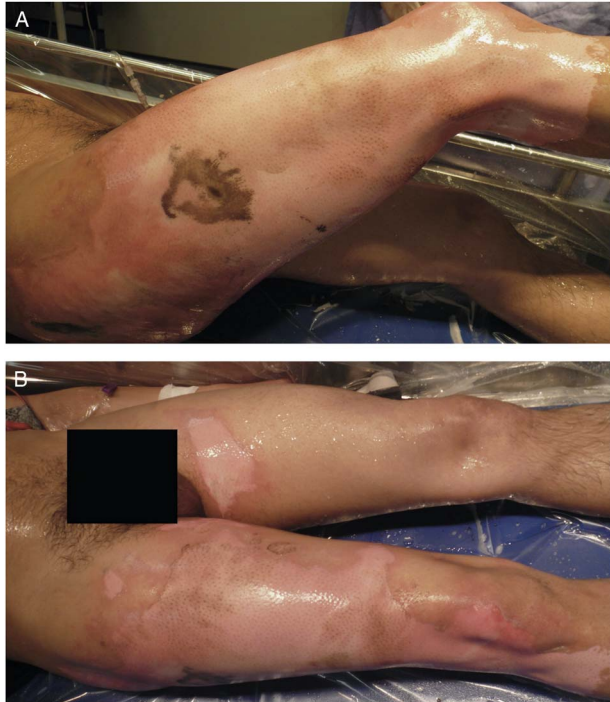


Figure 1. A) Right buttock and thigh burns of the patient in Case I. B) Bilateral anterior thigh burns in the patient in Case I, on the day of the burn injury.

admission. The patient's pain was adequately controlled with oral hydromorphone, ibuprofen, and acetaminophen, and supplemented by intravenous hydromorphone or fentanyl postoperatively and for dressing changes. Gabapentin was added as an analgesic adjunct postoperatively, to address neuropathic pain after skin grafts were harvested. His postoperative recovery was uneventful. He received outpatient physiotherapy and recovered full function within 2 months.

CASE REPORT II

A 36-year-old previously healthy male had been storing an e-cigarette battery in the pocket of his pants along with several coins and keys. The patient was not aware that lithium ion batteries carried any risk of explosion. He recalls hearing a sound like a sparkler or firework when the battery spontaneously ignited and engulfed his pants in flame. He put the flames out with his hands and by dousing his pants with water. The patient was initially taken to a community hospital by Emergency Medical Services before a same day transfer to the regional burn centre for further management.

The patient sustained deep partial and full thickness burns to his right anteromedial thigh and superficial partial thickness burns to his right hand, cumulating in 3% TBSA (Figure 2, A). Part of the battery case was



Figure 2. A) Anterior right thigh burn of the patient in Case II on the day of the burn injury. B) E-cigarette battery device and fragment of the casing removed from the thigh of the patient.

embedded in his thigh and was removed at the burn centre on arrival (Figure 2, B). The wounds were thoroughly irrigated with sterile water and dressed with silver sulfadiazine cream in sterile gauze. Two days following the injury, the patient was noted to have developed cellulitis of the burn wounds, manifesting as tachycardia and a low-grade fever. He was treated with a course of cefazolin. His wounds were debrided on the third day following the injury. The underlying deep tissue injury necessitated excision of deep fascia overlying part of the sartorius and rectus femoris muscles. Due to the extent of the injury and the presence of burn wound infection, the wound was closed in two stages. Meshed, deceased donor allograft skin and negative pressure wound therapy were used to cover the wound in the first surgery. At the second operation, the allograft was found to be adherent, and no further debridement was deemed necessary. Meshed autograft was used to definitively close the wound, again bolstered by negative pressure wound therapy to optimize graft take. The patient required a 12-day hospital stay and returned to full function within 2 months of his injuries. He continues to be followed in the outpatient setting for scar management and uses pressure garments.

REVIEW OF LITERATURE AND MEDIA REPORTS

An electronic search was conducted using the MEDLINE database in May 2016. Search terms included “e-cigarette” AND “injury” OR “burn” OR “explosion” OR “trauma,” “vaping and burn,” “vaping and injury,” and “cigarette and battery and burn.” Articles were excluded for lack of relevance or for descriptions of chronic health effects of e-cigarettes rather than burns or explosions. Sixteen cases of spontaneous e-cigarette or e-cigarette battery ignition were retrieved. The Google search engine was used to identify news media reports of accidental e-cigarette or e-cigarette battery ignitions from 2015 to 2016 using the same terms listed previously. The media search was initially conducted in May 2016 and updated in June 2016.

The academic literature review yielded four case reports, two case series, and one published abstract describing injuries sustained from overheating or explosion of an e-cigarette device (Table 1). Six incidents involved isolated explosions of a lithium ion battery, similar to the cases presented in this series. Three e-cigarette devices exploded while in use, and one device exploded while not in use.

There has been a sharp increase in the number of e-cigarette-related reports in the literature (Figure 3). All reports involving explosion of e-cigarette batteries resulted in burn injuries, primarily to the lower extremities and hands. When reported, the extent of the burn injuries ranged from 1% to 8% TBSA and most commonly involved the lower extremity, hands, head and neck, and genitalia. Burn depth was predominantly deep partial and full thickness. In keeping with the depth of the injuries, at least 50% required surgical management of the burn wound. This report features a burn injury involving 10% TBSA, which at the time of writing is the most extensive burn resulting from an e-cigarette battery explosion published to date.

A search of general public media reports revealed 35 burns and associated injuries related to e-cigarette explosions between January 2015 and May 2016 (Table 2). Remarkably, over 60% of these incidents occurred in 2016 alone (see Figure 3).

The U.S. Federal Emergency Management Agency (FEMA) published a report in October 2014 documenting all media reports of e-cigarette battery explosions from 2009 to 2014. The search revealed 25 cases, resulting in 9 injuries, including 2 serious burns.³ The U.S. National Fire Protection Association (NFPA) published the only other review of incidents related to e-cigarette explosions in April 2016. From January to December 2015, a total of 15 cases of burns and/or explosions related to e-cigarettes were found, with 12 incidents involving injuries to a person.¹ Our media search yielded 22 additional cases between January and June 2016. Although growing media attention may account for some of this upsurge in reports, the rising popularity of e-cigarettes is almost certainly contributory.

DISCUSSION

As more cases are reported, the spectrum of injury following e-cigarette battery explosions will be better delineated, thus allowing for targeted management approaches. The most frequent sites of injury observed with e-cigarette battery burns involve the lower extremities and hands. Nearly half of the reported incidences, including the two cases reported herein, required surgical management as a result of the depth of injury. Burns are typically less than 10% TBSA and therefore do not meet the threshold for formal fluid resuscitation. As with all burns, acute care physicians should follow the Advanced Trauma Life Support

Table 1. Academic reports e-cigarette explosions, 2015-2016

Authors	Publication date	Involved body areas	Depth/size of burns	Other injuries	Interventions	Trigger
Shastry S, Langdorf M. Electronic. <i>J Emerg Med</i> 2016;17(2):177-80. ⁷	January 2013	Chest, abdomen	Partial thickness burn v. foreign body penetration upper chest and upper abdomen	Soft tissue wounds from shrapnel	Routine wound care	E-cigarette device exploded during use
Jablow LM, Sexton RJ. <i>Am J Case Rep</i> 2015; 3(4):93-4. ⁸	February 2015	Thigh, leg	8% TBSA; partial thickness burns to right thigh and circumferential partial thickness to right knee	-	Unknown (transferred to burn centre)	Lithium battery combustion
Walsh et al. <i>BMJ Case Rep</i> 2016;Epub 2016 March 9. ⁹	February 2016	Thigh	1.5% mixed depth burn to lateral right thigh	-	Conservative dressings	Lithium battery combustion
Colaiani et al. <i>Eplasty</i> 2016;16:ic9. ¹⁰	February 2016	Thigh, genitalia, hands	Full thickness burns to legs and partial thickness burns to genitalia and hands	-	Debridement and grafting	Explosion of lithium battery
Colaiani et al. <i>Eplasty</i> 2016;16:ic9. ¹⁰	February 2016	Thigh, genitalia, hands	Full thickness burns to legs and partial thickness burns to genitalia and hands	-	Debridement and grafting	Explosion of lithium battery
Colaiani et al. <i>Eplasty</i> 2016;16:ic9. ¹⁰	February 2016	Face	-	Facial lacerations and tooth fractures	Intubation, laceration repair	E-cigarette device exploded during use
Nicoll et al. <i>Burns</i> 2016; 42(4):e42-6. ¹¹	April 2016	Thigh, hand	4% TBSA superficial partial thickness to thigh; superficial burns to right hand		Conservative care, wound dressings	Lithium battery combustion
Nicoll et al. <i>Burns</i> 2016; 42(4):e42-6. ¹¹	April 2016	Thigh, hand	3% TBSA superficial partial thickness to thigh; superficial burns to right hand		Conservative care, wound dressings	Lithium battery combustion
Patterson et al. <i>J Burn Care Res</i> 2016;37 (Suppl 1):S247. ¹²	May 2016	Thigh, genitals, hand	1% TBSA burn	-	Burn debridement and grafting to thigh; circumcision	Device explosion
Roger et al. <i>J Oral Maxillofac Surg</i> 2016; 74(6):1181-5. ¹³	June 2016	Abdomen, head/face	Abdominal burns, details not disclosed	Oral soft tissue injury, tooth fracture, tooth avulsions	Laceration repair, oral surgery	E-cigarette device exploded during use

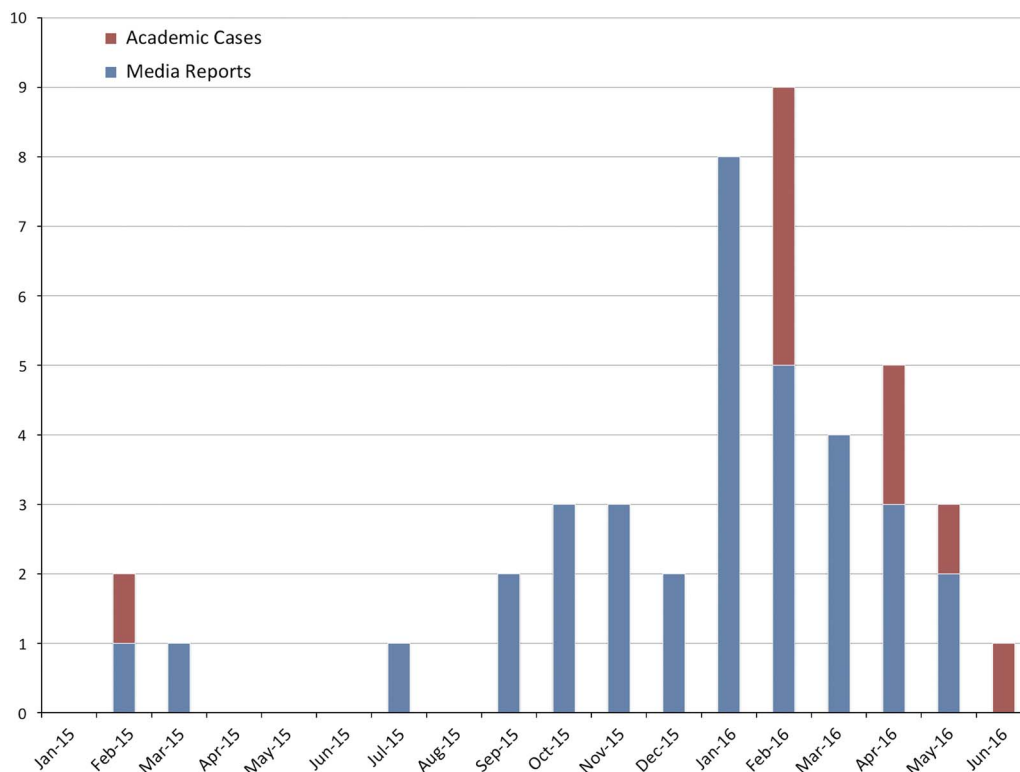


Figure 3. Incidence, by media and academic reports, of e-cigarette explosion-related injuries, 2015-2016 (as of June 26, 2016).

guidelines on patient arrival. Important adjunctive treatments include cleaning and cooling all burned areas with water prior to application of a non-adherent dressing. Importantly, burns to the hand, the genitalia, the face, chemical burns, and deep burns require a consultation with a burn surgeon, as per the referral guidelines of the American Burn Association.

First aid for exposure to the contents of lithium ion batteries includes a thorough irrigation of the affected site with water.⁴⁰ Rechargeable lithium ion batteries do not contain lithium metal and thus the use of water is safe and appropriate.⁴¹⁻⁴² Nonetheless, medical staff should always don appropriate personal protective equipment because the other components of lithium ion batteries may cause skin or eye irritation. In addition to flame burns, a recent case report by Nicoll et al.⁵ discusses a patient who presented with features of both flame and alkali burns. The authors verified the alkali component of the burn through skin pH testing.¹¹ With suspicion of a chemical or mixed burn pattern, acute care physicians are urged to contact the regional burn centre for early, specialized management.

Metal objects, such as coins or keys, can create a short circuit when stored with batteries, which initiates

battery overheating.⁴³ Khundkar et al.⁴³ presented a report where loose change in the pocket of their patient created a short circuit by connecting the positive and negative electrodes of a non-rechargeable battery. Walsh et al.⁹ also reported a case where an e-cigarette battery stored with keys ignited in a patient’s pocket, resulting in a mixed depth burn of the thigh.

The regulatory landscape for e-cigarette sales in Canada lags behind their rapid spread of use. At present, if an e-cigarette device or liquid contains nicotine or makes a health claim, they fall under the Food and Drugs Act. Because Health Canada has not yet approved e-cigarettes as delivery vehicles for nicotine, they are illegal to sell in Canada.² Regardless, both nicotine and non-nicotine containing e-cigarette products are widely available for purchase in Canada. Manufacturing guidelines established by the United Nations require lithium ion batteries and battery components to be tested to meet specific safety criteria, but batteries purchased through unreliable distributors or manufacturers of counterfeit products may not meet these guidelines and are thus at greater risk of igniting or exploding.⁴² Without regulation or control of the sale of these products, consumers must rely on safety advice that they

Table 2. Media reports of e-cigarette explosions, 2015-2016

Date of incident	Source	Involved body areas	Depth/size of burns	Other injuries	Treatment	Trigger
February 2015 ¹⁴	Daily Mail	Head/face	Partial thickness burns to face, neck, ear	Facial fracture, concussion	Unknown	Device combustion while using e-cigarette
March 2015 ¹⁵	ABC Los Angeles	Head/face, hand	Superficial facial burns	Laceration to hand	Unknown	Device combustion while using modified e-cigarette
July 2015 ¹⁶	Tech Times	Head/face, neck	Superficial facial burns, oropharyngeal burns, ocular burns	Dental trauma, fracture vertebrae	Unknown	Device combustion while using e-cigarette
September 2015 ¹⁷	Fox 17 News	Stomach, thigh/leg	Full thickness burns on thigh and knee, burn to stomach	-	Unknown	Device combustion, stored with keys in pants pocket
September 2015 ¹⁴	Daily Mail	Thigh/leg	Partial thickness burns	-	Debridement and grafting	Lithium battery combustion
October 2015 ¹⁸	Seattle Times	Head/face	Ocular burns	Facial lacerations, dental trauma	Unknown	Device combustion while using e-cigarette
October 2015 ¹⁹	Fox News	Head/face, neck	Facial and neck burns	-	Hospitalization	Device combustion while using e-cigarette
October 2015 ¹⁴	Daily Mail	Head/face, hand	Burn to 5th digit, oropharyngeal burns	Oral trauma	Amputation of affected digit	Device combustion while using e-cigarette
November 2015 ²⁰	Denver Post	Head/face, neck	Oropharyngeal burns	Fractured vertebrae, facial fractures, dental trauma	Intensive care hospitalization, spinal stabilization, ± craniofacial surgery	Device combustion while using e-cigarette
November 2015 ¹⁸	Seattle Times	Head/face	-	Facial lacerations	Laceration repair	Device combustion while using e-cigarette
November 2015 ²¹	Newser	Head/face, hand	Burns to hand, oropharyngeal burns	Facial lacerations, dental trauma	Unknown	Device combustion while using e-cigarette
December 2015 ²²	Fox 17 News	Thigh	Partial and full thickness burns	-	Unknown	Lithium battery combustion, stored with coins in pants pocket
December 2015 ²³	KFOR News	Face	-	Facial laceration	Laceration repair	Device combustion while refilling cartridge
January 2016 ²⁰	Denver Post	Leg	Partial thickness burn	-	Debridement and grafting	Lithium battery combustion, stored with coins in pants pocket
January 2016 ²⁴	NBC Los Angeles	Thigh/leg	Partial and full thickness burns	-	Debridement and grafting	Lithium battery combustion, stored with coins in pants pocket
January 2016 ²⁵	WCVB Boston	Thigh, hand	Partial and full thickness burns	-	Debridement and grafting	Lithium battery combustion
January 2016 ²⁶	CBC	Lethbridge	Head/face	Mixed depth facial and oropharyngeal burns	Dental trauma	Dental repair
Device			combustion while using e-cigarette			
January 2016 ²⁷	Daily Mail	Head/face	-	Dental trauma	Unknown	Device combustion while using e-cigarette

Table 2. (Continued)

Date of incident	Source	Involved body areas	Depth/size of burns	Other injuries	Treatment	Trigger
January 2016 ²⁸	Mirror	Head/face, hand	Facial and hand burns	Dental trauma	Debridement and grafting	Device combustion while using e-cigarette
January 2016 ²⁷	Daily Mail	Head/face	-	Ocular trauma and facial laceration	Surgical repair, eye	Device combustion while using e-cigarette
January 2016 ²⁹	BBC	Head/face, neck, forearm	Burns to face, neck, wrist	Dental trauma	Unknown	Device combustion while using e-cigarette
February 2016 ¹⁸	Seattle Times	Head/face, hand	Second degree burn	-	Unknown	Device combustion while using e-cigarette
February 2016 ³⁰	CNN	Thigh	Partial thickness burns	-	Unknown	Lithium battery combustion
February 2016 ³¹	Fox 13 News	Thigh/leg, hand	Partial thickness burns	-	Unknown	Lithium battery combustion, stored with coins in pants pocket
February 2016 ³²	NY Daily News	Thigh	Partial thickness burns	-	Unknown	Lithium battery combustion
February 2016 ³³	Fox 13 News	Thigh/leg	Mixed depth burns, including partial and full thickness	-	Unknown	Combustion of e-cigarette and charger unit
March 2016 ³⁴	CBS New York	Head/face	-	Facial and ocular trauma, visual impairment	Unknown	Device combustion while using e-cigarette
March 2016 ³⁵	Pittsburgh Post-Gazette	Thigh, genitals	Partial and full thickness burns	-	Debridement and grafting	Lithium battery combustion, contact with keys or coins in pants pocket
March 2016 ³⁵	Pittsburgh Post-Gazette	Thigh	Partial and full thickness burns	-	Debridement and grafting	Lithium battery combustion, contact with keys or coins in pants pocket
March 2016 ³⁵	Pittsburgh Post-Gazette	Hand	Partial and full thickness burns	-	Unknown	Lithium battery combustion, contact with keys or coins in pants pocket
April 2016 ³⁶	AJC News	Thigh/leg	Partial and full thickness burns	-	Unknown	Lithium battery combustion
April 2016 ³⁷	Global News	Head/face	-	Facial fracture, ocular trauma, and vision impairment	Surgical repair of facial fractures	Device combustion while using e-cigarette
April 2016 ³⁸	Daily News New York	Thigh/leg	Full thickness burns	-	Debridement and grafting	Lithium battery combustion
May 2016 ³⁹	Fox 2 Now	Thigh	Full thickness burns	-	Debridement and grafting	Lithium battery combustion
May 2016 ³⁹	Fox 2 Now	Thigh	Full thickness burns	-	Unknown	Lithium battery combustion

receive at the point of sale or on the Internet, which is inconsistent at best. Furthermore, given the lack of a user manual and product labeling regulations for e-cigarettes, consumers are often unaware of the risks of improper lithium ion battery storage or charging.

CONCLUSION

As e-cigarette use continues to rise in popularity, burns resulting from e-cigarette battery explosions will become a more prevalent presentation in the acute care setting. For acute care physicians, the recognition of these injuries is paramount in initiating an appropriate management algorithm, which often includes referral to a regional burn centre. This case series and literature review highlight the need for improved regulation of e-cigarette devices and advocate for clear warnings on product labels, to make e-cigarette users aware of the risks of battery explosion.

Competing interests: None declared.

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