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## Review

# E-cigarette burn injuries: Comprehensive review and management guidelines proposal

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## ARTICLE INFO

## ABSTRACT

**Introduction:** Electronic cigarettes (EC) have been reported to be associated with burns secondary to explosions of the device or battery, or contact from overheating, resulting in flame, contact or chemical burns. In addition to this, there have also been reported cases of soft tissue and bony trauma with or without associated burns.

Using collective evidence, this review aims to summarise all reported burns associated with ECs, and its implications on immediate management with a particular focus on surgical treatment.

**Methods:** A search was conducted on PubMed, EMBASE and Medline for all case reports, case series and letters to editors published since 2014, using terms “electronic cigarette”, “e-cigarette”, “vaping” and “burn”. The search was repeated by the co-author to avoid bias and a review of the bibliographies of each paper was conducted to ensure all relevant cases were included. The mechanisms, type and severity of burn injury, and management and treatment outcomes of the patients were recorded.

Exclusion criteria included non-English articles, explosions with no associated burn and publications with insufficient information.

**Results:** 90 patients from 19 case series or case reports were included. With the exception of one study, gender was recorded with a male predominance (95.6%). Mean age is 30.1 years (range 18–59). The most common type of burn was flame. However, there were reports of chemical burns associated with ECs. The mean total body surface area (TBSA) affected was 4.9% (range 1–27.25%) with the majority of burns being mixed partial and full thickness.

22 patients underwent excision and autologous skin grafting within range of three to 21 days. One patient had a full thickness contact burn excised and closed, one patient received a xenograft following debridement and one had biosynthetic skin dressing.

42 patients were managed conservatively with dressings or ointments.

**Discussion:** In this review over a three-year period (2015–2017), 90 cases of EC related burn injuries were reported, however, this is likely an underestimation of the problem.

The suggested mechanism for EC related injuries is battery malfunction. ECs are powered by Lithium ion batteries which are susceptible to “thermal runaway” reactions, which result in device overheating with potential for subsequent explosion. We explain hypothesized

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triggers for these reactions and mechanisms of other injuries associated with ECs such as chemical burns and blast injury.

**Conclusion:** EC-associated burn injury results in combined thermal and chemical burns, which should be managed in tandem. Explosion injuries sustained whilst using the device may result in both facial trauma or inhalation injury and therefore should be reviewed with a high index of clinical suspicion.

It is noted that there is no agreed standard for management for such burns by specialist bodies in the UK. We suggested a treatment algorithm to provide guidance for the burn injuries associated with ECs.

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## 1. Introduction

Following the invention of the modern electronic cigarettes (EC) in 2003 by Hon Lik [1] as an aid to smoking cessation, there has been a steady increase in its use in the UK (Hassan), with an estimated global market of around £1.8 billion in 2014 [2]. The EC is a battery-powered electronic device administers a dose of nicotine in a vaporised solution that is inhaled and is composed of a mouthpiece, a cartridge, a heating element, a microprocessor and a battery [3].

Once activated, the microprocessor turns on the heating element, creating temperatures of up to 100–250°C, which in turn vaporises the liquid solution, which may be inhaled. The liquid solution contains nicotine, flavouring, and a solvent, which is typically a combination of glycerin and polyethylene glycol. The heating element is powered by a battery, usually a rechargeable lithium battery.

In 2015, Public Health England published an expert independent evidence review that concluded that EC are significantly less harmful to health than tobacco and can potential aid smokers in smoking cessation [4].

There have been reported cases of burns secondary to explosions of the EC or its battery, flame or contact burns from overheating of the device, and chemical burns from the Lithium ion battery. In addition to this, there have also been reported cases of facial soft tissue injury in the form of full thickness skin loss of the cutaneous upper lip and complex facial fractures, with or without associated burns [5–7].

Using collective evidence, this review aims to summarise all reported burns associated with ECs, and its implications on immediate management with a particular focus on surgical treatment.

## 2. Methods

A search was conducted on PubMed, EMBASE and Medline for all case reports, case series and letters to editors published from 2014, using terms “electronic cigarette”, “e-cigarette”, “vaping” and “burn”. The search was repeated by the co-author to avoid bias and a review of the bibliographies of each paper was conducted to ensure all relevant cases were included. The mechanisms, type and severity of burn injury, and management and treatment outcomes of the patients were recorded.

Eligible papers were identified and screened using PRISMA 2009 checklist denoted in Fig. 1. Exclusion criteria included non-English articles, explosions with no associated burn and publications with insufficient information.

One paper was excluded as there was insufficient information with regards to patient demographics, mechanism of injury or treatment [8]. Two case reports and one patient in a case series were excluded because the injuries were secondary to explosion of the EC without associated burns [5–7].

## 3. Results

Our search yielded 15 case series and five case reports, with a total of 98 patients over a 4-year period. There was a male predominance (96.4%) with a mean age is 30years (range 17–58).

Flame burns were the commonest mechanism, accounting for 73 patients [1,6,9–23]. Other types of burns include three with mixed flame and chemical [12,24], six with mixed flash and chemical [25] and one with contact [26]. In the remaining 15 patients [9], the cause of burn was not clear. This study also found three patients with injuries secondary to explosions without associated burn injuries [5–7]. These were not included in our analysis.

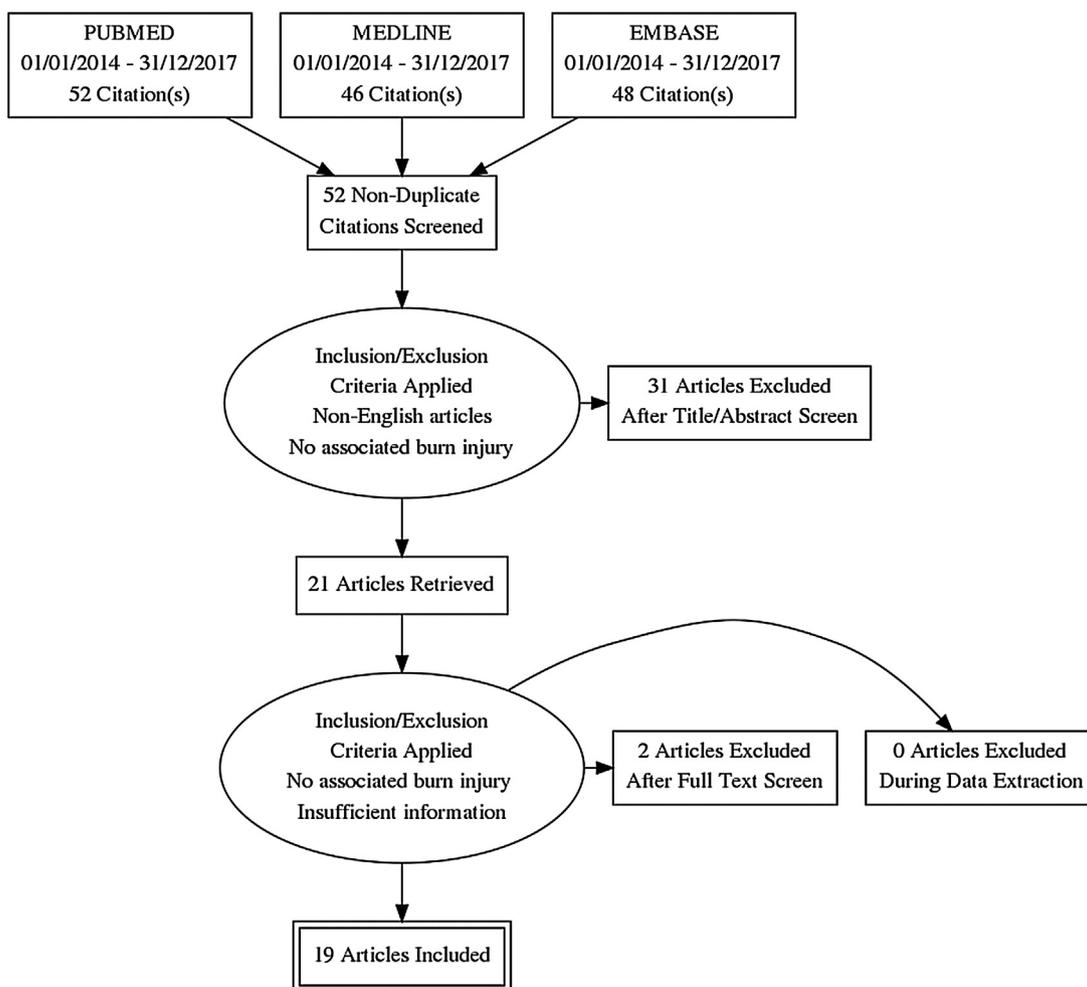


Fig. 1 – PRISMA flowchart for screening search results.

In 70 patients, where information was available, the mean percentage total body surface area (%TBSA) affected was 5.3% (range 1–27.25%) [1,11,21,23,24,12,14-20] with the majority of burns being mixed partial and full thickness. Depth was not reported in 51 patients [1,6,9,10,13,22,23]. Table 1 describes the different anatomical locations affected and number of sites affected per patient. The lower limbs were most commonly affected (97.1%), however, two patients had concomitant intraoral burns [13,22] and 12 patients had concomitant facial burns [1,9-11,20,23], one of whom underwent intubation [23]. Only two patients were reported to have received first aid [12,16].

With regards to surgical management, 30 patients with deep burns underwent excision (either sharp or hydro-surgical debridement) and autologous skin grafting within a range of 3–21 days [1,6,12,15,16,19-21,24,25]. Additionally, two other patients were treated non-autologous dressings after initial debridement; one patient received a xenograft [17] and one had biosynthetic skin dressing [12]. Furthermore, one patient had burn excision and direct closure [26].

Conservative management was used in 48 patients in the form of conventional dressings including silver-based dressings and tullegras for extremity burns and ointments for the

Table 1 – Demographics and distribution of EC-related burn injuries based on anatomical location and areas affected. There was insufficient data to work out multiple sites from Ramirez et al. and Brownson et al.

Age (years, range)	30 (17-58)	
Sex (n)	80 Male	3 Female
Mean & median TBSA (range)	4.8% & 4.5% (1-27.25%)	
Anatomical location (n)		
Face	13	
Neck	2	
Upper limb	46	
Lower limb	76	
Anterior trunk	7	
Genitalia	14	
Areas affected (n)		
1	20	
2	23	
3	5	
4	7	

**Table 2 – Summary of case reports and series on e-cigarette burns (M=male, F=female, LL=lower limb, UL=upper limb, SPT=superficial partial thickness, PT=partial thickness, FT=full thickness, TE=tangential excision, SSG=split-thickness skin graft, DNS=did not specify).**

Author (year)	Study type (number of patients)	Age (years)	Gender	Burn anatomical site	Burn	%TBSA (%)	Depth	Management
Maraqa (2017)	Case series (n=8)	20	M	LL	Flame	16	PT	Debridement+dressings
		27	M	LL	Flame	10	Mixed PT/FT	TE+SSG
		29	M	LL	Flame	6	Mixed PT/FT	TE+SSG
		29	M	Bilateral LL, genitalia	Flame	8	PT	Debridement+dressings
		23	M	LL and UL	Flame	5	PT	Debridement+dressings
		17	M	Trunk and UL	Flame	4	PT	Debridement+dressings
		36	M	LL	Flame	7	PT	Debridement+dressings and antibiotics
		47	M	LL, UL, genitalia	Flame	9	PT	Debridement+dressings
Ramirez (2017) <sup>a</sup>	Case series (n=30)	Mean 30	24M, 6F	LL– 19, UL– 16, genitalia– 4, face– 4, trunk– 4	Flame	Mean 4 (<1-8)	–	7 TE+SSG, 23 dressings only
Harshman (2017)	Case report (n=2)	30	M	Bilateral LL	Flame	10	Mixed PT/FT	TE+SSG day 3
		36	M	LL and UL	Flame	3	Mixed PT/FT and SPT	Debridement+allograft, then autograft
Treitl (2017)	Case report (n=3)	Mid 20s	M	LL	Flame	6	PT	Debridement+dressings
		Early 40s	M	LL, bilateral UL, genitalia	Flame	3-4+<1	PT	Debridement+dressings
		Early 30s	M	LL	Flame	10	PT/FT nearly circumferential	Wide excision+xenograft
Arnaout (2017)	Case report (n=3)	22	M	LL, bilateral UL	Flame	1	SPT	Tullegras dressings only
		22	M	LL, UL, genitalia	Flame	1	Mixed depth and SPT	Silicone-based dressings only
		49	M	LL	Flame	7	SPT and central deep dermal	Silver-based dressings only
Bauman (2017)	Case report (n=3)	58	M	LL	Flame	7	Mixed DPT/FT	Surgery offered but refused, then infected and TE+SSG
		20	M	LL	Flame	4	SPT	Dressings only
		37	M	LL	Flame	11	Mixed DPT/FT	Debridement+SSG
Serror (2017)	Case report (n=1)	–	M	LL	Contact	4.5×2.5 cm	FT	Excision and direct closure
Jiwani (2017) <sup>a</sup>	Case series (n=10)	Mean 26 (range 18-46)	9M, 1F	5 LL and/or genitalia, 1 UL, 4 both LL UL, 1 face	Flame	Mean 5.95% (1-27.25%)	4 PT, 5 mixed PT/FT, 1 FT	

Table 2 (continued)

Author (year)	Study type (number of patients)	Age (years)	Gender	Burn anatomical site	Burn	%TBSA (%)	Depth	Management
Scheckter (2017)	Case report (n=3)	34	M	LL	Flame	2	Mixed PT/FT circumferential	4 debridement+SSG, 1 debridement+dressings, 5 dressings/creams only
		19	M	LL	Flame	7	Mixed PT/FT	TE+allograft day 2 then day 6 SSG
		35	M	LL	Flame	15	Mixed PT/FT	TE+SSG day 3 Dressings only
Harrison (2016)	Case report (n=1)	28	M	Intraoral	Flame	–	–	DNS
Anderson (2017)	Case report (n=1)	30	F	LL, UL, face, bilateral corneas	Flame	2	–	Intubated, bronch–no airway injury, erythromycin corneal burns, dressings and ointment
Brownson (2016)	Case series (n=15)	–	–	Face 20%, UL 33%, LL 53%	Flame 12, chemical 5, blast injuries 27%	–	–	DNS
Hassan (2016) <sup>a</sup>	Case series (n=6)	–	All M	All LL and genitalia	Flame and chemical	–	Mixed depth	Versajet debridement or TE+SSG
Herlin (2016)	Case report (n=2)	24	M	Bilateral LL	Flame and chemical	5	Deep burns	TE+SSG
		37	M	Bilateral LL	Flame and chemical	3	Deep burns	TE+SSG
Paley (2016)	Case report (n=2)	45	M	UL, face	Flame	–	Superficial	Ointment
		16	M	Face, neck, bilateral UL	Flame	–	–	Ointment and dressings only
Kumetz (2016)	Case report (n=2)	29	M	Perioral	Flame	–	Superficial	Debridement and dressings only
		23	F	LL, UL	Flame	4	Mixed PT/FT	Dressings only
Nicoll (2016)	Case report (n=2)	39	M	LL, UL	Flame and chemical	4	–	Versajet debridement+SSG on day 3

(continued on next page)

Table 2 (continued)

Author (year)	Study type (number of patients)	Age (years)	Gender	Burn anatomical site	Burn	%TBSA (%)	Depth	Management
Colaïanni (2016)	Case report (n = 2)	30	M	LL, UL	Flame	3	Mixed PT/FT (thigh), superficial (hand) SPT	Debridement+Biobrane <sup>b</sup>
		41	M	-	Flame	-	-	Debridement+cadaveric allograft, then 5 day later SSG
		26	M	-	Flame	-	-	Debridement+cadaveric allograft, then 5 day later SSG
Rogér (2016)	Case report (n = 1)	18	M	Intraoral and trunk	Flame	-	-	DNS
Jablów (2015)	Case report (n = 1)	30	M	LL	Flame	8	SPT	Dressings only

<sup>a</sup> Case reports or series that reported their findings collectively.

<sup>b</sup> Biobrane (Smith & Nephew, New Zealand).

facial or ocular burns [1,10,11,14,15,17–21,23]. In 17 patients, the type of burn treatment was not recorded [9,13,22].

#### 4. Discussion

Electronic cigarettes have been available in the UK since 2007, but have only been licensed for use by the Medicines and Healthcare Products Regulatory Agency (MRHA) since January 2016 [27]. This was following a Public Health England independent review that suggested that EC were 95% safer than smoking tobacco [4]. Through the freedom of information act, it was found within this report, that over a two-year period (2013–2014) there have been 105 house fires linked to EC [4]. Over this period, there were with 19 fatalities, however, it is not clear what proportion were caused by ECs [3]. Similar figures were found over a 12-month period in the USA [28]. In this review, 90 cases of EC-related burn injury were reported over a three-year period (2015–2017), however, this is likely to be an underestimation of the actual scale of these burns (Table 2).

The mechanism for EC-related injuries is likely to be battery malfunction. ECs are powered by Lithium-ion batteries which are susceptible to “thermal runaway” reactions [15,17]. These reactions are exothermic and are potentiated by increasing temperatures of the reactants. This results in the device overheating, with the potential for subsequent explosion.

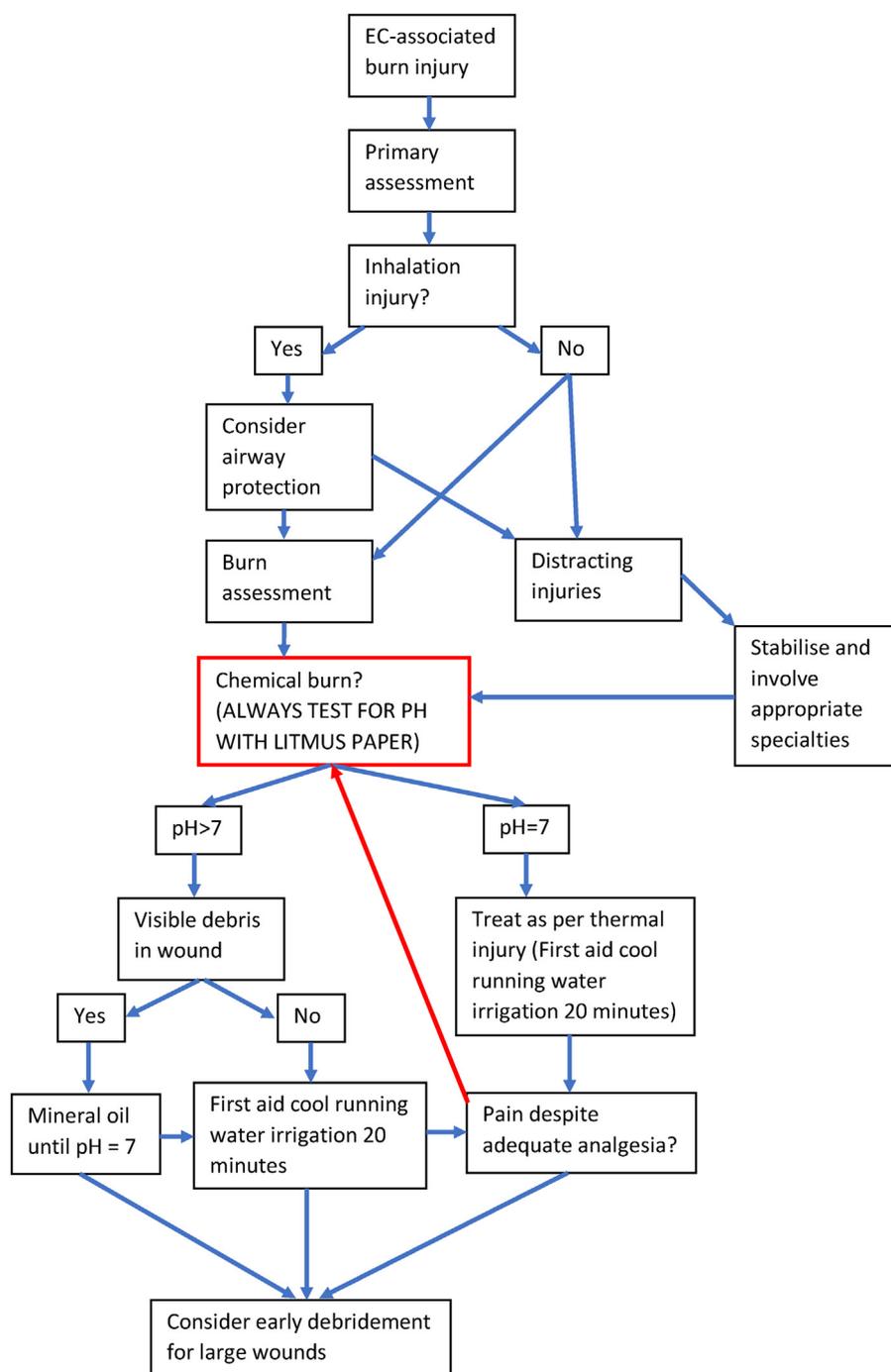
The precipitating event is thought to be multi-factorial and includes exposure of the device to a damp environment, contact with metal objects, over-charging, over-heating or faulty product casing [17,18].

Two separate triggers for the “thermal runaway” reaction have been hypothesised and include a reaction of lithium deposits on the battery anode, with moisture in a damp environment (such as a trouser pocket). This results in the formation of lithium hydroxide and hydrogen, which is highly exothermic [18].

The second theory is that metallic objects such as coins, keys or buttons in a pocket may come into contact with the EC case, producing a short-circuit and causing the battery to overheat [16,24].

Our review found 40 patients (40.8%) with spontaneous ignition or explosions of the device in their trouser pocket [1,6,11,12,16–21,24–26]. Of these, 7 patients also reported carrying coins or keys in the same pocket [16,18,19,24]. Hassan et al., Ramirez et al. and Maraqa et al. report additional patient who did carry metallic objects in the same pocket as the ignited EC, but did not specify patient numbers [1,15,25]. Jiwani et al. reported a case involving an EC explosion following motorcycle crash [20], but did not suggest an underlying cause for the device explosion.

In addition to flame and/or contact burns, which made up 76.5% (75 patients) of our study, there were reports describing EC causing chemical burns. Discharge of elemental lithium and its compounds can result in alkaline burns through the production of lithium hydroxide [18]. Our study found 9 patients (9.2%) to have combined thermal and chemical burns, which were confirmed using pH testing [12,24,25]. In this cohort, the TBSA ranged from 2 to 5%, with all burn depths described as deep partial thickness receiving surgical



**Fig. 2 – Suggested management guidelines for EC-related burn injuries.**

debridement and skin graft reconstruction. These patients represented 25.7% of all patients with EC-related burns who underwent surgical debridement and skin grafting.

Nicoll et al. and Hassan et al. reported that patients with mixed chemical and flame burns had ongoing pain due to the chemical component, despite appropriate analgesia [12,25]. In these patients, pH testing using Litmus paper confirmed an alkali burn. The pain was markedly improved following either prolonged irrigation or early debridement. It is possible that a

large proportion of the burns included in this study were due to both a chemical, and a thermal injury. However, as pH testing was not routinely performed on all patients with EC-associated burns, the chemical component is likely to have been underestimated.

Water irrigation of burns from elemental forms of earth metals such as lithium are contraindicated because of the risk of an exothermic reaction producing both thermal and chemical injury to the tissues. It is recommended that such burns are

initially managed with mineral oil. Mineral oil is a practical, inexpensive and safe. Only after the complete mechanical extraction of metal should the wound be approached with water. After complete removal of the sodium, traditional burn treatment, including debridement, may begin [29-31].

In this literature review, we found that the majority of patients sustained mixed partial, or full thickness burns from EC malfunction. 33 of these patients underwent surgical debridement of their burns, and 30 of these received split skin graft reconstruction.

At present, there is no published guidance on the management of burns from ECs. However, as ECs are becoming more popular, it is expected that there will be a rise in the number of patients presenting with EC-related burn injuries. Therefore, it is important that healthcare professionals treating burn injuries are aware of the different types of burn associated with these devices and manage them appropriately.

Finally, a small number of cases reported where explosion related injuries have occurred in isolation of associated burn injury [5-7]. It is vital that these patients undergo a thorough assessment of their airway to exclude an associated inhalational burn injury, which may result in airway compromise secondary to the blast injury.

## 5. Conclusion

With the steady rise in the use of ECs, there has been an increasing number of burn injuries secondary to the device malfunction. The resultant burn is due to a combination of thermal and chemical injuries, which should be managed in tandem. Patients presenting with explosion injuries sustained whilst using the device, may have either facial trauma and/or inhalation injuries and therefore should be assessed with a high index of clinical suspicion. The authors propose that all patients who present with such burns should have pH testing using Litmus paper prior to irrigation. If an alkali burn is confirmed, then this should be managed using mineral oil in the first instance to prevent potential exothermic burn injuries secondary to the chemical components of the EC.

It is noted that there is no agreed standard for management for such burns by specialist bodies in the UK. The authors have suggested a treatment algorithm to provide guidance for the burn injuries associated with ECs (Fig. 2). In this management flowchart, we emphasise:

- 1 Assessment for soft tissue or boney injury secondary to blast component.
- 2 Assessment for inhalation injury/airway compromise, if blast occurs whilst using device.
- 3 Always check pH with Litmus paper prior to irrigation of burn injury.
  - If pH alkaline, use mineral oil.
  - If neutral, use standard practice.
- 4 Consider surgical debridement and skin grafting vs conservative management.

## Declaration of interest

The authors herewith certify that we have no commercial, proprietary, or financial interest in the products or companies described in the manuscript. The authors did not receive grants or a consultant honorarium to conduct the study, write the manuscript or otherwise assisting the development of the above-mentioned manuscript. All authors declare that they have no conflict of interest.

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