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Title Page

Case Report:

"Thigh burns from exploding e-cigarette lithium ion batteries: First case series"

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Case Report

Thigh burns from exploding e-cigarette lithium ion batteries: First case series

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Abstract

E-cigarette (EC) use has risen meteorically over the last decade. The majority of these devices are powered by re-chargeable lithium ion batteries, which represent a fire hazard if damaged, over-heated, over-charged or stored inappropriately. There are currently no reports in the medical literature of lithium ion battery burns related to EC use and no guidance on the appropriate management of lithium ion battery associated injuries.

We report two individual cases of burn injury resulting from explosion of EC re-chargeable lithium ion batteries. Both patients required in-patient surgical management. We provide evidence that lithium ion battery explosions can be associated with mixed thermal and alkali chemical burns, resulting from the significant discharge of thermal energy and the dispersal of corrosive lithium ion compounds. We would recommend, as with other elemental metal exposures, caution in exposing lithium ion battery burns to water irrigation. Early and thorough cleaning and debridement of such burns, to remove residual lithium contamination, may limit the risk of burn wound extension and potentially improve outcomes.

1. Introduction

E-cigarettes (ECs) represent a means of avoiding exposure to the carcinogenic products of tobacco combustion. An estimated 2.6 million people in the United Kingdom (UK) now partake in this process of inhaling nicotine vapour, commonly known as 'vaping' [1]. EC's deliver a vaporised mixture of nicotine, propylene glycol, glycerol, water and food flavouring, heated by an atomiser and powered by a lithium-ion battery. Despite experimental concerns regarding safety [2-4], EC use is now considered significantly safer than cigarette smoking [5].

We present two cases of EC lithium ion battery explosion which resulted in burn injuries requiring in-patient surgical management. A search of national media revealed a number of similar injuries, indicating these are not isolated events. To the authors' knowledge, no such injuries are currently described in the medical literature. We also provide evidence that lithium ion battery burns result in mixed aetiology thermal and chemical burns. These represent unique descriptions of a mechanism of burn injury which, as EC use continues rise meteorically, may become more frequent presentations to specialist burn care providers in coming years. There is also a lack of available guidance on the management of lithium ion battery burns. As such, we aim to highlight a potential hazard of lithium ion battery injuries and its implications on immediate care and surgical management.

2. Case I

A 39 year old male steel worker was admitted to the burns unit with a presenting complaint of burn injuries to the right thigh. His injuries were sustained following the explosion of a single cell re-chargeable lithium ion battery which was stored in the right trouser pocket. The battery had been left to charge overnight. It was not engaged with the e-cigarette device and was not noted to be damaged or over-heated prior to this event. He described the explosion as rapid and without warning, with the battery roof venting flames like a "rocket in my pocket" (**Figure 1.**). On examination, approximately 4% total burn surface area (TBSA) superficial partial thickness burns to his right thigh were identified (**Figure 2 a.**) in addition to minor superficial burns to the right hand which was used to remove his clothing.

The burns were irrigated with water in the emergency department and dressed with a soft silicone dressing. On admission the patient persistently complained of a hot burning sensation, despite repeated prescriptions of standard dose analgesia. Given these complaints, a chemical aetiology was also suspected. Litmus paper testing of the burn confirmed an alkali pH of around 9-10 in direct comparison to normal adjacent unaffected skin (**Figure 2 b and c.**). Further water irrigation was attempted to neutralise this pH. On day 3 the burns were cleaned and debrided using the Versajet™ hydrosurgery system (Smith and Nephew) under general anaesthetic. A small 0.5% TBSA of deep dermal burn was noted which was debrided and grafted using a meshed split thickness skin graft. Both the persistent burning sensation and analgesic requirements significantly improved following burn wound debridement and recovery was uneventful thereafter.

3. Case II

Within two weeks of the original case, an un-related 30 year old bus driver presented to the same burn unit with injuries to the right thigh. Again these burns were sustained following the explosion of a single cell re-chargeable lithium ion battery which the patient had stored in the trouser pocket. He described a hot sensation followed by an explosion. Again, the battery roof vented flames, like a “rocket in my pocket” (**Figure 3.**). On examination approximately 3% TBSA superficial partial thickness burns to his right thigh were identified (**Figure 4.**). Minor superficial burns were also sustained to the right hand, which was used to extinguish flames. On admission the burns were gently debrided dry and dressed with soft silicone dressings overnight. The patient remained comfortable with no significant analgesic requirements. Day 1 post-injury the thigh and hand burns were cleaned with chlorhexidine preparation and scrubbed under general anaesthetic. Superficial partial thickness burns to the thigh were confirmed and managed with a temporary biosynthetic Biobrane^{TM} (Smith and Nephew) dressing, which remained clean and adherent on out-patient follow-up.

4. Discussion

Lithium ion cells are now ubiquitously utilised in consumer electronics [6]. However, their instability and potential for fire has been well documented. Damage to batteries via persistent over-charging, over-heating or crushing can result in erosion of integral safety features [6]. Such damage can trigger a hazardous short circuit, driving a “thermal runaway” reaction and battery fire [7]. Reports of these events include a significant re-call of re-chargeable laptop batteries due to fires [8] and a small number of published case reports of battery fire injuries relating to mobile phones [9-13].

There are currently no cases of lithium ion battery injuries reported in the medical literature specifically relating to EC use. However, an internet search did reveal an alarming spate of household fires relating to EC batteries [14] and a number of media reports of similar burn injuries [15] - including one fatality reported by national news outlets [16]. Given the significant number of EC users nationwide [1] and the frequency of these media reports, it is possible that the impact of such injuries is significantly under-reported and under-estimated by the medical community.

The Medicines and Healthcare Products Regulatory Agency (MHRA) recently awarded the first UK licence to an EC device, allowing it to be specifically marketed as a smoking cessation aid [17], pathing the way for the prescription of these devices to patients. Currently the import and sale of EC devices (including batteries and chargers) is unregulated, indicating that some may not currently comply with British Standard (BS) specifications [5].

Both battery fires in this report were of non-brand re-chargeable lithium ion batteries manufactured in the far-east. Both patients alleged that no shop-floor guidance on safe battery charging or the potential for fire hazard was given at the time of purchase. The use of EC's as a medical device would undoubtedly drive significant improvements in operating guidance, as well as product quality and safety standards.

Once the battery is breached by explosion, there is risk of leakage and exposure to its contents, including corrosive lithium ion compounds (such as lithium cobalt oxides or lithium manganese oxides [18]). Residual elemental lithium and its compounds react vigorously with water in an exothermic reaction producing alkali lithium hydroxide and hydrogen gas [18]. In Case 1 the patient experienced a persistent burning sensation following water irrigation and an alkali pH was confirmed on litmus paper testing. These findings suggest such a reaction may have been triggered by water irrigation, which formed heat and lithium hydroxide and potentially exacerbated his symptoms.

Previous case reports involving mobile phone burns have not demonstrated evidence of an alkali chemical component [9-12] and a literature search offered no published guidance on the specific management of lithium ion battery burns. Elemental metal exposures should not be irrigated with water as this can result in exothermic reactions and both thermal and chemical burns [19]. The use of mineral oil to cover these burns and prevent such heat-producing reactions has been advocated [20]. The authors would recommend caution in exposing lithium ion battery burns to water irrigation. Mineral oil may be useful in preventing the exothermic reaction of lithium compounds that could theoretically worsen injury. We would advocate the removal of any residual unreacted lithium compounds with early cleaning and debridement.

5. Conclusions

A current lack of guidance on safe battery use exposes EC users to the risk of harmful fires from re-chargeable lithium ion batteries. The authors would recommend further consumer guidance on the safe charging and storage of lithium ion batteries in order to further reduce this risk. There is also a lack of guidance specifically on the management of lithium ion battery burns. Potential mixed thermal and chemical burns should be considered when assessing and treating burns sustained from lithium ion battery fires, particularly when in close contact to skin. An alkali aetiology can be confirmed with litmus paper pH testing and if positive, caution should be exercised in exposing these burns to irrigation with water. The early and thorough cleaning and debridement of these burns, to remove residual lithium contamination, may limit burn wound extension and potentially improve outcomes.

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