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Case report

Canary in the coal mine—Initial reports of thermal injury secondary to electronic cigarettes☆

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ABSTRACT

The use of electronic cigarettes has become increasingly popular with claims suggesting healthier alternatives to tobacco cigarettes. However, research regarding the safety of such devices has been limited to an analysis of the inhaled vapor and the short and long-term effects on the body. A lesser recognized risk of electronic cigarette use is that of lithium-ion battery failure causing ignition, leading to severe thermal injury. Such incidents have been reported in the media but with inconsistencies from a lack of focus on the injuries sustained and a cause of ignition. The cases presented here are among the first recognized thermal injuries sustained from electronic cigarette lithium-ion battery failure, the potential rationale for these failures, and a need for increased awareness of the safety hazards of these devices.

1. Introduction

The use of electronic cigarettes (e-cigarettes) has grown in popularity in the United States since they were made available in 2007 [1]. According to the Centers for Disease Control and Prevention in 2014, 12.6% of adults 18 years and older have tried an e-cigarette at least once and 3.7% of adults use e-cigarettes regularly [2]. These battery-powered devices simulate tobacco smoking by producing heated vapor similar to cigarette smoke [3]. They work by vaporizing a liquid solution that contains variable amounts of nicotine, flavorings, propylene glycol, glycerin, and other compounds and have been marketed as a "healthier" and "cleaner" alternative to tobacco smoking [4]. While there are several ongoing investigations into the safety of inhaling these vapors, there has been little investigation to address the hidden health risk of device malfunction and subsequent explosion leading to severe burns. In fact, the Food and Drug Administration excludes the electronic component of these devices in the proposed regulations on the safety of e-cigarettes [5].

There are a variety of types of e-cigarettes with the majority of them utilizing rechargeable lithium-ion batteries. The lithium battery core is comprised of alternating layers of anode and cathode metal separated by a porous film containing a liquid electrolyte composed of lithium salts dissolved in an organic solvent [6]. The core is inserted into a metal cylinder that is sealed to prevent the electrolyte from evaporating and being released [7]. A variety of problems including thermal damage, mechanical damage, and electrical injury can initiate a phenomenon known as thermal runaway

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[8]. This results in the internal temperature of the battery increasing uncontrollably due to exothermic reactions between the lithium electrolyte and electrodes [8]. Once initiated, thermal runaway causes the heated lithium to vaporize and decompose, thus releasing gaseous lithium causing an increase in the internal pressure of the battery [8,9]. This increased pressure can cause the electrolyte components to ignite resulting in an explosion or fire [8,9]. Thermal runaway usually occurs at temperatures ranging from 70 to 250°C (with an average of 150°C), depending on the components of the battery [9]. If the consumer happens to be carrying the e-cigarette device at this time of explosion, they may suffer severe flame burns.

In a 2014 report by the U.S. Fire Administration, 25 cases of e-cigarette fires and explosions were examined and reported in the media from 2009 to 2014 [10]. This report indicated that 20 of these cases occurred while the e-cigarette battery was charging and 8 of these cases resulted in burns [10]. Another report of e-cigarette explosions in the media revealed 16 instances in the United States from 2013 to 2016, of which 5 occurred while the device was charging and the other 11 occurred when the device was in use or in the consumer's pocket, resulting in varying burns from small superficial partial thickness burns, to large, full thickness burns [10–12]. Locally, we have begun to see e-cigarette burn patients on a regular basis, treating three patients in the past four months. This frequency is likely to continue to increase as batteries become fatigued, and the numbers of patients using electronic cigarettes increases. This case series is among the first attempts in the medical literature to demonstrate the significant burns that can result from e-cigarette battery failure.

2. Case presentations

2.1. *Case #1*

A 58-year-old male presented to the emergency department (ED) after apparent lithium-ion battery thermal runaway resulting in the explosion of his e-cigarette located in his left anterior pants pocket. It was unclear at the time of presentation whether or not the patient had additional objects in his left pocket or how he had been charging his lithium battery at home. The explosion resulted in a 7% total body surface area (TBSA) combination of deep partial-thickness and full-thickness burns to the anterior and lateral aspect of his left thigh (Fig. 1). Initially, the patient was managed by daily debridements and silver sulfadiazine (SSD) dressing changes to allow declaration of the burn wound. Over the course of a three days, the wound evolved into nearly a totally full thickness burn, and it was determined the patient would benefit from split-thickness skin grafting (STSG), however he refused. Therefore his wounds continued to be managed conservatively with daily SSD dressing changes and he was discharged from the hospital.

After approximately 3 weeks of dressing changes and a bout of burn wound cellulitis, for which he required parenteral antibiotics, the patient agreed to undergo tangential excision and STSG. His wound bed had developed appropriate granulation tissue by this time allowing for nearly 100% take of the meshed graft. He was discharged home and has made a full recovery.

Fig. 1 – Patient #1: granulating wound 20 days after combination of partial and full-thickness burns to left thigh sustained from thermal runaway of e-cigarette device.

2.2. *Case #2*

A 20-year-old male presented to the ED with a burn to his right lower extremity. Immediately prior to the burn, the patient had disassembled his e-cigarette and changed out the used battery, putting the device in his right anterior pants pocket, which also contained his car keys and some spare change. These metallic items likely caused a short in the unshielded battery leading to thermal runaway and the resulting flame

Fig. 2 – Patient #2: 4% partial-thickness burn to right medial thigh after his e-cigarette battery failed while in patient's pants pocket.

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