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Blast injury of the finger caused by mobile battery explosion: A case report

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ABSTRACT

Lithium-ion batteries can cause several types of injuries upon explosion due to misfire. We report a case in which a mobile battery explosion resulted in high-pressure injection of metal debris into a small entry point on the skin creating puncture wounds on a patient's index finger, necessitating surgical intervention for massive debridement. A healthy 45-year-old, right-hand-dominant woman presented to the emergency department 4 h after a mobile battery had exploded in her left hand, causing burns to the left index finger. The battery had exploded due to misfire because the patient had accidentally hit it with a hammer. Radiographs of the index finger demonstrated foreign material extending from the fingertip to the ulnar proximal phalanx along the flexor tendon sheath, which was consistent with a high-pressure injection injury. She underwent semiurgent incision, irrigation, and debridement of the left index finger the day after the injury. The wound healed uneventfully within a month. At the 6-month follow-up, the palm-to-tip distance was 1 cm, and sensation at the tip was recovered. Compositional analysis of the debris revealed that the two major elements were aluminum and nickel (both less than 10%); lithium constituted less than 1% of the debris, a level deemed safe in humans. The protocol of semiurgent incision, irrigation, and debridement was safe and effective in the treatment of the injection injury caused by the mobile battery explosion.

Introduction

Lithium-ion batteries have many advantages such as high energy density and a long cycle life despite their potential risk of explosion that can cause several types of injuries [1]. Several processes may cause ignition, including contact of the lithium metal with water, which produces flammable hydrogen gas; dendrite formation, particularly in rechargeable systems, with internal short-circuiting; thermal runaway from self-heating; and oxidation of organic solvents. The failure rate of lithium batteries is 1 in 10 million. At least four billion lithium-ion batteries are generated per year, and the number of devices in which they are used is increasing; consequently, the number of related injuries is also rising [2]. Despite several case reports of electronic cigarettes exploding because of a malfunction of the lithium-ion battery [3], blast injuries caused by mobile battery explosions have not been reported

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Fig. 1. Radiographs of the index finger demonstrated foreign material tracking from the fingertip to the ulnar proximal phalanx along the flexor tendon sheath.

Fig. 2. Intraoperative assessment of the left index finger after deep dissection revealed black material that was diffusely tracking along the neurovascular bundles and deep subcutaneous tissue but did not penetrate the flexor tendon sheath tissue.

previously, according to our search of the recent literature and to the best of our knowledge.

We report a case in which a mobile battery explosion, caused by the impact of a hammer, resulted in high-pressure injection of metal debris into a small entry point on the skin creating puncture wounds on a patient's index finger, thereby necessitating surgical intervention for massive debridement.

Case presentation

A healthy 45-year-old, right-hand-dominant woman presented to the emergency department 4 h after a mobile lithium-ion battery had exploded in her left hand, resulting in burns to the left index finger. The battery had exploded because the patient had accidentally hit it with a hammer. Radiographs of the index finger demonstrated foreign material tracking from the fingertip to the ulnar proximal phalanx along the flexor tendon sheath, which was consistent with a high-pressure injection injury (Fig. 1). The patient was referred to our institute the day after injury for incision, irrigation, and debridement of the left index finger. Intraoperative examination revealed a tiny hole at the distal aspect of the digit that opened to deep tissue. An ulnar lateral incision starting at the distal phalanx at the level of

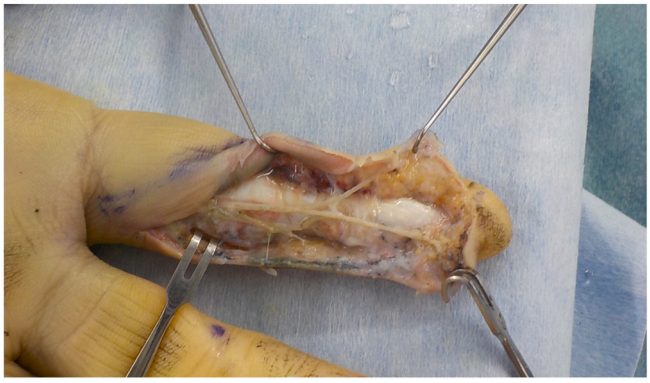

Fig. 3. Postoperative appearance of left index finger after the thorough irrigation and debridement of foreign material.

Fig. 4. Ulnar side of the finger at the time of the latest follow-up, 6 months after surgery.

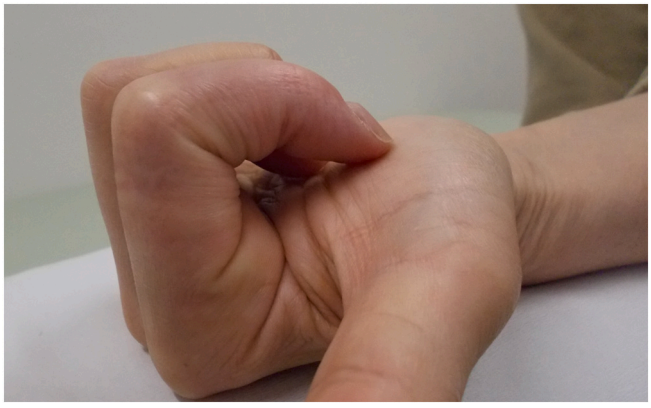

Fig. 5. Palm-to-tip distance was 1 cm at the time of the latest follow-up, 6 months after surgery.

the hole and extended into the proximal phalanx was made. Deep dissection revealed black material that was diffusely tracking along the neurovascular bundles and deep subcutaneous tissue but did not penetrate the flexor tendon sheath tissue (Fig. 2). The finger was thoroughly irrigated with saline. Foreign material was not adhered to the subcutaneous soft tissue and neurovascular bundles and could be easily and thoroughly debrided (Fig. 3). No flexor tendon sheath injury was observed after debridement. The finger was then closed loosely, and the patient was discharged after surgery.

Result of compositional analysis

Inductively coupled plasma optical emission spectroscopy [4] with an ICPS-8100 spectrometer (Shimadzu Corporation, Kyoto,

Japan) was used to confirm the elemental composition of debrided foreign material. Aluminum and nickel constituted the majority of the debris (both were less than 10%); the rest of the debris comprised lithium, sulfur, manganese, cobalt, and copper (each less than 1%).

Postoperative management

Supervised range-of-motion (ROM) rehabilitation started the day after surgery. Oral loxoprofen (1 tablet 3 times a day) was prescribed for postoperative pain management for 2 weeks. The wound was treated conservatively with daily dressing using white petrolatum. The wound healed uneventfully within a month after surgery (Fig. 4). The patient continued to have some altered sensation at the tip and ulnar aspect of the finger. At the time of the latest follow-up, 6 months after surgery, the palm-to-tip distance was 1 cm, ROM of distal and proximal interphalangeal joint were 90° and 45°, and sensation at the tip was recovered (Fig. 5).

Discussion

We report a case of high-pressure injection injury resulting from a mobile battery explosion caused by the impact of a hammer. Semiurgent incision, irrigation, and debridement enabled uneventful wound healing and resulted in good clinical outcome. Most mobile battery explosions have occurred while the device was charging [5]. Heat buildup in the device can damage the insulation layer and cause an electrical shortage, and the temperature can rise rapidly to 500 °C (932 °F), resulting in fire or explosion of the device. This thermal runaway is known as “venting with flame” [2]. High-pressure injection injuries of the digits usually occur in industrial settings when equipment capable of high-pressure injections inadvertently injects substances into the fingers or hand [5]. Because the use of batteries in mobile devices is widespread, high-pressure injection injury caused by device explosion may occur in daily life.

The lithium-rich and manganese-based material is one of the new generations of cathode materials in lithium-ion batteries and is widely used because of its high energy density, low cost, and lesser toxicity [6]. Park et al. conducted a risk assessment of hydrofluoric acid and lithium hydroxide, which can leak from lithium-ion batteries, and concluded that skin exposure to lithium hydroxide was deemed safe for humans because the quantity of lithium in a mobile battery is low [7]. This finding is consistent with the findings of the compositional analysis in our patient. All findings indicate that emergency surgical intervention and massive debridement are not always required, but the patient should be monitored for blistering caused by the heat injury. Semiurgent incision, irrigation, and debridement were safe and effective in the treatment of the injection injury caused by a mobile battery explosion in our patient.

Declaration of competing interest

None.

Acknowledgements

None.

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