



Review article

Pediatric button battery injuries: 2013 task force update[☆]

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ABSTRACT

Over the last 10 years, there has been a dramatic rise in the incidence of severe injuries involving children who ingest button batteries. Injury can occur rapidly and children can be asymptomatic or demonstrate non-specific symptoms until catastrophic injuries develop over a period of hours or days. Smaller size ingested button batteries will often pass without clinical sequelae; however, batteries 20 mm and larger can more easily lodge in the esophagus causing significant damage. In some cases, the battery can erode into the aorta resulting in massive hemorrhage and death. To mitigate against the continued rise in life-threatening injuries, a national *Button Battery Task Force* was assembled to pursue a multi-faceted approach to injury prevention. This task force includes representatives from medicine, public health, industry, poison control, and government. A recent expert panel discussion at the 2013 American Broncho-Esophagological Association (ABEA) Meeting provided an update on the activities of the task force and is highlighted in this paper.

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1. Introduction

Injuries related to button batteries in children have been a problem for several decades [1–3]; however, a dramatic rise in severe or fatal outcomes has occurred [4]. In the United States, a child may be seen in the emergency room with a battery related complaint as often as every 3 hours [5]. This has prompted increased attention to this issue. There are more and more consumer electronics available today that are powered by button batteries. Many of these batteries are 20 mm or greater and contain 3 V, making them large enough to get stuck and more powerful, leading to more severe injuries in children. In fact, 12.6% of children who ingested a 20 mm battery suffered severe or fatal injuries [6]. Furthermore, it is typical in nearly all households, to find several button battery-powered devices and button batteries themselves.

To develop prevention strategies for pediatric battery ingestions, battery ingestions ($N = 3989$) reported to the National Battery Ingestion Hotline (NBIH) with known battery source, occurring in children younger than 6 years, were analyzed [6]. In these young children, 61.8% of ingested batteries were most often obtained directly from the product by the child, 29.8% were loose, sitting out or discarded, and 8.2% were obtained from battery packaging.

Until safer battery technology is developed and common in the market place, securing the battery compartment of the product is the single most important intervention required to prevent battery ingestion injuries. Parent and caregiver education is needed to eliminate those left out, loose. Finally, battery package redesign with child-resistant packaging enclosing each battery in the package has the potential to further reduce ingestions.

Knowledge of the intended use of the ingested batteries also helps us direct our prevention efforts. While hearing aid batteries lead the list when all battery sizes are considered (31% of ingested batteries reported to NBIH from July 2010 to June 2012), these batteries are smaller (7.9 or 5.8 mm in diameter), thus pose a risk of nasal cavity or ear canal insertion, but much less risk when swallowed. In contrast, during this same period, the most common intended use of ingested 20 mm lithium cells was remote control devices, implicated in 36.2% of cases, and not surprisingly readily-accessible to young children. Other ingested 20 mm lithium cells were intended for games and toys (13.1%), watches and stopwatches (8.5%), flameless candles (7.7%, ironically this “safer candle” introduces another hazard), bathroom and kitchen scales (3.8%), and key fobs (3.1%). Less common uses remind us that these dangerous batteries are everywhere, as evidenced by ingestions of 20 mm lithium batteries intended for book lights, calculators, garage door openers, glucometers, talking books, timers, lighted jewelry, digital thermometers, music players, and cameras.

To effectively mitigate injuries, a formalized, multi-disciplinary national task force was established in 2012 and includes members of the American Broncho-Esophagological Association (ABEA), American Academy of Pediatrics (AAP), American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS), American College of Surgeons (ACS), American Society of Pediatric Otolaryngology (ASPO) and representatives from industry, government, poison control, and public health.

The *Button Battery Task Force* has been divided into subcommittees including industry re-design, education, government relations, and funding/finance. The goals stem from a multi-prong strategic approach:

- (1) Outreach and education of medical and non-medical community: Can we increase awareness of this issue?

- (2) Button battery compartment design: Can these be more secure?
- (3) Electronic product and button battery warning labels: Can these be made more effective?
- (4) Button battery packaging: Can this be as safe as possible to limit a child's direct access from packaging?
- (5) Button battery design: Can we eliminate the hazard by making the battery safe?

The taskforce established a central mission statement:

A collaborative effort of representatives from relevant organizations in industry, medicine, public health and government to develop, coordinate and implement strategies to reduce the incidence of button battery injuries in children.

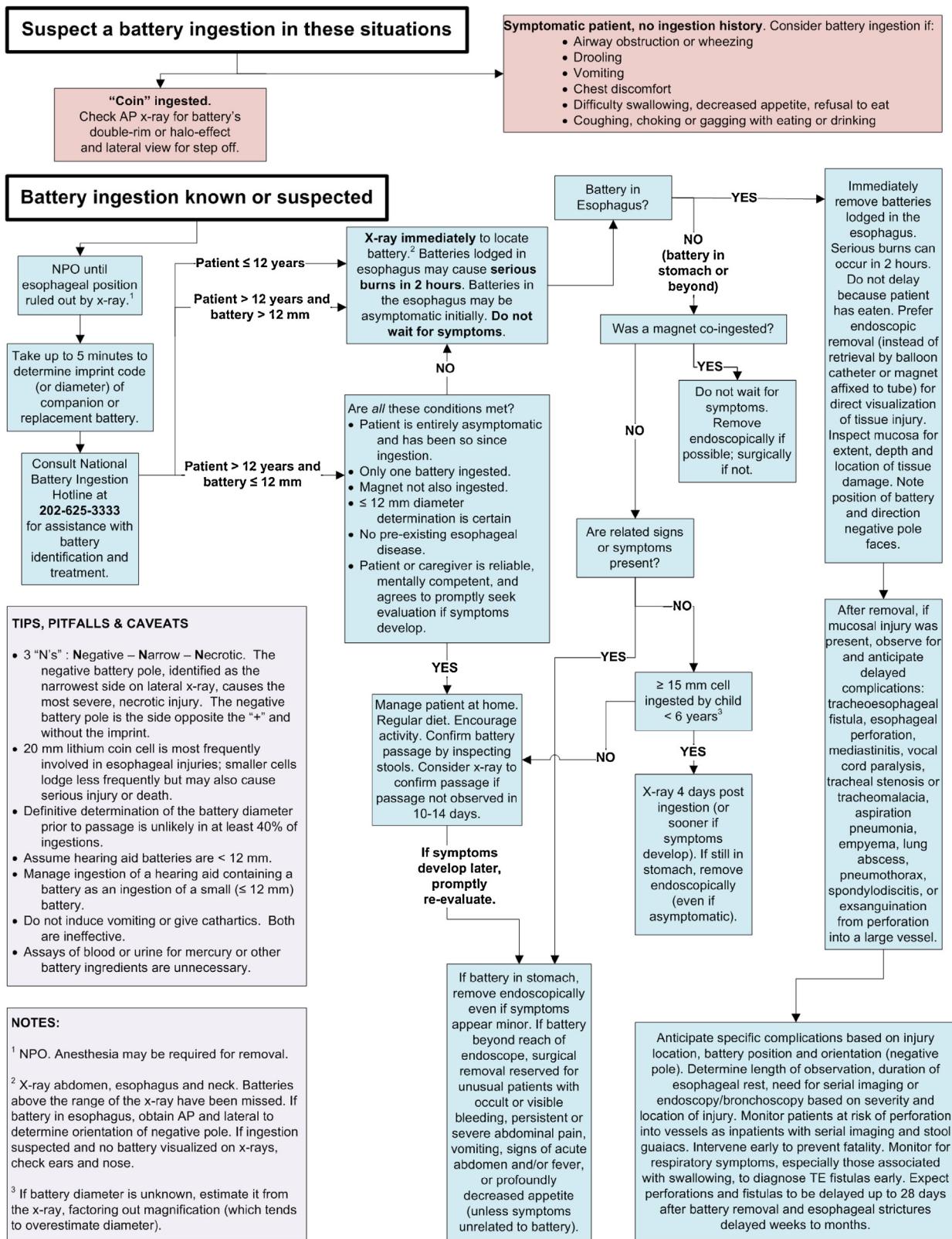
In this report, we provide an update on pediatric button battery injuries and outline the strategies of the task force based on a recent expert panel of the taskforce at the ABEA meeting in Orlando, FL.

2. Clinical diagnosis

When caretakers do not witness the event, foreign body ingestion (including button battery ingestion) can be a difficult diagnosis for physicians to make, as the symptoms are similar to other common viral illnesses seen in children. Symptoms of cough, fever, decreased oral intake, difficulty swallowing, sore throat, vomiting can be seen with both situations. Not every child with any of these symptoms will have an X-ray performed looking for a foreign body. With button battery ingestion, the challenge is that the clock is ticking, and injury can occur from the moment the battery is placed within the body. In as little as 2 hours, severe injury can occur. Even when a witnessed button battery ingestion occurs, it can be very difficult to get that child to an emergency room and taken to surgery for removal in less than 2 hours. When diagnosed at non-pediatric facilities, prompt communication and expedited transfer to a capable facility is imperative; an alert to the accepting surgical team can help avoid any further delay. The current NBIH triage and treatment guideline (Fig. 1) focuses on the 2 hours window during which esophageal batteries must be removed to avoid serious esophageal damage. The algorithm urges providers to X-ray immediately to exclude an esophageal position for ingested batteries and to remove those batteries expeditiously [4]. While all children 12 years and younger who have ingested a battery must get an X-ray immediately, whether symptomatic or not, older patients who ingest a single battery that is 12 mm in diameter or less need not have an initial X-ray if completely asymptomatic (assuming no co-ingested magnet, no pre-existing esophageal disease and reliable follow-up is possible). When the ingested battery diameter is unknown or uncertain, an X-ray is always indicated. It is important to consult the guideline for specific nuances of case management.

3. Radiographic diagnosis

X-ray imaging is essential to make the diagnosis of button battery ingestion and confirm the exact location in the body. When looking at any round, opaque foreign body on anterior-posterior X-ray, it is useful to *zoom in* and look for a *double ring* or *halo sign* to distinguish it from a coin (Fig. 2), [7]. The lateral X-ray can be helpful if a *step-off* can be noted, as seen with some batteries, however, there are some slimmer designed batteries on the market now that may not be distinguishable from a coin on a lateral image alone (Fig. 3). Close inspection of the imaging is important to quickly make the correct diagnosis. The negative or narrower



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Fig. 1. NBIH Triage and Treatment Algorithm for Battery Ingestions. Reproduced with permission from www.poison.org/battery/guideline.asp and adapted from: Litovitz et al. [4].

part of the battery can help guide clinicians to where the most severe tissue injury may occur and what potential complications should be considered in the patient. The 3 N's mnemonic, "Negative – Narrow – Necrotic", reminds the clinician where to anticipate the most severe damage.

4. Mechanism of injury

The battery size, voltage, location in the body, tissue contact, and local fluid environment can all affect the potential degree as well as speed of injury. The more common 11.6, 7.9 and 5.8 mm

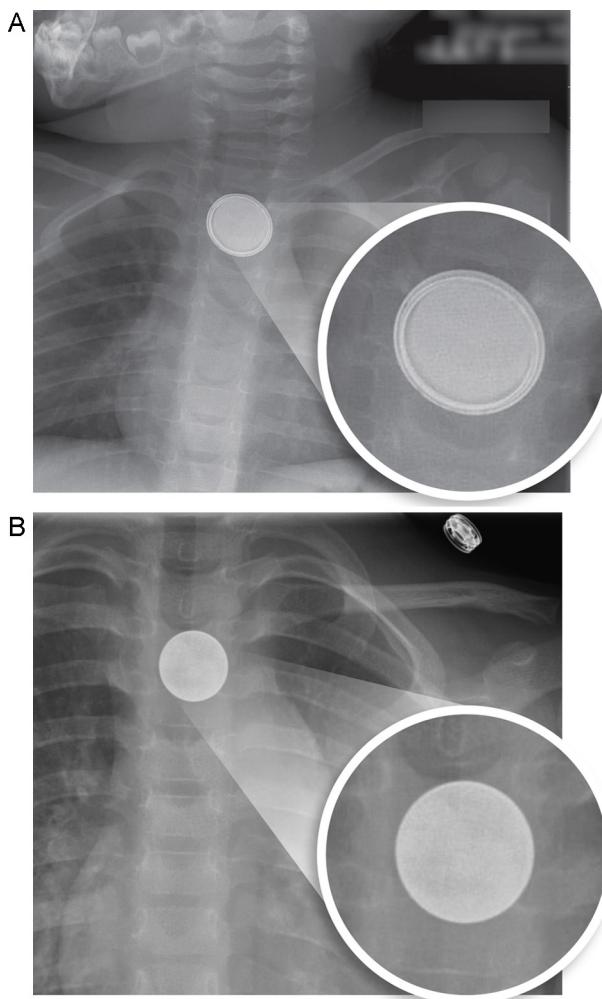


Fig. 2. Anterior-posterior X-rays. (A) On top, a button battery with *double ring* or *halo sign*; (B) On bottom, a coin with homogenous appearance. Reproduced with permission from Jatana [7].

traditional button cells while an injury risk when placed in the nasal cavity or ear canal, are less likely to get stuck in the esophagus and cause injury. The larger diameter lithium batteries, particularly 20 mm or greater, increases the risk of esophageal lodgment, especially in small children. Further, these cells have a higher voltage (3 V compared to 1.5 V for the traditional and smaller button cells). Lithium cells are readily recognized by their imprint codes; the most common, in descending frequency order, are CR2032, CR2025, or CR2016 (the prefix DL may be used instead). Lithium cells do not contain an alkaline electrolyte, but only a mildly irritating organic electrolyte, thus contrary to popular belief, leakage is not the cause of lithium coin cell injuries.

The most significant mechanism is the generation of hydroxide ions at the negative pole of the battery caused by the current created through the adjacent tissue. Human tissue basically acts to 'connect the circuit' around the two poles of the battery. The

resulting hydroxide accumulation is comparable to an alkaline caustic injury, leading to tissue liquefaction and necrosis. A tissue pH of >10 can occur rapidly driven by the voltage of the battery, but this is a *powered alkaline burn*. The higher the voltage, the faster this process occurs. While a clinically significant outcome is 3.2 times more likely with a fresh compared to a spent cell, of particular note, cells that are "dead" or "spent" and no longer meet the specifications required to power a product, still retain sufficient residual voltage to generate hydroxide and cause severe, even fatal, tissue damage. Any button battery with a residual voltage of 1.2 V or greater can cause injuries to surrounding tissue. Systemic heavy metal or lithium poisoning from leakage of button battery contents is not typically an issue, and the pressure of the battery itself is also not a major source of injury.

5. Surgical management

Once the diagnosis is made, emergent removal from within the body offers the best potential outcome for the patient. When located in the nasal cavity or ear canal, removal can sometimes be accomplished in the emergency room setting. Button batteries located in the esophagus are typically managed in the operating room. Endoscopic removal from the esophagus with direct visualization can be performed with optical graspers. Care must be taken to avoid blind passage of an endoscope that could potentially exacerbate injury.

Fluoroscopic removal of esophageal button batteries with a magnet has been reported, however, this technique fails to directly assess the site of acute injury after removal.

Assessment for the extent of acute injury should be performed, and the location and direction of the negative pole of battery allow the physician to anticipate the location of potential acute and delayed complications (Fig. 4). Airway evaluation with laryngoscopy and bronchoscopy in the operating room, even in absence of airway symptoms, should be considered to evaluate the membranous trachea, especially when the negative pole of the battery is facing anteriorly within the esophagus [7]. When the ingestion has occurred in the United States it is essential to report the case to the National Battery Ingestion Hotline (NBIH) at (202) 625-3333 with the size/type of battery, source of battery, and any available clinical data.

6. Post-operative considerations

Depending on the extent of injury noted at the time of endoscopic removal, several additional tests can be considered. Table 1 shows a summary of reported complications from button battery injury. A contrast esophagram can rule out a perforation in the acute setting. If a perforation exists, alternative feeding methods will be required. If any voice change, symptoms of aspiration, or stridor occurs, awake flexible laryngoscopy should be performed to assess vocal cord mobility. Laryngeal EMG can also be considered in cases of vocal cord paresis or paralysis to help guide clinical decision-making.

Progression of injury is a hallmark of button battery injury, and sometimes it takes days to weeks for tissue to declare itself as

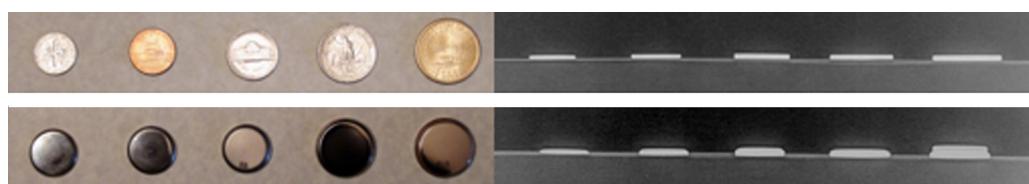


Fig. 3. Top row showing lateral X-ray imaging of the photographed coins; bottom row showing lateral X-ray imaging of the photographed button batteries. An obvious step-off CANNOT always be seen with all button batteries on lateral radiographic imaging (especially the 2 batteries on the far left).

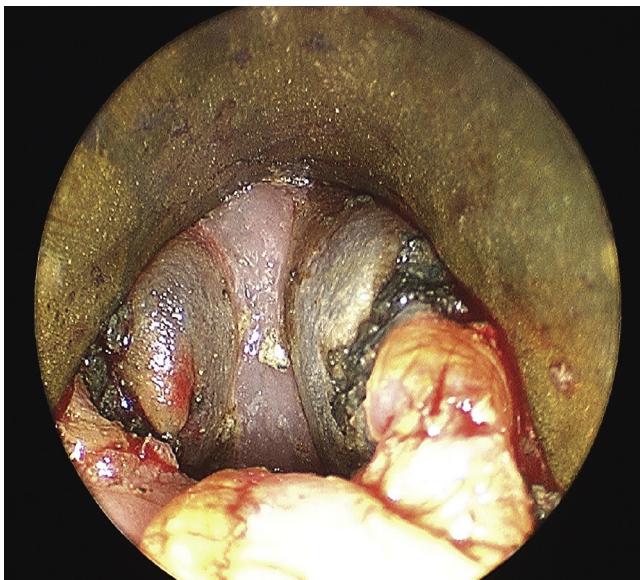


Fig. 4. Rigid esophagoscopy in a 4 y/o boy, visual inspection after removal of the battery can assess the extent of injury. Here the injury extended into the muscular layer of the esophagus. The negative pole was facing anteriorly, and the worse injury (tissue necrosis) is seen at the step-off of the negative pole. Direct laryngoscopy and bronchoscopy, flexible awake laryngoscopy, and esophagram were normal. Reproduced with permission from Jatana [7].

viable or non-viable. Although severe injuries can occur in cases when the battery lodges in the esophagus for just 2 hours, these complications are actually delayed up to 9 days following battery removal for tracheoesophageal fistulas, up to 28 days following battery removal for aorto-esophageal fistulas, and weeks to months for esophageal strictures or spondylodiscitis. In stark contrast, batteries which pass to the stomach usually traverse the remainder of the gastrointestinal tract without incident, and if the patient remains asymptomatic, most of these cases (a few exceptions are defined in the algorithm) can simply be followed in 10–14 days with an X-ray to confirm passage if the battery was not noted in the stool.

Contrast enhanced CT or MRI can help assess for mediastinitis and/or proximity of inflammation to major blood vessels. When the negative pole of battery faces posteriorly, spondylodiscitis can present as neck pain or stiffness, and can be further assessed with MRI.

After discharge from the hospital, when significant esophageal injury is present, either contrast esophagram or repeat endoscopic evaluation of the esophagus should be considered for surveillance as stricture formation can occur several weeks after

Table 1
Summary of button battery complications.

Site	Complication
<i>Nasal cavity</i>	Nasal septal perforation, intranasal synchiae, periorbital cellulitis
<i>Ear canal</i>	Tympanic membrane perforation, hearing loss, facial nerve paralysis
<i>Esophagus</i>	Mucosal burns to complete perforation, mediastinitis, stenosis/stricture formation
<i>Larynx</i>	Vocal cord paralysis (unilateral or bilateral) from recurrent laryngeal nerve dysfunction
<i>Thyroid</i>	Parenchymal hemorrhage
<i>Tracheobronchial</i>	Tracheoesophageal fistula, battery aspiration, bronchial stenosis
<i>Spine</i>	Spondylodiscitis
<i>Aorta or other major vessels</i>	Aortoesophageal or other major arterial branch fistula (death)

the initial injury. If stricture occurs, early dilation can lead to best swallowing outcomes. Nevertheless, further prospective studies are needed to elucidate the exact timing of repeat endoscopy and/or imaging.

In severe cases, some children will require open surgery to repair the esophagus and/or trachea, and be unable to eat by mouth, requiring gastrostomy tube placement. Other cases complicated by airway obstruction symptoms from vocal cord paralysis may require tracheostomy tube placement. A definite potential morbidity and mortality exists with button battery injuries in children, and this is why prevention of these injuries is of critical importance.

7. Trending and monitoring the button battery ingestion problem

The NBIH was established at the National Capital Poison Center in 1982. The hotline was established to gather battery ingestion case data to inform clinical triage and treatment algorithms and identify hazards that could be eliminated through changes in product design, packaging, warnings and education. Over the subsequent 30 years, the health professionals staffing the NBIH have provided 24/7 guidance to the public and providers, analyzed more than 14,000 battery ingestions to identify factors contributing to severe outcomes, and published and refined clinical guidelines for case management. Health professionals managing serious battery ingestion cases are urged to contribute to future advances by reporting cases to the NBIH at (202) 625-3333. Call for assistance or just to report cases.

Updated statistics, safety tips, clinical data on severe and fatal cases, updates to the triage and treatment algorithm, and an extensive discussion of the mechanism of injury can be found at www.poison.org/battery.

Looking back, multiple data sources demonstrate a dramatic increase in the severity of button battery ingestions beginning around 2006, and the rate of major or fatal outcomes was more than 5-fold higher in 2006–2012 compared to the rate two decades prior (1986–1992). The National Poison Data System (NPDS), capturing data from all US poison centers, fails to show a consistent trend in battery ingestion frequency from 1985 to 2012, but displays a dramatic increase in cases with significant clinical outcomes over the past 7 years (Fig. 5). In 2012, 3435 button battery ingestions (10.8/million population) were reported to NPDS, but that is assumed to be just the tip of the iceberg, as most battery ingestions are not reported. Children younger than 6 years comprised 66% of button battery ingestions reported in 2012 [8], and all 30 of the fatalities reported to date have occurred in children 4 years of age or younger [9].

The increased marketing and use of lithium coin cells, especially the 20 mm diameter cells, is responsible for the increase in severity. Currently, nearly all severe button battery ingestion cases involve lithium cells; the few exceptions occur with ingestions in very young children (younger than one year of age). Further, an alarming 12.6% of children younger than 6 years who ingested 20 mm diameter lithium coin cells experienced a major effect such as a perforation, tracheoesophageal fistula, fistulization into major vessels, esophageal strictures, vocal cord paralysis, or spondylodiscitis [6].

8. Voluntary efforts, product safety standards

The product standards industry is another avenue for major product safety testing and certification. Companies such as Intertek® and Underwriters Laboratories (UL) will determine the root cause of product injuries by analyzing products for design flaws, child behavior patterns and consumer behavior and make

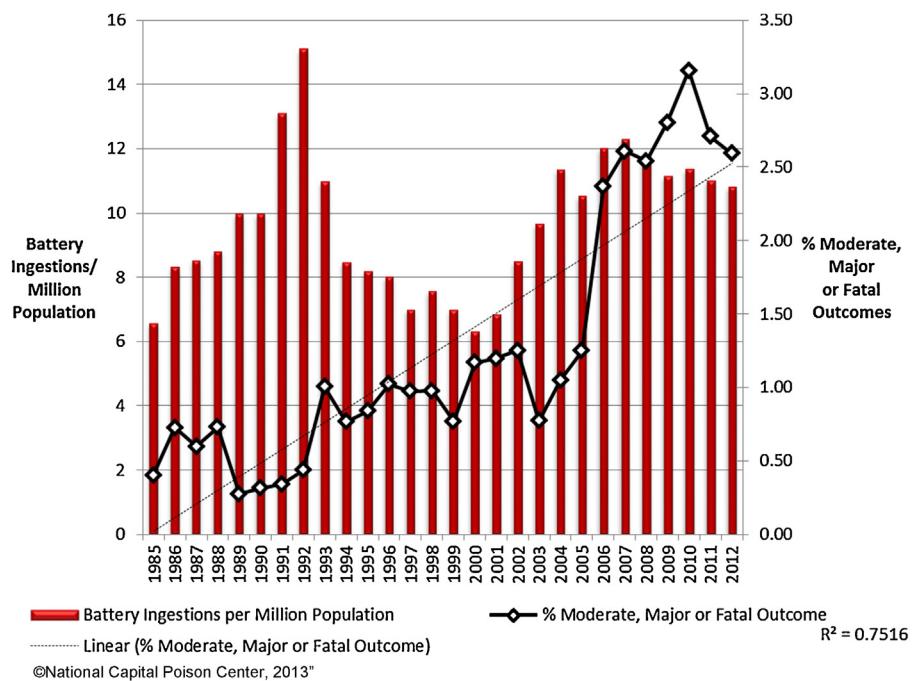


Fig. 5. National Poison Data System (NPDS) Button Battery Ingestion Frequency and Severity. Reproduced from www.poison.org/battery/stats.asp, with permission [8].

safety recommendations. In addition, the majority of batteries ingested have been obtained directly from products so safer compartment design could provide the single most effective intervention to mitigate injury. UL, of the product standards industry along with the American National Standards Institute (ANSI), has also addressed this issue with ANSI/UL 60065: *Standard for Audio, Visual, and Similar Electronic Apparatus-Safety Requirements* [10]. The button battery must be contained and a tool or a minimum of 2 simultaneous independent movements required to gain access to it. This standard obtained consensus in April 2012 and mandatory compliance is effective in January 2014. A newer standard with broader scope, ANSI/UL 4200A: *Standard for Safety for Products Incorporating Button Cell Batteries of Lithium and Similar Technologies*, is currently under development. The proposed product requirements also include abuse and stress testing, as well as battery replacement testing. These requirements will be American National Standards-applicable to electronic devices supporting safe design principles.

9. Energizer's part of voluntary industry efforts

Energizer® has taken a number of important steps to mitigate or eliminate injuries due to the ingestion of lithium coin batteries. Their holistic approach focuses on: (1) education and outreach, (2) battery compartment design, (3) warning copy, (4) packaging, (5) battery design.

In the area of education and outreach, Energizer's diverse efforts have included letters to the medical community and device manufacturers, active participation in the voluntary standards setting process, conference participation and presentations. The biggest single focus has been on The Battery Controlled public awareness campaign with Safe Kids Worldwide to get out a common message through websites, materials, partnerships, and integrated outreach. In just 6 months, this has stimulated a significant increase in public awareness.

Access to lithium coin batteries in devices can be made "child resistant" by implementing minimum requirements for battery compartment design. Such design requirements are being applied

to all appropriate Energizer devices and to the larger industry through standards such as UL 60065.

Warning copy has been expanded to better describe the nature and mitigation of the hazard. Work in this area also includes pictogram development and implementation for the "keep out of reach of children" safety recommendation. The pictogram is being pushed to the industry voluntary standards development groups for further consideration.

Energizer has already introduced new child-resistant packaging that meets U.S. Consumer Product Safety Commission guidelines. This packaging is made from more durable and flexible materials and includes the improved warning copy and safety pictogram. Also, in the absence of a satisfactory battery solution, removal of a warning label sticker covering the negative pole is necessary for the battery to work in a device and should help educate the consumer regarding the need for proper battery handling safety and disposal (Fig. 6). The sticker does not protect against potential injury if battery is ingested with sticker still attached.

Efforts continue regarding root cause analysis to develop a more thorough understanding of the hazard. As discussed earlier, the formation of hydroxide compounds is most likely associated with caustic burns to tissue adjacent to the ingested battery. Ongoing investigation also includes changes in battery chemistry and/or battery design to potentially prevent injury from even occurring inside the body. Energizer remains committed to mitigating or eliminating injuries due to the ingestion of button batteries.

10. Legislation

Members of the current *Button Battery Task Force* presented at the U.S. Consumer Product Safety Commission in March 2011, regarding the increasing concern of button battery injuries in children. On June 9, 2011, S. 1165, the *Button Cell Battery Safety Act of 2011*, was introduced by Senators Rockefeller and Pryor and referred to the Committee on Commerce, Science, and Transportation. This legislation, aimed at the requirement of product safety standards for products that contain button batteries remained dormant. Members of the *Button Battery Task Force* have had follow-up meetings with several government representatives.



Fig. 6. A new warning label sticker on the negative pole of Energizer battery. The consumer has to manually remove this warning label and this should increase awareness of the hazard.

While most of our current effort is directed toward immediate, collaborative, voluntary changes with members of industry, we will continue to keep government representatives informed.

11. Discussion

The best approach to battery injury prevention combines reduction in the both exposure and the hazard. Exposure reduction involves changes in behavior and risk reduction through continued education, better packaging, better warning labels, and more secure compartment design. Social media now allows for multiple platforms for education of consumers. The dissemination of the knowledge of the dangers of button batteries to parents, caretakers and medical professionals is helpful, but complete knowledge of the dangers of button batteries is not enough to prevent injuries. Hazard reduction ideally also involves button battery redesign to reduce the risk of injury; the ultimate solution is direct reduction or elimination of the hazard itself.

It will take time to assess the outcomes with regard to injury from the multi-faceted approach that has been performed by the *Button Battery Task Force*. This approach helps to reduce both the exposure and the hazard. Nevertheless, even over the past year, injuries continue to occur despite the marketing, media coverage, and recent product change measures. It will take time for the new changes to have an impact as they make their way to consumers and also for other members of industry to incorporate recommended product changes. Furthermore, all efforts directed at the mitigation of injuries are counteracted by the rise in button battery sales and their increasing use in electronic devices. Our hope is that all electronics manufacturers incorporate voluntary product safety standards for devices that contain button batteries, to help prevent injury in children.

In addition, there are technical challenges and problems still to overcome with regard to button battery redesign, to completely eliminate the hazard. Not all compartments connect the circuit at the same point. A battery that cannot 'connect the circuit' inside the body, without requiring any change in battery compartment design will be the answer. One such design by Tim Cassidy of Best Buy[®], Inc., as shown in **Fig. 7** consists of soft metal plate which

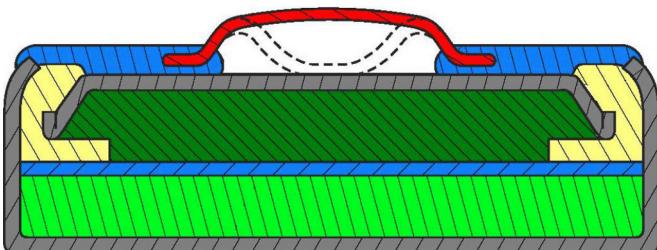


Fig. 7. Proposed modification to the button battery to prevent injury from occurring when not in a device. A switch which flips down to connect circuit is only active when within a compatible device compartment. Developed by Tim Cassidy, Best Buy, Inc.

when pressed down will make contact with the anode and complete the circuit [11]. In the normal position the battery is not active. One limitation to this is backward compatibility of electronic devices, as the battery compartment circuit must connect in this specific location. Alternative battery designs that mitigate or eliminate the hazard, while altogether avoiding the backward compatibility issue are also being considered.

Given that button batteries can look similar to coins, some have suggested making a radio-opaque marker on batteries mandatory to help make the diagnosis even more obvious on imaging. The limitation is that if clinicians become dependent on this, if they do not see it, they may miss a button battery, as there are always going to be batteries that can enter domestic circulation from other countries. By zooming in on an anterior-posterior film, one can see the *double-ring* or *halo sign*. As previously discussed, a lateral film alone is not reliable, as slimmer lithium batteries *may not* demonstrate a *step-off*. Perhaps more useful, a salivary amylase-activated dye coating on a battery, staining the lips and mouth a designated color, may help alert a caregiver that the child ingested something and suggest the need for prompt medical attention.

Once a button battery is ingested rapid medical response is essential to obtain the best possible outcome. The clinical challenge is making the diagnosis. Button battery ingestions are not witnessed in 92% of fatal outcomes and 56% of major complications; 36% of patients with esophageal batteries are initially asymptomatic [4]. If symptoms occur, they are non-specific. Not every child with symptoms of fever, vomiting, cough, poor oral intake is going to have an X-ray performed. Nevertheless, in many cases, severe injuries can occur before the battery is removed or develop in a delayed manner after the battery is removed. Clinicians must do their best to minimize the battery exposure time, assess initial damage, conduct surveillance for delayed complications, and treat complications as they arise. When dealing with such a potentially life-threatening problem, prevention needs to be the underlying, long-term goal.

12. Conclusion

Too many, otherwise healthy children, have had their lives changed by button battery injuries. Some of these children have required a feeding tube for nutrition, a tracheostomy tube to relieve airway obstruction, or major surgery; other children have died from button battery injury. In order to quantify the degree of the problem over time, all injuries must be reported to the NBIH at (202) 625-3333. Given the increasing severity of button battery injuries in children, the efforts of our *Button Battery Task Force* will continue. This requires a well-orchestrated collaboration of passionate experts in medicine, public health, industry and government to improve the safety of children. Often individuals cannot achieve their desired goals without the collaboration of other disciplines with complementary skills. Nonetheless, we look

forward to the day when button battery injuries in children are a topic of the past, but there are many obstacles ahead.

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