Title Page

Title:

Identifying Predictive Factors for Long-Term Complications Following Button Battery Impactions: A Case Series and Literature Review

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Abstract

Objectives: To complement a case series review of button battery impactions managed at our single military tertiary care center with a thorough literature review of laboratory research and clinical cases to develop a protocol to optimize patient care. Specifically, to identify predictive factors of long-term complications which can be used by the pediatric otolaryngologist to guide patient management after button battery impactions.

Methods: A retrospective review of the Department of Defense's electronic medical record systems was conducted to identify patients with button battery ingestions and then characterize their treatment course. A thorough literature review complemented the lessons learned to identify potentially predictive clinical measures for long-term complications.

Results: Eight patients were identified as being treated for button battery impaction in the aerodigestive tract with two sustaining long-term complications. The median age of the patients treated was 33 months old and the median estimated time of impaction in the aerodigestive tract prior to removal was 10.5 hours. Time of impaction, anatomic direction of the battery's negative pole, and identifying specific battery parameters were identified as factors that may be employed to predict sequelae.

Conclusion: Based on case reviews, advancements in battery manufacturing, and laboratory research, there are distinct clinical factors that should be assessed at the time of initial therapy to guide follow-up management to minimize potential catastrophic sequelae of button battery ingestion.

Keywords

Button battery; aerodigestive tract; predictive factors; esophageal foreign body; aspiration; Quantum Tunneling Composite Coating (QTCC)

1.1 Introduction

Ingestion, aspiration, and impaction of small, coin-shaped, button batteries account for over 3,300 exposures reported annually to the American Poison Control Centers and can result in clinically morbid and even fatal sequelae [1-8]. In 2013, incidence of button battery ingestions was estimated at 10.5 per million people with a fatality rate of 0.5% [1]. Invasive procedures are often required to remove ingested disc batteries from the aerodigestive tract or external auditory canal. Clinical presentation frequently involves mucosal damage to respiratory or digestive epithelium from direct pressure necrosis, electrolysis, caustic exposures, or possibly heavy metal toxicity. However, atypical and grave sequelae from battery impactions have been described to include pneumonia, tympanic membrane perforation, vertebral osteomyelitis, vocal fold paralysis, trachea-esophageal, aorto-esophageal fistula, and death [2-8].

Long-term and morbid complications of disc battery impaction are being reported in the literature but guidance on measures to predict or even prevent these sequelae has been disparately presented. The objective of this manuscript is to complement an introspective assessment of cases managed at our single military tertiary care center with a thorough literature review of laboratory research and clinical cases to develop a protocol to optimize patient care. Specifically, predictive factors of long-term sequelae are identified which can be used to guide patient management.

1.2 Methods

After obtaining approval from the local Institutional Review Board, a retrospective review of the Department of Defense electronic medical record systems at a single military tertiary care medical center was performed. Inpatient and outpatient records were queried using three International Code of Disease, Version 9 (ICD-9) codes thought to be most predictive of clinically relevant button battery impactions in the aerodigestive tract. The codes included were 935.1 (foreign body in esophagus), 934.9 (foreign body in respiratory tree), and 478.19 (nasal septum abnormalities) from a period of 01 January 2008 to 22 July

2015 occurring at our tertiary medical center responsible for 253,000 beneficiaries. Records were subsequently reviewed for evidence of button battery ingestion or impaction. Additionally the institution's pediatric otolaryngology and gastroenterology physicians were queried for recollection of cases of button battery impactions that occurred during this timeframe and could have been missed with record review.

1.3.1 Results

Eight cases of accidental button battery impaction were managed at our institution during the time period analyzed and are described (Table 1). The median age at time of injury was 33-months old. As shown, the presenting symptoms were variable and only two of the eight cases were witnessed ingestion/impactions. The long-term outcomes of these patients varied and multiple patients required repeated procedures for management of long-term complications following the initial ingestion. Two cases with unique, long-term complications are reviewed here with a focus on factors that may have been used to predict their sequelae. The other six patients required physician intervention for direct or endoscopic visualization and subsequent removal of the disc battery from the aerodigestive tract or external auditory canal. Their initial presenting symptoms are described in Table 1, but following removal and recovery from minor epithelial injuries they suffered no significant long-term complications.

1.3.2 Case 1

A two year old male presented to the emergency room (ER) with two hours of excessive drooling and intolerance of anything by mouth. A chest radiograph revealed the classic “double ring sign” concerning for a button battery (Figure 1) and a 3-volt lithium button battery (CR 2032) was ultimately removed using rigid esophagoscopy in the operating room. Superficial charred mucosal and muscular injury at the level of the cricopharyngeus muscle was noted at time of removal with low concern for esophageal perforation. At the time of battery removal neither the imaging nor intra-operative views evaluated the orientation of the battery to see where the narrow end, or negative pole, of the battery was facing.

Six-weeks after removal he presented to the otolaryngology clinic with new onset hoarseness and productive cough concerning for aspiration since the battery ingestion. Office flexible fiberoptic laryngoscopy revealed left true vocal fold immobility and a swallow study demonstrated aspiration of thin and thick liquids. He has subsequently required multiple injection medialization procedures for prevention of aspiration. The patient continues to be observed periodically without full return of vocal fold function presumably the result of direct injury caused by the proximity of the battery's negative pole to his left recurrent laryngeal nerve. He also underwent multiple esophageal dilations to manage subsequent proximal esophageal stricture formation. He continues to struggle with oral aversion secondary to his history of aspiration, although he now has return of normal esophageal caliber. He has been admitted for inpatient intensive feeding therapy in the past and currently requires outpatient occupational therapy.

1.3.3 Case 2

A two year old female presented to the ER with a 48-hour history of mild intermittent epistaxis and purulent drainage from her left nasal passage along with left-sided facial swelling. No aspiration or placement of a foreign body was witnessed. X-rays obtained in the ER revealed two concentric radiopaque circles (double ring) on lateral view and a "step-off" on anterior-posterior (AP) view (Figures 2,3). ENT was then consulted for airway foreign body removal. Anterior rhinoscopy revealed extensive sloughing of soft tissue and necrotic drainage from the left nasal passage with a button battery abutting the nasal septum. On rigid nasal endoscopy a three centimeter area of necrotic tissue destruction was present on the left along with near complete erosion of the inferior turbinate after removal of the battery (Figure 4). Cartilaginous exposure of the nasal septum with contralateral mucosal necrosis was also noted on exam. Nasal stenting was considered but not required to maintain a patent nasal airway. Over the next week her facial edema and epistaxis resolved, but a small perforation persisted in her anterior nasal septum at her last examination four months following removal. Currently, the nasal tip and superstructure remain adequately supported despite persistence of the anterior septal perforation.

1.4 Discussion

The incidence of button battery impaction requiring therapeutic intervention continues to rise concurrently with the increase in desire for miniaturized electronics [9]. Consistent with our series, children less than 6 years of age represent 68% of the more than 56,000 reported ingestions from 1985 to 2009 [10]. The most effective management strategy for battery ingestions is prevention and thus a national multi-disciplinary task force was created in 2012 to better address preventive measures. This task force published an update in 2013 to discuss such actions ranging from governmental legislature to manufacturer modification of packaging and labeling [9]. Public service messages and patient/parent education of this particular threat are additional levels of prevention and should happen at all stages of healthcare. Beyond prevention, early detection and urgent removal of disc battery impactions represent the next level of defense against long-term complications. Unwitnessed ingestions leading to a delay in prompt removal of ingested batteries are due to the function of pediatric populations and an often incomplete parental history. The median estimated time of impaction presented in this case series was over ten hours and this is commensurate with other cases of major complications presented as case reports [2-4].

The next level of care provided by an otolaryngologist should go beyond prevention and urgent removal and focus on predicting and preventing the rare catastrophic sequelae from the battery exposure. Upon reflection of the case series presented and the available literature, we have identified clinical factors that can be assessed at time of initial injury to guide management.

One such factor is identifying the anatomic location receiving the battery's electrical discharge and thus the tissue more likely to experience delayed damage. Figure 2 shows the classic "step off" that is the beveled battery edge resting on the nasal septum of the patient presented in Case 2. The narrow end represents the negative pole of the disc battery, which is often responsible for the most severe damage due to directional electrical discharge causing liquefactive necrosis [7,10,12]. The mucosal surface permits

electron discharge resulting in hydroxide ion formation near the negative pole and a subsequent increase to a basic pH that results in a focal caustic burn [9, 10]. This likely justifies the extensive necrosis and the persistent perforation to this patient's nasal septum, but may also explain why the orientation in the esophagus causes a fistulous tract preferentially to either the trachea or aorta. Thus, radiographic and/or direct visual indications of the anatomic structures abutting the narrow end of the battery can more accurately direct attention to anatomic regions requiring closer follow-up

The duration of battery impaction in the aerodigestive tract is the second major clinical factor to consider when assessing the need for interval monitoring and long-term follow-up. Ingestion time is often difficult to ascertain, as many of the incidents are unwitnessed. However, animal studies have confirmed that time to removal is a major factor in predicting long-term outcomes. Specifically, alkalization and electrolysis of the local tissue is minimized if the battery is removed within 2-3 hours; a timeframe not met in any of the eight cases in this series nor most other cases presented with major complications [10-12]. In a retrospective study of 24 children with suspected battery ingestion, Russel et al report shortened time to removal of the battery and no long-term complications when treating ingestions with a Level 1 Trauma protocol in place of the standard emergency room triage [11].

A third clinical factor which predicts the possibility of long-term sequelae is the character of the battery itself. Three volt batteries are being used with greater frequencies in newer electronics and represent greater potential for tissue electrolysis than the traditional 1.5 volt batteries. Additionally, older versions of miniaturized batteries contain heavy metals creating an additional threat of toxicity that does not exist with more recently developed lithium batteries. Based on increasing awareness of button battery toxicity, Quantum Tunneling Composite Coating (QTCC) is now being used in battery manufacturing. The QTCC prevents electrical discharge in the absence of significant pressures typically applied by battery housing equipment [15]. Thus, after removal from the patient, the battery should not be discarded, but instead thoroughly assessed to obtain information which may impact subsequent risk stratification. The voltage

rating, model number, presence of heavy metal exposure, and protective factors such as the QTCC should be noted.

Epithelial injury visualized at time of removal such as a circumferential burn in the esophagus or a partial thickness mucosal lesion heightens concern for delayed complications. Specifically, any esophageal mucosal injury warrants esophageal rest, serial imaging and/or endoscopy, serial stool guaiacs, and consideration of nasogastric tube placement to minimize the effects of stricture [10]. Based on their series of five patients, Ruhl et al recommend a close second-look esophagoscopy (CSLE) at two to four days after removal to re-assess the extent of mucosal injury [2]. In their review, CSLE permitted appropriate downgrading of the injury to facilitate earlier return of oral diet, shorter hospital stays, and provided useful prognostic information. Wurzel et al also endorses early interval bronchoscopy to monitor tracheal mucosal healing for batteries lodged specifically in the airway [7]. However, the lack of immediate visual evidence of extensive injury at time of initial removal does not rule out more serious follow-on injury [16]. Thus, there remains a need for additional factors to consider when managing patients after initial removal. In addition to these anatomic findings at time of removal, risk factors including an impaction duration greater than 2-3 hours, an impacted battery with its negative pole directed towards high value anatomy such as the aorta, a battery with greater than 1.5 volts, without QTCC, or with concern for heavy metal or lithium toxicity, should serve as red flags to aid the otolaryngologist in determining when a second look is indicated for a particular patient.

In retrospect, the two cases highlighted here represented opportunities to utilize these predictive factors to guide follow-up management. In case 1, neither lateral films nor operative reports specified the orientation of the battery's negative pole. This, in addition to the higher risk three-volt battery that was noted at removal, may have heightened concern for potential damage to the recurrent laryngeal nerve prompting interval laryngoscopies to detect vocal cord paralysis and thereby prevent his subsequent aspiration symptoms that directed delayed cord medialization procedures. Furthermore, a CSLE may have revealed a circumferential esophageal scar that would have predicted the need for dilations and

permitted earlier intervention to potentially prevent his development of oral aversion. As discussed in Case 2, the extended time of impaction in the nasal passage (48 hours) and narrow end orientation towards the septum could have been used to predict the septal perforation that was not visualized on exam at time of removal.

This study's efficacy is limited by the retrospective nature of the case series. Furthermore, it is possible that due to the inaccuracy of the ICD-9 reporting and failure to control for providers' coding that cases of button battery ingestion may have been missed during data collection. Additionally, since there are other tertiary care institutions in our catchment area for military beneficiaries it is entirely possible others were not seen and treated at our institution, thus affecting our understanding of the incidence of this complication in our military patient population.

This case series and literature review have revealed that we have sufficient knowledge to improve clinical outcomes from button battery impactions in the aerodigestive tract. Locally, we are instituting a protocol to urgently coordinate a multi-disciplinary approach with emergency medicine providers, pediatricians, and pediatric specialists in gastroenterology, surgery, and otolaryngology that acknowledges these predictive factors and works to mitigate their effects. More globally, progress in reducing the risk of small disc batteries is being made. The aforementioned QTCC batteries developed at Harvard's medical school require high pressures from equipment's battery housing compartment in order to permit electrical conduction and thus are not an electrolytic threat to tissue at physiologic pressures in the aerodigestive tract [15]. Furthermore, battery manufacturers have employed child-safe packaging that is difficult to open and with child precautions to aid in prevention of accidental impactions.

1.5 Conclusions

Small coin-shaped button batteries continue to present a hazard to young children. Incidence of these batteries becoming impacted in the aerodigestive tract remains high and major sequela continue to occur due to delay in diagnosis or treatment. Prevention and urgent battery removal are key to preventing long-term complications, but there are clinical factors that should be assessed at time of battery removal to

guide follow-on management. Specifically, the orientation of the battery's negative pole, the estimated time of impaction, and the characteristics of the specific battery should be used to guide whether an interval exam is indicated. A protocol to utilize these predictive factors to guide management is being implemented locally with plan to track its efficacy and modify as needed with the goal to minimize and possibly prevent long-term complications.

Table 1. Patient Results Summary

Age (Months)	Gender	Presenting Symptom	Location of Impaction	Estimated Time of Impaction
19	M	Decreased oral intake, Reflux Symptoms	Esophagus	3 months
38	M	Acute abdominal pain, Vomiting	Esophagus	12 hours
49	F	Witnessed ingestion, chest pain	Esophagus	5 hours
27	F	Witnessed ingestion	Esophagus	9 hours
38	F	Sore throat, chest pain	Esophagus	6 hours
26	M	Decreased oral intake, drooling, cough	Esophagus	6 hours
28	F	Epistaxis, Facial swelling	Left nasal passage	48 hours
121	M	Otalgia, Muffled Hearing	External Auditory Canal	3 days

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Figure 1. Chest radiograph in AP view showing double ring or halo concerning for impacted disc battery in the proximal esophagus.

Figure 2. AP view of disc battery in the left nasal passage demonstrating step-off. The narrow end is the negative pole and is positioned against the nasal septum.

Figure 3. Lateral view of the disc battery impacted on the left nasal passage demonstrating the classic “double ring” or “halo” sign with two concentric circles

Figure 4. Endoscopic image of left-sided nasal passage showing obliteration of the inferior turbinate on the right and liquefactive necrosis of the nasal septum on the left.