Button battery injuries in the pediatric aerodigestive tract

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Abstract

Children with a button battery impaction present with nonspecific symptoms that may account for a delay in medical care. We conducted a retrospective study of the clinical presentation, management, and complications associated with button battery ingestion in the pediatric aerodigestive tract and to evaluate the associated long-term morbidity. We reviewed the medical records of 23 patients who were treated for button battery impaction at our tertiary care children's hospital from Jan. 1, 2000, through July 31, 2013. This population was made up of 14 boys and 9 girls, aged 7 days to 12 years (mean: 4 yr). Patients were divided into three groups based on the site of impaction; there were 9 impactions in the esophagus and 7 each in the nasal cavity and stomach. We compiled information on the type and size of each battery, the duration of the impaction, presenting symptoms, treatment, and outcomes. The mean duration of battery impaction was 40.6, 30.7, and 21.0 hours in the esophagus, nasal cavity, and stomach, respectively. We were able to identify the specific type of battery in 13 cases; 11 of these cases (85%) involved a 3-V 20-mm lithium ion battery, including all cases of esophageal impaction in which the type of battery was identified. The most common presenting signs and symptoms were vomiting (n = 7 [30%]), difficulty feeding (n = 5 [22%]), cough (n = 5), and bloody nasal discharge (n = 5); none of the presenting signs and symptoms predicted the severity of the injury or the outcome. The median length of hospital stay was far greater in the esophageal group (12 days) than in the nasal and stomach groups (1 day each; p = *0.006). Battery impaction in the esophagus for more than 15 hours was associated with a significantly longer postoperative hospital stay than impaction for less than 15 hours (*p = *0.04). Esophageal complications included strictures (n = 5), perforation (n = 3), and tracheoesophageal fistula formation (n = 2). Clinicians should consider battery impaction in the upper aerodigestive tract as an emergency that can lead to significant long-term morbidity, and therefore immediate surgical intervention is required.*

Introduction

Foreign-body impaction in the upper aerodigestive tract is an extremely common clinical scenario in the pediatric population, and it is often managed by otolaryngologists, general surgeons, gastroenterologists, and emergency department physicians. Children are especially susceptible to foreign-body injuries because of their tendency to orally explore their environment during play. Consequently, it comes as no surprise that the peak incidence of ingestion and inhalation of foreign bodies by children occurs between 1 and 3 years of age.[1-3] Although most upper aerodigestive foreign-body injuries can be safely treated by endoscopic removal with minimal long-term complications, button battery ingestion and impaction pose a unique set of circumstances that set it apart from the typical foreign-body case.

Button batteries are small, disc-shaped power cells that increasingly are being used in watches, toys, hearing aids, and other similar appliances. Paralleling this increase in use, the incidence of battery ingestion increased by 80% between 2002 and 2010.[4,5] Ingested button batteries can pass through the esophagus and proceed on a relatively uneventful transit through the gastrointestinal system. However, such a benign clinical picture is in stark

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contrast to the potentially devastating complications associated with button batteries that become lodged in the esophagus or nasal cavity. Once impacted in the upper aerodigestive tract, button batteries generate an external electrolytic current and release a toxic alkaline solution that can cause significant liquefactive necrosis in the surrounding tissue within 4 to 6 hours.[2,6,7]

Button battery impactions in the upper aerodigestive tract represent a clear medical emergency, and the benefits of an immediate chest x-ray and subsequent endoscopic removal have been definitively established.[8,9] However, there remains surprising heterogeneity in how these impactions are managed in the pre- and postoperative setting.[1,4,8] For example, the identification and management of patients who are most at risk of developing serious complications have been relatively unexplored.

In this article, we describe our study to identify the clinical variables that are associated with an increased risk of significant postoperative complications in children with button battery impaction. With the increasing prevalence of button-battery–related injuries, it is critically important that clinicians be able to identify high-risk patients and manage them accordingly to avoid possible severe complications.

Patients and methods

We conducted a retrospective review of the database at the Children's Hospital of Pittsburgh of UPMC to identify all patients younger than 21 years who had presented to the emergency department for suspected button battery impaction in the upper aerodigestive tract from Jan. 1, 2000, through July 31, 2013. Although the method of battery removal was surgeon-dependent, all patients had undergone an endoscopic evaluation irrespective of battery location.

Data were collected and entered into a spreadsheet using de-identified information. The collected data included battery location; age at presentation; sex; comorbidities; the duration of battery impaction, battery size and type; presenting signs, symptoms, and vital signs; initial endoscopic findings; the length of hospital stay; the duration of follow-up; and the presence or absence of acute and chronic complications.

Statistical analysis. The Fisher exact test and the Mood median test were used to compare patients with esophageal, nasal, and stomach impactions. Statistical significance was defined as a p value of less than 0.05.

Ethical considerations. The study protocol was reviewed by the University of Pittsburgh's Institutional Review Board and approved with expedited review.

Results

A total of 23 patients—14 boys and 9 girls, aged 7 days to 12 years (mean: 4 yr)—met our eligibility criteria. Patients were divided into three groups based on the site of impaction; there were 9 impactions in the esophagus and 7 each in the nasal cavity and stomach (table 1). Of the esophageal impactions, 5 were located in the middle, 3 in the distal, and 1 in the proximal esophagus. Of the nasal cavity impactions, 5 were located between the septum and the anteroinferior turbinate and 2 between the septum and the middle turbinate.

The most common comorbid conditions were asthma (n = 5 [22%]), attention-deficit/hyperactivity disorder (n = 3 [13%]), and developmental delay/autism (n = 2 [9%]) (table 1).

Duration of impaction. The mean duration of impaction was 40.6 hours in the esophageal group (standard deviation [SD]: 42.6; range: 2 to 96), 30.7 hours in the nasal cavity group (SD: 32.2; range: 3 to 72), and 21.0 hours in the stomach group (SD: 36.7; range: 3 to 96) (table 1).

Batteries that had been lodged in the esophagus for more than 15 hours (n = 5) were associated with a significantly longer median postoperative hospital stay (60 days; range 12 to 136) than those (n = 4) that had been impacted for less than 15 hours (3.5 days; range: 2 to 5; $p = 0.04$, Mood median test).

Battery type. The type of battery could be determined in 13 cases. The most common by far was the 3-V, 20-mm lithium ion battery, which was identified in 11 cases: 7 in the esophageal group, 3 in the stomach group, and 1 in the nasal cavity group. The other two cases involved 2-V, 10-mm alkaline manganese batteries, both of which were located in the nasal cavity. In the remaining 10 patients, the battery was too corroded to be identified (table 1).

Among the identified cases of lithium battery ingestion, patients with esophageal impaction (n = 6) were significantly younger (median age: 1.4 yr; range: 7 days to 2.5 yr) than those (n = 3) with stomach impaction (median age: 4 yr; range: 3 to 4; $p = 0.048$) after a single outlier was excluded (an 8-year-old).

Presenting signs and symptoms. Vital signs at presentation were within normal limits for all 23 patients. Fisher exact tests were conducted to identify significant relationships between presenting signs and symptoms and battery location. Vomiting was unique to patients in the esophageal group, and it affected 7 of these 9 patients (78%; $p < 0.001$). Batteries in the nasal cavity were strongly associated with bloody nasal discharge (n = 5 [71%]; $p = 0.001$). Patients whose battery had transited past the gastroesophageal junction were either

Table 1. Selected characteristics of patients with esophageal, nasal cavity, and gastric impactions

Variable	Esophagus (n = 9)	Nasal cavity (n = 7)	Stomach (n = 7)	Total (N = 23)
Mean age, yr	4.0	3.5	4.4	4.0
Sex				
Male, n (%)	7 (78)	3 (43)	4 (57)	14 (61)
Female, n (%)	2 (22)	4 (57)	3 (43)	9 (39)
Comorbidities				
Asthma	2	2	1	5
ADHD	2	0	1	3
Developmental delay	1	1	0	2
Mean impaction time, hr	40.6	30.7	21.0	31.6
Battery type				
Lithium (3-V, 20 mm)	7	1	3	11
Alkaline manganese (2-V, 10 mm)	0	2	0	2
Unknown	2	4	4	10
Presenting signs and symptoms, n				
Vomiting	7*	0	0	7
Difficulty feeding	4	0	1	5
Bloody nasal discharge	0	5*	0	5
Cough	3	2	0	5
Chest pain	3	0	1	4
Abdominal pain	0	0	3†	3
Fever	1	1	0	2
Rash	2	0	0	2
Nausea	0	1	1	2
Drooling	1	0	0	1
Stridor	1	0	0	1
Facial swelling	0	1	0	1
Headache	0	1	0	1
None	0	2	4†	6
Median postop hospital stay, days	12*	1	1	18.0
Mean follow-up, mo	14.3	16	1.2	10.8

* $p < 0.01$.
† $p < 0.05$.

asymptomatic (n = 4 [57%]; $p = 0.022$) or presented with mild abdominal pain (n = 3 [43%]; $p = 0.04$) (table 1).

On physical examination, batteries in the nasal cavity were easily identified by anterior rhinoscopy with a nasal speculum. Findings in patients in the esophageal and the stomach groups were unremarkable. The severity of the presenting signs and symptoms did not predict the extent of battery-related injury or subsequent postoperative complications.

Postoperative course and hospital stay. The median length of hospital stay was significantly greater in the esophageal group (12 days; range: 2 to 136) than in the nasal cavity group (1 day; range: 1 to 9) and the stomach group (1 day; range: 1 to 5 days; $p = 0.006$).

All patients with esophageal impactions were placed on a "nothing by mouth" regimen until an endoscopic evaluation could be completed. Five of the 9 patients (56%) required a repeat endoscopy during their initial

Table 2. Distribution of acute and chronic complications after battery impaction

Complication	Esophagus (n = 9)	Nasal cavity (n = 7)	Stomach (n = 7)	Total (N = 23)
Acute, n				
Esophagitis	9	0	2	11
Septal necrosis	0	7	0	7
Gastritis	0	0	4	4
Esophageal perforation	3	0	0	3
Atelectasis	3	0	0	3
Septal perforation	0	3	0	3
Tracheoesophageal fistula	2	0	0	2
Pneumothorax	2	0	0	2
Chronic, n				
Stricture	5	0	0	5
Diverticulum	2	0	0	2
Gastric reflux	1	1	0	2
Sleep apnea	1	1	0	2
Chylothorax	1	0	0	1
Hiatal hernia	1	0	0	1
Saddle-nose deformity	0	1	0	1

hospital stay, and 7 of them (78%) underwent esophagography to evaluate the integrity of the esophagus. Other common procedures performed in the esophageal group after battery removal included mechanical ventilation in 4 patients (44%), a partial esophageal resection in 4, and dilation of an esophageal stricture in 4. As a result of a significant esophageal injury, 4 patients required total parenteral nutrition, and 3 patients underwent placement of a gastrostomy tube.

All 4 patients who required an esophageal resection had a 20-mm lithium battery impaction, with a median impaction time of 36 hours. The 4 patients who required stricture dilation had a median age of 1.5 years and a median duration of impaction of 66 hours, and the 5 patients who did not require dilation had a median age of 7.8 years and a median duration of impaction of 6 hours; despite the apparent magnitude of these differences, they were not statistically significant.

Two patients in the esophageal group in whom a 20-mm lithium battery had been identified developed significant postoperative cardiopulmonary decompensation, and they were placed on extracorporeal membrane oxygenation (ECMO). One patient was a 7-day-old boy who had had a lithium battery impacted in his distal esophagus for 16 hours, and he presented with significant transmural necrosis; 2 weeks after admission, he was placed on ECMO for 14 days. The other was a 2.5-year-old girl who had had a lithium battery impacted in the mid-esophagus for more than 96 hours, and she required 10 days of ECMO. Both of these patients were diagnosed with a tracheoesophageal fistula by bronchoscopy, and both required subsequent repair.

Patients younger than 3 years with esophageal impaction (n = 6) had a median impaction time of 66 hours (range: 6 to 96) and a median hospital stay of 23.5 days (range: 1 to 136 days), while those older than 3 years (n = 3) had a median impaction time of 5 hours (range: 3 to 13; $p = 0.167$) and a median hospital stay of 1 day (range: 1 to 4; $p = 0.167$). Again, although these differences were substantial, they were not statistically significant according to the Mood median test.

One patient in the nasal cavity group experienced significant erosion of cartilage and bone. Otherwise, patients with nasal impaction were typically discharged after debridement (n = 5 [71%]) and a course of antibiotics (n = 4 [57%]).

All button batteries in the stomach group had been impacted for more than 24 hours. All 7 were retrieved endoscopically, and no further management was required.

Complications. The mean duration of follow-up was 10.8 months. A summary of acute and chronic complications is shown in table 2.

Acute complications. Acute complications were those that were recognized within 24 hours of hospital admission. They were identified on the basis of signs and symptoms and endoscopic and radiologic findings.

The acute injuries in the esophageal group included esophagitis (n = 9 [100%]), atelectasis (n = 3 [33%]),

esophageal perforation (n = 3), pneumothorax (n = 2 [22%]), and tracheoesophageal fistula formation (n = 2). We stratified the degree of esophagitis based on the Zargar grading system, which ranges from 0 (normal findings) to 3b (extensive necrosis) (table 3).[10] Among the 6 patients younger than 3 years, mucosal injuries were classified as grade 1 in 1 patient, grade 2a in 1 patient, grade 3a in 2 patients, and grade 3b in 2 patients. In the 3 patients older than 3 years, 2 had a grade 1 injury and 1 had a grade 2a injury. Figure 1 shows a grade 3b injury.

Table 3. Esophageal grading system[10]

Grade	Definition
0	Normal findings on endoscopy
1	Mucosal edema and hyperemia
2a	Friable mucosa, hemorrhages, erosions, blisters, whitish membranes, and superficial ulcerations
2b	Grade 2a findings + deep/circumferential ulcerations
3a	Small scattered multiple ulcerations and areas of necrosis
3b	Extensive necrosis

All 7 patients with a button battery impaction in the nasal cavity presented with mild to moderate septal necrosis. A full-thickness septal perforation was noted in 3 of them (43%). Figure 2 shows a button battery in the nasal cavity that caused significant necrosis and damage to the contralateral septal mucosa. Patients with a septal perforation did not differ significantly from those without a perforation in terms of age or the duration of impaction.

Button battery impactions past the gastroesophageal junction resulted in mild gastritis in 4 of the 7 patients (57%) at the site of impaction. In all cases, the gastritis resolved without further complications. Two of the 7 patients (29%) also experienced esophagitis.

Chronic complications. Chronic complications represented all medical problems that were identified at least 24 hours after presentation.

Six of the 9 patients with an esophageal impaction experienced chronic complications following removal: 5 cases of stricture (56%), 2 cases of diverticulum formation (22%), and 1 case each of gastric reflux and hiatal hernia (11%). One patient with strictures required 7 dilations over the course of 18 months. Another patient developed disseminated intravascular coagulation while on ECMO and experienced significant long-term morbidity, including necrosis of the distal extremities, stage III chronic kidney disease, and *Enterobacter* bacteremia.

In the nasal cavity group, the only long-term complications were sleep apnea and saddle-nose deformity, which occurred in 1 patient each (14%).

Discussion

Despite a concerted effort by physicians and electronics companies to reduce the incidence of button-battery–related trauma, there was a 6.7-fold increase in the percentage of battery ingestions that resulted in serious, including fatal, outcomes between 1982 and 2009.[11] The increased morbidity and mortality associated with button battery impaction appears to be related to the introduction of the 3-V, 20-mm lithium ion battery. Although the 3-V lithium batteries contain a milder alkaline solution than the earlier, smaller 2-V, 10-mm alkaline manganese batteries, they are capable of producing a local current that is far more destructive; they are also large enough to become easily impacted in the pediatric aerodigestive tract.[2,6,12,13]

In our study, lithium batteries accounted for 11 of the 13 cases (85%) in which the type of battery could be identified. Although our findings suggest that lithium batteries are responsible for most esophageal impactions, it is important to note that 3 of the 10 ingested lithium batteries (30%) passed harmlessly through the esophagus and into the stomach. The patients who presented with a lithium battery in the esophagus were significantly younger than those who presented with a

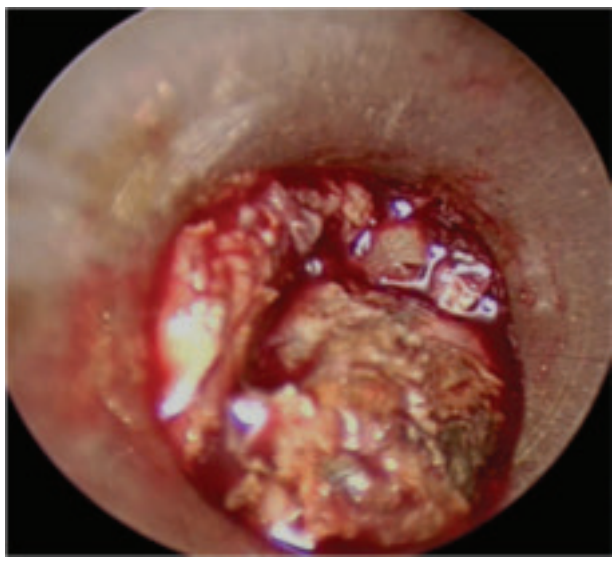

Figure 1. Photo shows a grade 3b esophageal injury caused by impaction of a 20-mm lithium button battery.

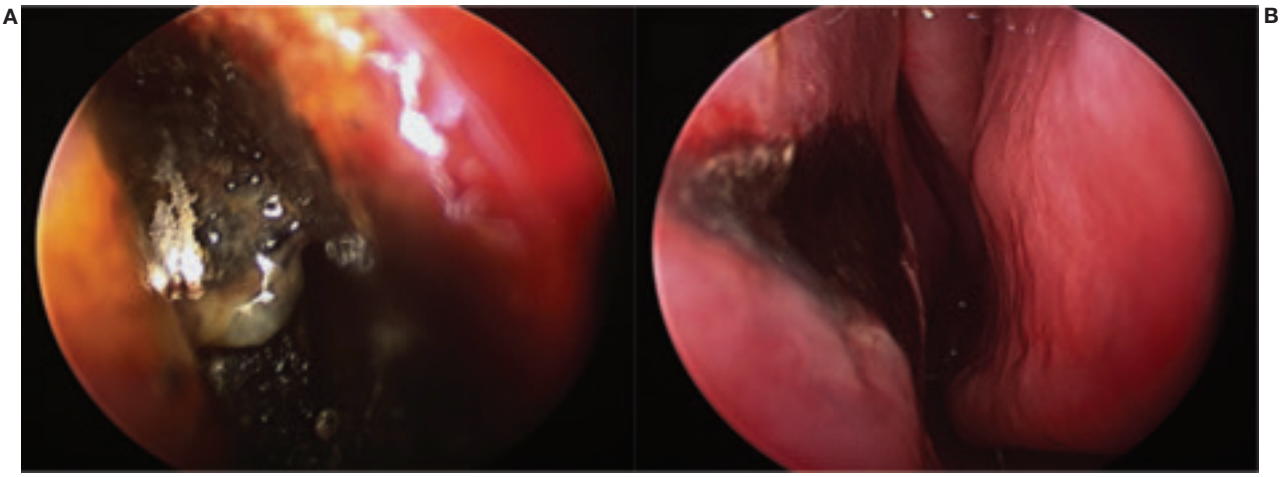

Figure 2. ***A:*** *In this patient, a 10-mm alkaline manganese button battery is impacted in the nasal cavity, which resulted in significant and diffuse necrosis.* ***B:*** *The contralateral septum exhibits necrotic changes, which place the patient at a high risk for septal perforation.*

lithium battery in the stomach. Based on this finding, we conclude that patients younger than 3 years who are suspected of lithium battery ingestion will likely present with esophageal impaction and require immediate surgical intervention, while lithium button batteries in those who are older than 3 years will often pass through the gastroesophageal junction and cause minimal trauma and sequelae.

In our study, the smaller 2-V, 10-mm alkaline manganese battery was identified in 2 nasal group patients and in none of the esophageal or stomach groups. Jatana et al demonstrated that nearly 13% of children younger than 6 years who had ingested a 20- to 25-mm battery went on to experience significant complications.[8]

The duration of battery impaction in the esophageal group was an important determinant in our patients' postoperative hospital course. Patients whose battery impaction had exceeded 15 hours had a notably longer postoperative hospital course than those whose impaction lasted less than 15 hours. Based on our findings, as well as those in the literature, we conclude that battery size, the location of impaction, and the duration of impaction are the three main variables that clinicians must consider when initially evaluating a case of battery impaction.[8,11]

The severity of the initial presentation in our study did not predict the extent of battery-related injury or subsequent postoperative complications. The most common presenting signs and symptoms were vomiting, difficulty feeding, cough, and bloody nasal discharge. In view of the nonspecific nature of these presentations, clinicians often misdiagnose a button battery impaction as a case of upper respiratory tract infection, especially if no history of battery ingestion is provided. For example, 1 patient in our esophageal group was initially diagnosed as having a viral upper respiratory tract infection, and this led to a 72-hour delay in battery removal.

It is important to note that in our study, vomiting was strongly associated with esophageal impactions and that it was not observed in any patient in the stomach group. Therefore, we believe that patients who present with suspected battery ingestion accompanied by vomiting of undigested foods have a high probability of an esophageal impaction. Once a battery passed beyond the gastroesophageal junction, the patient was either asymptomatic or experienced only mild abdominal pain.

To avoid a clinical oversight, it is important that physicians obtain a complete history from a patient's caregiver and to keep the possibility of a foreign-body impaction in mind for the differential diagnosis when evaluating a patient with nonspecific symptoms. All patients with suspected battery ingestion should undergo an immediate chest x-ray.

While nasal cavity and gastric impactions were associated with a relatively indolent clinical course, button batteries in the esophagus often led to devastating acute and chronic complications. All patients in our case series experienced varying degrees of inflammation and mucosal damage at the impaction site, irrespective of battery location.

Although it was not statistically significant, we noticed a clear pattern develop when we stratified patients with esophageal impaction by age, as patients younger than 3 years demonstrated a trend toward longer durations of battery impaction and longer postoperative hospital stays. Furthermore, most patients younger than 3 years

(67%) had a traumatic grade 3a or 3b esophageal injury while older patients commonly presented with superficial grade 1 and 2a esophagitis. Therefore, patients younger than 3 years with esophageal battery impaction may experience a delay in diagnosis and battery removal and consequently present with significant, often transmural, esophageal injury.

Unfortunately, because of our small sample size, it is difficult to determine the relative contribution of age versus impaction time in predicting subsequent esophageal injury. It is likely that in patients younger than 3 years, esophageal impactions remain unnoticed for a longer period of time and consequently this leads to more severe injury. Tanaka et al demonstrated that lithium battery injuries can progress from superficial esophageal injury to transmural necrosis within 1 hour, underscoring the importance of minimizing battery impaction time.[14] Timely recognition of button battery impactions may not only reduce the extent of initial esophageal injury, it also may improve the long-term outcomes associated with battery-related trauma.

Button batteries can induce tissue injury through three different mechanisms: (1) release of an alkaline electrolyte solution, (2) generation of an external current, and (3) direct pressure necrosis.[15,16] While injury from battery impaction can involve a combination of all three factors, the main mechanism of tissue damage is the generation of an external electrolytic current.[5]

Previous research has demonstrated that lithium batteries impacted in the dog esophagus can induce full-thickness transmural necrosis without any leakage of battery contents.[14] In fact, one study showed that esophageal injury occurred within 15 to 30 minutes of impaction while leakage was observed after 1 to 5 hours.[14]

In our study, esophageal impactions were unique in that many patients required long-term follow-up for persistent complications. The most common chronic complication was esophageal stricture, which required multiple dilations over the course of several years. Although strictures represent a complex injury response, recent data suggest that high-dose methylprednisolone and early dilation may help decrease the incidence of strictures after esophageal burns.[17-19] However, no general consensus has been reached regarding the role of steroids in esophageal caustic injuries, and the topic remains controversial.

Follow-up studies may help identify specific postoperative interventions that clinicians can employ to reduce the occurrence of stricture formation. A significant delay between the time of the initial trauma and the downstream complication is a common theme with esophageal impactions.[4,5,20] Clinicians must be aware that button batteries in the esophagus commonly go through a minimally symptomatic phase before progressing to a life-threatening injury (e.g., a transesophageal fistula).

In our study, nasal button battery impactions commonly resulted in septal necrosis and perforation, but they required minimal intervention. Even though long-term complications were rarely encountered, 1 patient developed a saddle-nose deformity nearly 2 years after the inciting trauma and required significant reconstructive surgery at that time. Unlike the esophagus, which is close to numerous vital structures, the nasal cavity is a relatively isolated anatomic area. Consequently, nasal impactions commonly lead to local damage, but rarely do they cause a life-threatening injury (e.g., hemorrhage).

In contrast to esophageal and nasal impactions, the impaction of batteries past the gastroesophageal junction caused only mild gastritis; there were no long-term sequelae. In vitro studies have demonstrated that button batteries naturally corrode at an acidic pH and can release a heavy metal solution.[21] Therefore, researchers have postulated that the corrosion of a button battery in the gastrointestinal tract can lead to systemic absorption of toxic heavy metals.[5,20-22] In our case series, patients with gastric impactions did not exhibit any signs of heavy metal toxicity, and they were typically discharged within 24 hours.

Because of the low-risk nature of gastric impactions, we recommend that physicians wait 24 to 48 hours before attempting to remove a button battery that has crossed the gastroesophageal junction to allow time for an opportunity for an uneventful passage through the intestines.[1,3,9]

Ultimately, our study demonstrated that location is the most important prognostic factor associated with the impaction of button batteries.[23] Since battery size is the major determinant of where a battery will become impacted, electronics and battery companies can potentially reduce the morbidity associated with button battery impactions by decreasing the diameter of the 20-mm lithium battery (for example, to 15 mm).

A few limitations of this investigation include the relatively small size of our patient population and the retrospective nature of the study. With only 23 patients, it is difficult to conduct robust statistical analyses and identify significant differences within the sample. We suspect that a larger sample size would have allowed us to identify significant differences between key clinical variables.

Nevertheless, we are confident that our research

will increase awareness of the dangers associated with button batteries and prompt future multi-institutional studies that can pool data from several large hospital centers. Indeed, this current work has served as a pilot study to help us plan a multi-institutional investigation with a larger number of patients to further evaluate the management and outcomes of button battery ingestion in the pediatric aerodigestive tract and, we hope, to develop a consensus statement about best practices for the management of button battery injuries.

Conclusion

Button battery impactions in children present with nonspecific signs and symptoms that may account for a delay in medical care. The introduction of the 3-V, 20-mm lithium battery has led to an alarming rise in the incidence of life-threatening button battery injuries. In younger patients, physicians must maintain a high index of suspicion for esophageal impaction and plan for an immediate medical assessment and prompt intervention.

The most important factors that determine morbidity and mortality from battery impactions are battery size, the location of the impaction, and the duration of impaction. Clinicians must consider battery impaction in the upper aerodigestive tract as a surgical emergency that may lead to significant long-term morbidity, and therefore one that requires immediate intervention.

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