Journal of Pediatric Surgery xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

Journal of Pediatric Surgery

journal homepage: www.elsevier.com/locate/jpedsurg

Battery ingestions in children: Variations in care and development of a clinical algorithm☆

Eric H. Rosenfeld [a], Richard Sola Jr [b], Yangyang Yu [a], Shawn D. St. Peter [b], Sohail R. Shah [a,*]

[a] Texas Children's Hospital / Baylor College of Medicine, Division of Pediatric Surgery, 6701 Fannin Suite 1210, Houston, TX 77030, United States
[b] Children's Mercy Hospital, Division of Pediatric Surgery, 2401 Gillham Road, Kansas City, MO 64108, United States

ARTICLE INFO

Article history:
Received 13 June 2017
Received in revised form 8 January 2018
Accepted 26 January 2018
Available online xxxx

Key words:
Foreign body ingestion
battery ingestion
standardized protocols

ABSTRACT

Purpose: To review current management and outcomes of ingested batteries and develop a clinical management algorithm.
Methods: Children <18 years old who ingested a battery between 1/2011 and 9/2016 at two tertiary care children's hospitals were reviewed. Demographics, imaging, management and outcomes were analyzed using descriptive statistics, Chi-square and Wilcoxon Rank-sum tests.
Results: There were 180 battery ingestions. The median age was 3.9 (range 0.7–18) years, with 78 (43%) males. The most common symptoms were abdominal pain (17%) and nausea/vomiting (14%). Diagnosis was confirmed with plain radiographs in 170 (94%) patients. Locations on imaging were: stomach (37%), small bowel (24%), esophagus (18%), colon (11%), and non-specific location past the gastroesophageal junction (9%). Treatment was dictated by five different subspecialties including surgery (35%), gastroenterology (25%), emergency medicine (19%), primary care/emergency with a consulting service (13%), and otolaryngology (8%).
All esophageal batteries (n = 33) had an intervention. Interventions included fluoroscopic balloon extraction (6 attempted, 33% retrieval rate), rigid esophagoscopy (26 attempted, 96% retrieval rate), and EGD (6 attempted, 83% retrieval rate).
For batteries distal to the gastroesophageal junction 16 (11%) patients had an intervention. Interventions included EGD (13 patients, 69% retrieval), colonoscopy (1 patient, successful retrieval), and abdominal surgery in two patients.
Conclusion: Isolated batteries that pass the gastroesophageal junction rarely require intervention and can be managed conservatively. Given the variability in managing these patients, we developed an evidence based algorithm.
Level of Evidence: Level 2.
Study Type: Retrospective Study.

Young children have a natural tendency to explore their environment by placing objects in their mouth. While a majority of ingested foreign bodies pass spontaneously through the gastrointestinal tract, batteries and magnets have an increased potential to cause damage. Over the past two decades' emergency room visits for battery ingestions have increased in frequency. According to the National Electronic Injury Surveillance System (NEISS) between 1990 and 2009 the incidence of emergency room visits for battery ingestions has doubled [1].

While there is agreement regarding the need for urgent removal of esophageal batteries, the management of batteries which lie beyond the gastroesophageal junction is controversial. An expert opinion-based guideline from the Endoscopy Committee of the North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition (NASPGHAN) recommended endoscopic removal of button batteries in certain cases whereby the battery lies beyond the esophagus [2]. However, recommendations from the National Battery Ingestion Hotline (NBIH) and the National Capital Poison Center, suggest initial conservative management in asymptomatic children with postesophageal batteries [3,4]. The purpose of our study was to review the management and outcomes of battery ingestions from two tertiary-care academic children's hospitals and develop a standardized management algorithm.

1. Methods

1.1. Study design

Following approval by the Institutional Review Board (IRB) of Children's Mercy Hospital (IRB#16070546) and Texas Children's Hospital (IRB#H39198), medical records of all children less than 18-years-old with

☆ Disclosures: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. This is a Level II retrospective study.

* Corresponding author at: Texas Children's Hospital / Baylor College of Medicine, 6701 Fannin Suite 1210, Houston, TX 77030.3135; fax: +1 832 825 3141., United States.
E-mail addresses: ehrosenfe@bcm.edu, erichrosenfeld@gmail.com (E.H. Rosenfeld), rsola@cmh.edu (R. Sola), yxyangya@texaschildrens.org (Y. Yu), sspeter@cmh.edu (S.D. St. Peter), sohailshahmd@gmail.com (S.R. Shah).

https://doi.org/10.1016/j.jpedsurg.2018.01.017
0022-3468/

battery ingestions were retrospectively reviewed from January 2011 to June 2016. Patients were identified based on International Classification of Disease Ninth Revision (ICD-9) diagnosis coding. Patients diagnosed with foreign body ingestion, which included mouth, esophagus and stomach (935.0, 935.1, and 935.2), intestine and colon (936), and unspecified digestive system (938) were reviewed. Those with radiographic evidence of a battery ingestion were included and those with airway or other foreign body ingestions were excluded.

1.2. Data collection

Patient demographics including age, gender, and race were collected. Battery ingestion characteristics including location, symptoms, and diagnostic workup were recorded. Clinical management including procedures performed, hospital length of stay, and complications was included. Deidentified data from both institutions were used for data analysis.

1.3. Statistics

Data analyses were performed using STATA software version. 14.2 (STATACorp LLC., College Station, TX, USA). Patient characteristics and outcomes are described descriptively using counts and percentages for categorical variables and as median with interquartile range (IQR) for continuous variables. Comparative analysis was performed using the Wilcoxon rank test and Fisher's exact test or χ^2 square test, as appropriate. A $p < 0.05$ was used to determine significance.

2. Results

2.1. Patient Characteristics

There were 180 children with a confirmed battery ingestion. Hospital 1 contributed 94 patients (52%) and Hospital 2 contributed 86 (48%) to the total cohort. Overall, the median age was 3.9 years (range 0.7–18). There were 109 ingestions in children less than 5-years-old. The median weight was 16.9 kg (IQR, 12.4–28), and 43% were male. The most common symptoms were abdominal pain (17%) and nausea/vomiting (14%). At presentation the distribution of the battery location based on imaging was: esophagus (18%), stomach (37%), small bowel (24%), colon (11%), and a nonspecific location past the gastroesophageal junction (9%). The majority of patients presented less than one day after ingestion.

2.2. Clinical management

The diagnosis of a battery ingestion was confirmed with plain radiographs in 170 (94%) patients. The primary service managing the battery ingestion varied between five pediatric specialties: Surgery (35%), Gastroenterology (25%), Emergency Medicine (19%), Primary Care / Emergency Medicine with a consulting service (13%), and Otolaryngology (8%). Median hospital length of stay (LOS) for all patients was 0.1 days (range 0–20).

2.2.1. Esophageal batteries

There were 33 esophageal batteries, and 9 (27%) of the ingestions were witnessed. The median age was 1.8 years (IQR, 1.1–3.5). Twenty-four (73%) patients presented with symptoms: 18 (75%) with nausea or vomiting, six (25%) with respiratory symptoms, five (21%) with drooling, and two (8%) with abdominal pain. Diagnostic imaging identifying an esophageal battery included a chest radiograph in 18 (55%) patients, and a foreign body series (chest and abdominal radiograph) for 15 (45%) patients.

All esophageal battery patients had an intervention. Interventions included fluoroscopic balloon extraction, rigid esophagoscopy, and esophagogastroduodenoscopy (EGD). Fluoroscopic balloon extraction using a Foley catheter was only performed at Hospital 2 [5]. This technique was attempted on six (18%) patients, and was successful in two (33%). Both patients with successful removal had a postprocedure esophagram, and neither revealed a perforation. The time from ingestion to successful removal for this technique was less than 24 h. The four patients where the battery was unable to be removed with the fluoroscopic balloon extraction technique went on to uneventful removal by rigid esophagoscopy.

Rigid esophagoscopy was attempted in 26 (79%) patients, and the battery was successfully removed in 25 (96%). The one patient where the battery was not removed was followed-up with an EGD and fluoroscopy under the same anesthetic, and the battery was noted to have already moved past the Ligament of Treitz. On rigid esophagoscopy, 19 (73%) patients had evidence of mucosal irritation of the esophagus, and 20 (77%) subsequently underwent an esophagram. There were no perforations identified.

An EGD was attempted in six (23%) patients for esophageal battery removal, and the battery was successfully removed in five (83%). The one unsuccessful attempt was in the same patient as described above. On EGD four (67%) of patients had mucosal irritation of the esophagus and one was described as having a posterior esophageal burn. This patient underwent a computed tomography scan two days later, and was treated with nasogastric tube feedings owing to persistent dysphagia.

2.2.2. Gastric batteries

There were 67 batteries identified within the stomach, and 29 (43%) of the ingestions were witnessed. The median age was 5.7 years (IQR, 1.6–7.4). Seventeen (25%) patients presented with symptoms: 10 (59%) with abdominal pain, four (24%) with nausea or vomiting, two (12%) with throat pain, and one (6%) with drooling. Diagnostic imaging identifying a gastric battery included a foreign body series (chest and abdominal radiograph) in 41 (61%) patients, abdominal radiographs in 23 (34%) patients, and a chest radiograph in three (4%) patients.

The majority (84%, $n = 56$) of patients with a gastric battery were managed nonoperatively. Five patients were admitted for nonoperative management. Of the patients discharged home for outpatient management, four (6%) were placed on a bowel regimen, and 12 (18%) returned for serial radiographs. There were no complications in the nonoperative group.

An EGD was attempted in 11 (16%) patients. Five (45%) of these patients were symptomatic; three (60%) with abdominal pain, one (20%) with throat pain and two (40%) with nausea or vomiting. Of the asymptomatic patients, one underwent an EGD owing to ingestion of a battery and multiple magnets, a second owing to ingestion of 2 AAA batteries, the third swallowed a button battery 4 days prior which was still in the stomach, and the rest were prophylactic removal. Batteries were successfully retrieved in nine (82%) patients that underwent EGD. On EGD, four (36%) patients had gastric mucosal irritation. There were no perforations identified. The median time from ingestion to intervention was 1.5 days (IQR 0–4.5, $n = 8$). Of note, several patients in this review that arrived in the evening hours and were scheduled for a semielective EGD the next morning had the procedure canceled because the battery had already moved beyond the stomach by the next morning.

2.2.3. Small bowel batteries

There were 43 batteries identified in the small bowel, and 11 (26%) of the ingestions were witnessed. The median age was 5.1 years (IQR, 3.2–10.0). Nine (21%) patients presented with symptoms: nine (100%) with abdominal pain and one (11%) with additional nausea or vomiting. Diagnostic imaging identifying a battery in the small bowel included a foreign body series (chest and abdominal radiograph) in 27 (63%) patients, an abdominal radiograph in 15 (35%) patients, and a chest radiograph in one (2%) patient.

The majority (88%, $n = 38$) of patients with a battery in the small bowel were managed nonoperatively. Three patients were admitted

Please cite this article as: Rosenfeld EH, et al, Battery ingestions in children: Variations in care and development of a clinical algorithm, J Pediatr Surg (2018), https://doi.org/10.1016/j.jpedsurg.2018.01.017

for nonoperative management. Of the patients managed as outpatients, eight (24%, n = 33) were placed on a bowel regimen, and two (6%, n = 34) returned for serial radiographs. One patient initially managed with outpatient nonoperative management showed failure of the battery to progress over time and underwent an elective laparotomy (see patient with AA battery described below).

An EGD was attempted in two (5%) patients, and both were unsuccessful in retrieving the batteries as they were beyond the reach of the endoscope. Three other patients underwent intervention. One patient underwent a colonoscopy after a hearing aid battery was noted to be stagnant in the cecum four days after ingestion. The second patient underwent an exploratory laparotomy to retrieve a AA battery that failed to pass. A third patient had laparoscopic removal owing to co-ingestion of a magnet along with the battery and other metallic foreign bodies. The median time from presentation to intervention was 1.3 days (IQR 0.25–2).

2.2.4. Colonic batteries

There were 20 batteries identified in the colon, and 5 (25%) of the ingestions were witnessed. The median age was 5.9 years (IQR, 4.5–13.6). Seven (35%) patients presented with symptoms: six (86%) with abdominal pain and one (14%) with additional nausea or vomiting. Diagnostic imaging identifying a battery in the colon included a foreign body series (chest and abdominal radiograph) in 9 (45%) patients, an abdominal radiograph in 10 (50%) patients, and a chest radiograph in one (5%) patient.

All of these patients were managed non-operatively. Three (15%) were managed with a bowel regimen and four (20%) with serial x-rays.

2.2.5. Batteries in a nonspecific location beyond the gastroesophageal junction

There were 17 batteries identified past the gastroesophageal junction, but without a specific location identifiable on imaging. Six (35%) of these ingestions were witnessed. The median age was 3.3 years (IQR, 1.5–13.3). Three (18%) patients presented with symptoms: two (67%) with abdominal pain, and two (67%) with nausea or vomiting. All of these were managed nonoperatively without any complications.

2.3. Variation in management

In addition to the variation in the decision to intervene and remove the ingested battery, there were also differences identified in the treatment during nonoperative management based on specialty. There was variation in care in obtaining serial radiographs to monitor progression of the battery ($p < 0.01$) (Fig. 1) and in the frequency of initiating a bowel regimen ($p = 0.09$) (Fig. 1).

3. Discussion

Battery ingestions in children continue to increase in frequency, and the multiple specialty services caring for these children along with variations in current recommendations can lead to significant variation in management of these patients. In this multicenter review of battery ingestions in children, we demonstrated that this variation in care continues at two tertiary-care academic children's hospitals and can lead to variable resource utilization. The benefits of standardization for decreasing utilization of resources and costs have been well documented and are becoming increasingly important with changes to US healthcare payment algorithms [6,7].

A review of compiled data from the National Capital Poison Center in 1992 on more than 2300 battery ingestions over a seven year period found a 0.1% incidence of severe complications and no death [8]. However, over the past two decades, this has dramatically changed with a follow-up publication from the National Capital Poison Center in 2010. In this cohort of over 8600 button battery ingestions, there were complications in 73 (0.8%) patients, with death in 13 (0.2%) patients [4]. Additional cases of complications have also been reported [9,10]. Of note, all of the stated complications in this series were related to esophageal batteries which are known to cause esophageal stricture and perforation [7,11,12], vocal cord paralysis [13,14], and tracheoesophageal fistulas [15]. In our review, while there was variation in the method used for removal of esophageal batteries and the postremoval workup, all patients underwent urgent procedures for removal, as uniformly recommended, and there were no identified complications.

For batteries beyond the gastroesophageal junction, the recommended management algorithms are variable across published guidelines [2–4]. The NBIH and Button Battery Taskforce currently advocate abdominal radiographs and observation in asymptomatic patients and endoscopic removal in high-risk patients if the battery is in the stomach after 4 days [3,4]. More recent recommendations from the Endoscopy Committee of the NASPGHAN recommend consideration of endoscopic intervention even in cases of asymptomatic postesophageal batteries in high-risk patients (if aged <5 years and button battery ≥20 mm). The rationale for this is because of concerns for unrecognized esophageal

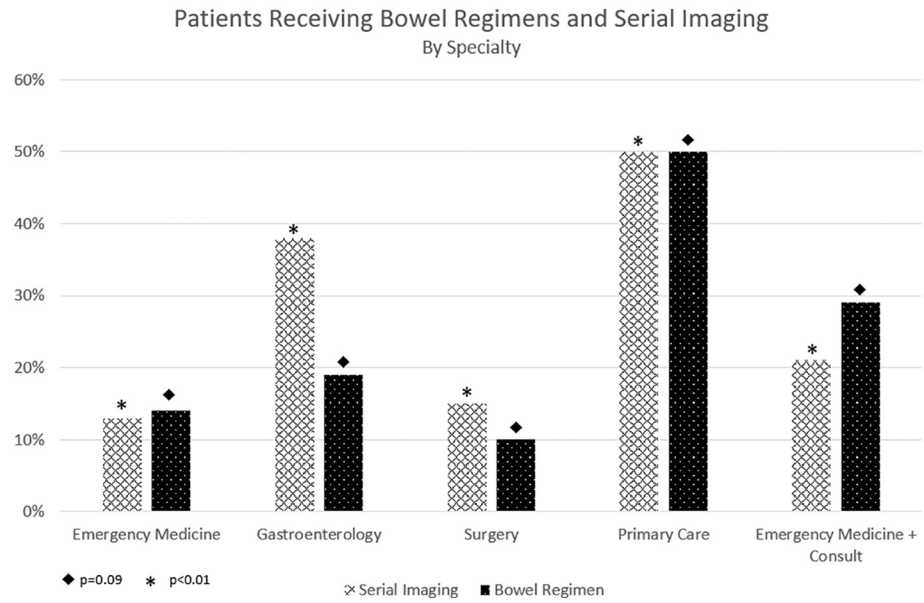

Fig. 1. Frequency of patients managed with serial abdominal radiographs or a bowel regimen by specialty.

Please cite this article as: Rosenfeld EH, et al, Battery ingestions in children: Variations in care and development of a clinical algorithm, J Pediatr Surg (2018), https://doi.org/10.1016/j.jpedsurg.2018.01.017

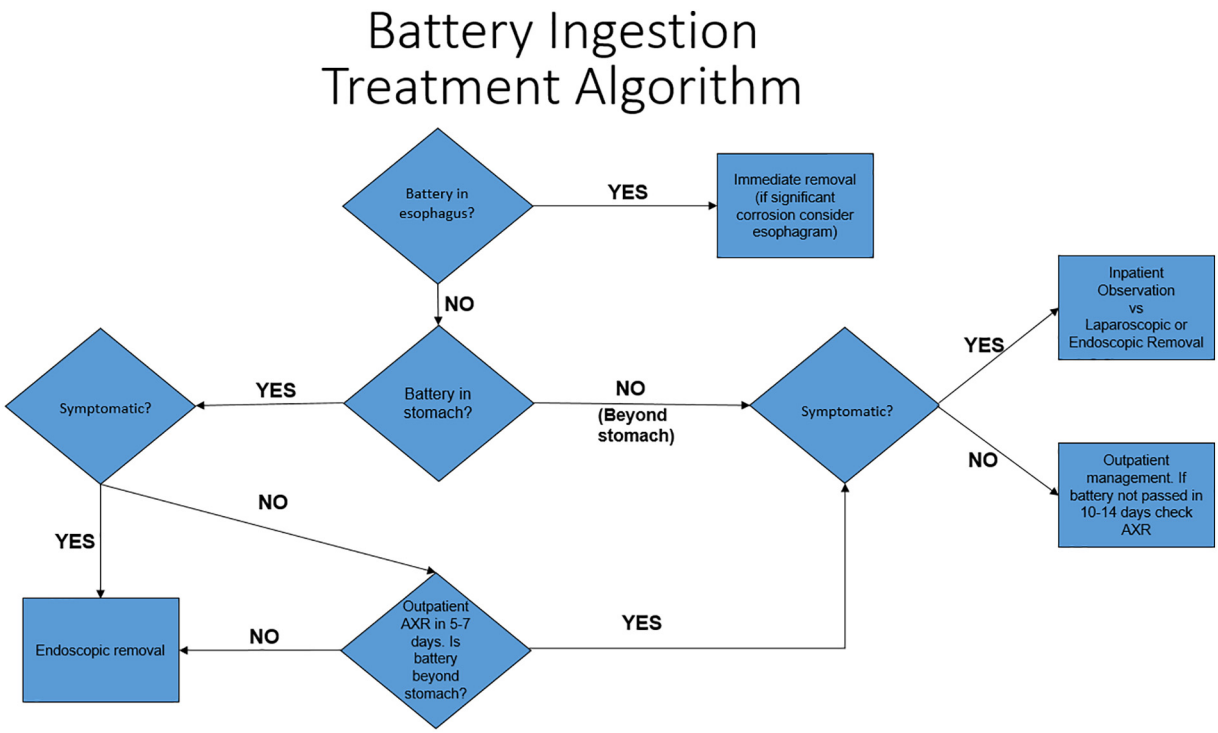

Fig. 2. Clinical algorithm for patients with battery ingestion.

injury [2]. Thus, the role of endoscopy in these cases is primarily diagnostic. An alternative, if one was concerned for esophageal injury would be to perform radiographic evaluation (e.g., an esophagram).

Complications from ingested batteries past the gastroesophageal junction are extremely rare, and we were only able to identify two case reports. These reports describe a 3-month-old with a gastric perforation after ingestion of a button battery which required surgical repair and a 1-year-old child who presented six days after ingestion of a button battery with a perforated Meckel's diverticulum [16,17]. In our series, two patients underwent operative intervention: one after co-ingestion of a magnet, battery, and other metallic foreign bodies, which was likely a complication of the magnet rather than the battery, and the second was after ingestion of a AA battery that failed to progress past the ileocecal valve. The low rate of complications for ingested batteries that are identified past the gastroesophageal junction allows these patients to be initially managed conservatively.

Based on review of existing management algorithms and our own multicenter data we propose an updated management algorithm for ingested batteries (Fig. 2). If an esophageal battery is identified, we recommend immediate removal with rigid esophagoscopy and consideration of an esophagram if substantial mucosal irritation is identified. In our series the majority of patients underwent an endoscopic intervention; however, six patients underwent attempted fluoroscopic balloon extraction at one of the institutions. Although this procedure has been shown to have potential benefits for removal of certain esophageal foreign bodies [5], we do not recommend its use for esophageal batteries owing to the 67% initial failure rate.

If the battery is noted within the stomach and the patient is symptomatic we recommend endoscopic removal. For asymptomatic patients with a gastric battery an outpatient abdominal radiograph can be obtained in 5–7 days to ensure the battery has passed the stomach. If the battery remains in the stomach at that time, then endoscopic removal is recommended. For any isolated battery that is beyond the stomach outpatient management is recommended in asymptomatic patients, and a follow-up abdominal radiograph can be obtained in 10–14 days if the battery is not passed. If the battery is beyond the stomach and the patient is symptomatic, then inpatient management is recommended with observation vs. laparoscopic or endoscopic removal based on clinical presentation.

The timing for repeat radiographs recommended in the algorithm is based on review of our data and the existing literature. Litovitz et al. suggested repeat radiographs in 4–5 days for children six years or younger, those that ingested large batteries (15 mm or larger), and those that are symptomatic because 74% of batteries passed within 4 days [4]. However, the evidence regarding timing of repeat radiographs is sparse and therefore the interval days to repeat radiographs in the algorithm are offered as recommended ranges.

Additionally, there is insufficient existing evidence to recommend routine use of a bowel regimen to facilitate passage of an ingested foreign body. Case reports evaluating polyethylene glycol for evacuation of iron pellets in children have shown mixed results [18–20]. Based on these data there is insufficient evidence to recommend the routine use of bowel regimens for ingested foreign bodies.

This study has several limitations. Limitations of this retrospective study include medical record accuracy, the potential for miscoding of diagnoses, and treatment bias based on the primary service. The size of the battery and timing from ingestion to presentation, while important factors, were not able to be obtained.

4. Conclusion

Variation in the management of battery ingestions in children continues to exist, especially for batteries that are beyond the gastroesophageal junction. In an effort to standardize care we developed an evidence-based algorithm for the management of battery ingestions in children. Future prospective evaluation of this algorithm is needed.

References

[1] Sharpe SJ, Rochette LM, Smith GA. Pediatric battery-related emergency department visits in the United States, 1990–2009. Pediatrics 2012;129(6):1111–7.

Please cite this article as: Rosenfeld EH, et al, Battery ingestions in children: Variations in care and development of a clinical algorithm, J Pediatr Surg (2018), https://doi.org/10.1016/j.jpedsurg.2018.01.017

[2] Kramer RE, Lerner DG, Lin T, et al. Management of ingested foreign bodies in children: a clinical report of the NASPGHAN Endoscopy Committee. J Pediatr Gastroenterol Nutr 2015;60(4):562–74.
[3] Jatana KR, Litovitz T, Reilly JS, et al. Pediatric button battery injuries: 2013 task force update. Int J Pediatr Otorhinolaryngol 2013;77(9):1392–9.
[4] Litovitz T, Whitaker N, Clark L, et al. Emerging battery-ingestion hazard: clinical implications. Pediatrics 2010;125(6):1168–77.
[5] Little DC, Shah SR, St Peter SD, et al. Esophageal foreign bodies in the pediatric population: our first 500 cases. J Pediatr Surg 2006;41(5):914–8.
[6] Richards MK, Li CI, Foti JL, et al. Resource utilization after implementing a hospital-wide standardized feeding tube placement pathway. J Pediatr Surg 2016;51(10):1674–9.
[7] Stauffer JA, Onkendi EO, Wallace MB, et al. Standardization and streamlining of a pancreas surgery practice improves outcomes and resource utilization: A single institution's 20-year experience. American journal of surgery 2017;214(3):450–5.
[8] Litovitz T, Schmitz BF. Ingestion of cylindrical and button batteries: an analysis of 2382 cases. Pediatrics 1992;89(4 Pt 2):747–57.
[9] Brumbaugh DE, Colson SB, Sandoval JA, et al. Management of button battery-induced hemorrhage in children. J Pediatr Gastroenterol Nutr 2011;52(5):585–9.
[10] Leinwand K, Brumbaugh DE, Kramer RE. Button battery ingestion in children: a paradigm for management of severe pediatric foreign body ingestions. Gastrointest Endosc Clin N Am 2016;26(1):99–118.
[11] Samad L, Ali M, Ramzi H. Button battery ingestion: hazards of esophageal impaction. J Pediatr Surg 1999;34(10):1527–31.
[12] Yardeni D, Yardeni H, Coran AG, et al. Severe esophageal damage due to button battery ingestion: can it be prevented? Pediatr Surg Int 2004;20(7):496–501.
[13] Mack RB. Some light on the charge brigade—disc battery ingestion. N C Med J 1983;44(9):560–1.
[14] Hamilton JM, Schraff SA, Notrica DM. Severe injuries from coin cell battery ingestions: 2 case reports. J Pediatr Surg 2009;44(3):644–7.
[15] Imamoglu M, Cay A, Kosucu P, et al. Acquired tracheo-esophageal fistulas caused by button battery lodged in the esophagus. Pediatr Surg Int 2004;20(4):292–4.
[16] Ozokutan BH, Ceylan H, Yapici S, Simsik S. Perforation of Meckel's diverticulum by a button battery: report of two cases. Ulusal travma ve acil cerrahi dergisi = Turkish journal of trauma & emergency surgery. TJTES 2012;18(4):358–60.
[17] Honda S, Shinkai M, Usui Y, et al. Severe gastric damage caused by button battery ingestion in a 3-month-old infant. J Pediatr Surg 2010;45(9):e23–6.

Please cite this article as: Rosenfeld EH, et al, Battery ingestions in children: Variations in care and development of a clinical algorithm, J Pediatr Surg (2018), https://doi.org/10.1016/j.jpedsurg.2018.01.017