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Button Batteries and High-Powered Neodymium Magnet Ingestion in Children

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Abstract

BACKGROUND: Foreign body ingestions in pediatrics are present highly variably. For each case, it is important to consider the size of the child, the age of the child, the size of the object, and the inherently different risk of different objects ingested. It is important to note that regardless of the type of object, any foreign body should be removed from the esophagus. Over the past decade, the medical literature has particularly identified the potential for morbidity and mortality in cases of button battery and magnet ingestions.

AIM: This study aims to describe the complications and how to avoid them in addition to studying the role of early endoscopic intervention in cases of button batteries (BB) and multiple magnets ingestion in children.

METHODS: There were 151 children enrolled in the study, classified into two groups. The first group constitutes ninety children with BB, the other group sixty children with multiple magnets ingestion. In addition to one patient with both multiple magnets and battery ingestion, which are extracted endoscopically from the stomach without complication. BB detected in the upper gastrointestinal tract (GIT) in the esophagus, stomach, and duodenum in 70 patients were extracted endoscopically. Other 20 patients where the batteries were detected distal to duodenum were observed till the discharge of batteries was confirmed. In patients with multiple magnets, the magnets were in the upper GIT in 46 patients while found distal to the duodenum in 14 patients.

RESULTS: There were 151 children enrolled in the study, classified into two groups. The first group constitutes ninety children with BB, the other group sixty children with multiple magnets ingestion. In addition to one patient with both multiple magnets and battery ingestion, which are extracted endoscopically from the stomach without complication. BB detected in the upper GIT in the esophagus, stomach, and duodenum in 70 patients were extracted endoscopically. Other 20 patients where the batteries were detected distal to duodenum were observed until the discharge of batteries was confirmed. In patients with multiple magnets, the magnets were in the upper GIT in 46 patients while found distal to the duodenum in 14 patients.

CONCLUSION: This study put alarm that multiple magnets ingestion carries a high risk of gastrointestinal perforation compared to battery ingestion. Invitation to ban on the sale of products with high-powered neodymium magnets, such as Buckyballs and Buckycubes, and to keep BB difficult reachable by children. In addition to encouraging urgent endoscopic management of suspected BB or multiple magnets ingestion.

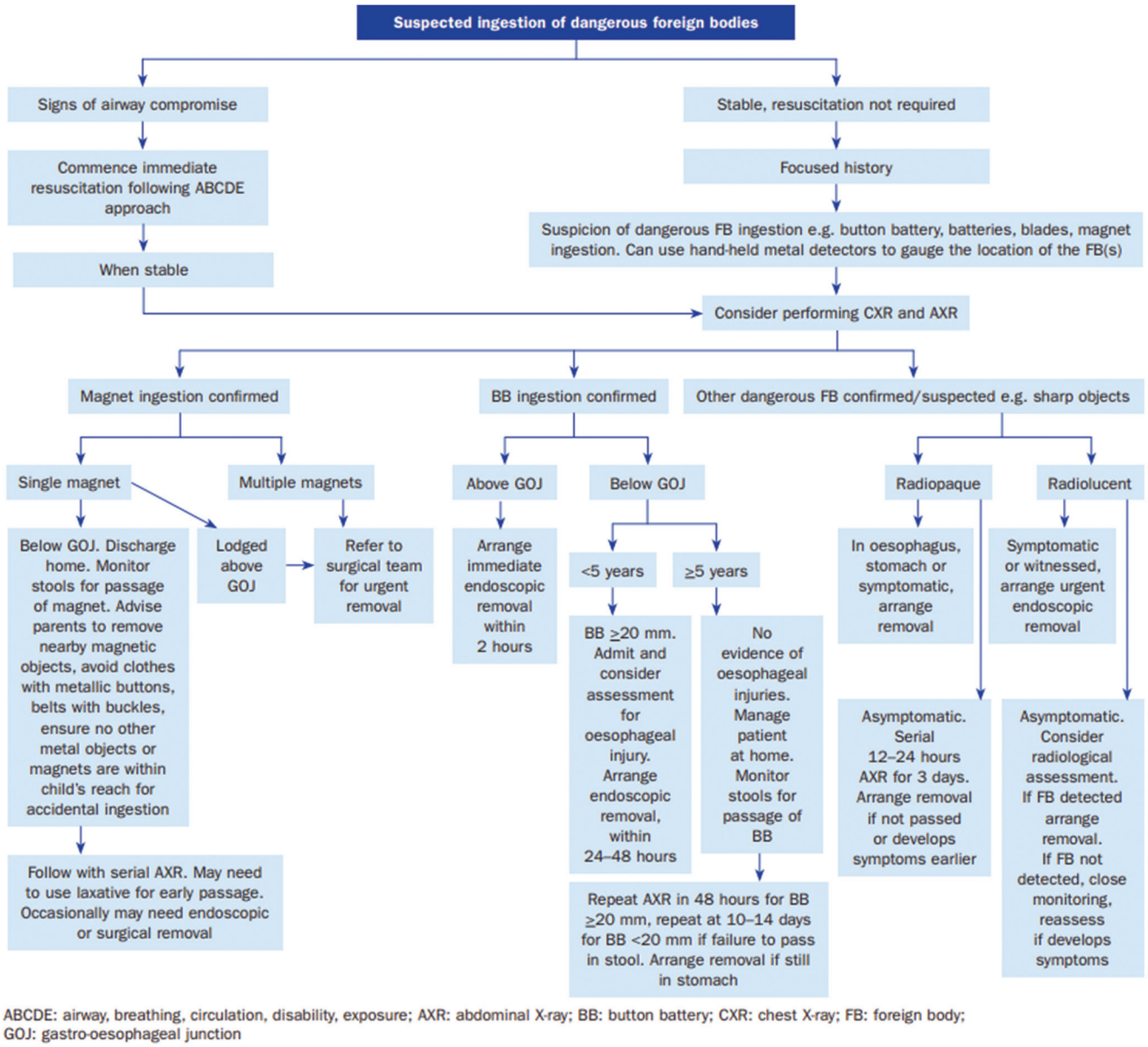
Introduction

Pediatric foreign body ingestion is an unfortunate, common occurrence that presents as a challenge both to pediatric gastroenterologists and primary care providers. The most common foreign body ingestions in children correspond with frequently found small household objects, such as coins, toys, magnets, and batteries [1].

The increasing prevalence of small, technologically advanced toys in the household has resulted in increased exposure to both high-voltage batteries (i.e. lithium) and powerful magnets that carry a high incidence of morbidity and mortality [2]. One of the most pediatric gastrointestinal (GI) endoscopy challenges is foreign body extraction. Many factors affect the proper management, including size variations, site, the timing of ingestion, and the type of foreign object ingested. Patient factors also affect management, such as age, and clinical presentation, which makes each case managed in a unique situation [3].

Button batteries (BB) affected in the GI tract (GIT) mainly the esophagus, can cause serious damage. The mechanisms for that are electrical, mechanical injuries, pressure necrosis, caustic injuries leakage of alkaline electrolytes, and coagulative necrosis [4]. Tracheoesophageal fistula, esophageal perforation, esophageal stenosis, vocal cord paralysis, mediastinitis, pneumothorax empyema, lung abscess, esophageal-aortal fistula, and mortality due to respiratory and circulatory failure are serious complications that can occur after BB ingestion [4].

Injury to esophageal mucosa was reported to start 2–4 h after ingestion and the chance for serious injury correlate with the number and diameter of ingested batteries. A certain study reported that the risk of severe injuries can continue days to weeks even after the removal of the battery. Aorto-enteric fistulas



ABCDE: airway, breathing, circulation, disability, exposure; AXR: abdominal X-ray; BB: button battery; CXR: chest X-ray; FB: foreign body; GOJ: gastro-oesophageal junction

Figure 1: Suspected ingestion for the foreign body [8]

causing death were reported 19 days after removal of the ingested battery [5]. Multiple magnets ingestion can cause serious complications such as GIT perforation, fistula, and other life-threatening complications. Recently, high-powered neodymium magnets in toys are 5- to 20-fold stronger than traditional iron magnets [6]. The most common complication is fistula formation between magnets in adjacent parts of GIT. Multiple magnets ingestion cause compression of the GIT between the magnets leading to pressure necrosis, and subsequent perforation. Other complications such as peritonitis, volvulus, and death have been reported [7].

Foreign body ingestions in pediatrics are present in a highly variable manner (Figure 1). For each case, it is important to consider the size of the child, the age of the child, the size of the object, and the inherently different risk of different types of objects ingested [9]. It is important to note that regardless of the type of object, any foreign body should be removed from the esophagus. Over the past decade, the medical literature has particularly identified the potential for morbidity and mortality in cases of BB and magnet ingestions [10].

This study aims to describe the complications and how to avoid them in addition to studying the role

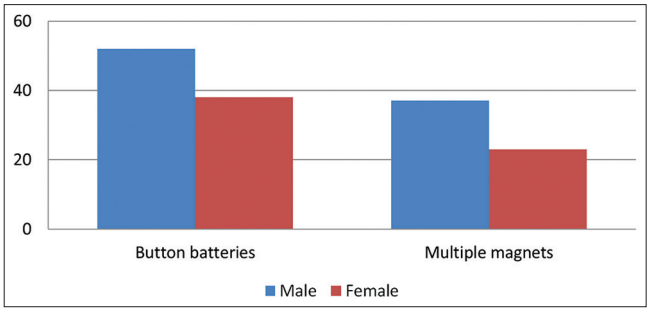


Figure 2: Comparison between button batteries and multiple magnets regarding the sex of patients

of early endoscopic intervention in cases of BB and multiple magnets ingestion in children.

Patients and Methods

Participants

This A cross-sectional study on children with foreign bodies, the study included 151 infants and children, 90 patients with BB ingestion (52 males and 38 females) Sixty patients with multiple magnets ingestion (37 males and 23 females) their ages ranged from 7 months to 12 years (Figures 1-6). In addition to one patient 3 years old male child with both multiple magnets and (Figure 10) one BB. They were diagnosed by history taking and X-ray of the chest and abdomen (Figures 6 and 9). The study started in 2012 till 2021 included patients from National Liver Institute – Menofiya University and Al Qassimi Women and children Hospital – Sharjah- UAE.

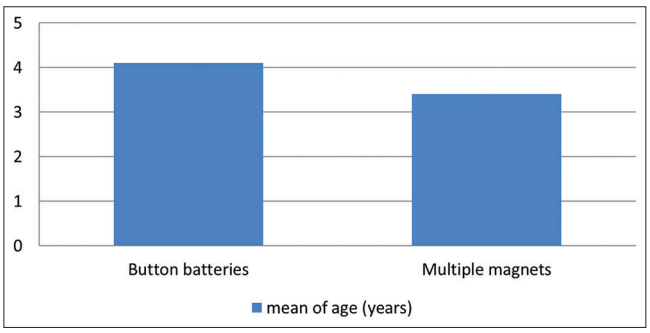


Figure 3: Comparison between multiple magnets and button batteries groups regarding age

Cases were included in the analysis if the ingested object was within the GIT beyond the mouth, ingestions of foods or liquids, the location of the object in the airway or mouth, aspiration, and choking. All patients were subjected to thorough medical history and Demographic Data (Age, Sex, Resident, etc.), then thorough clinical history with a thorough clinical examination which was done with proper abdominal examination, Laboratory investigations included full blood count, liver function tests, Prothrombin time and concentration, pre-procedures blood tests as HBsAg and HIV screen; chest and/or abdominal X-ray. BB and multiple magnets were extracted by

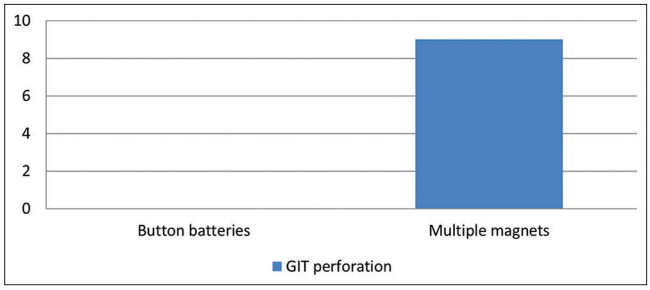


Figure 4: Comparison between button batteries and multiple magnets regarding GIT perforation

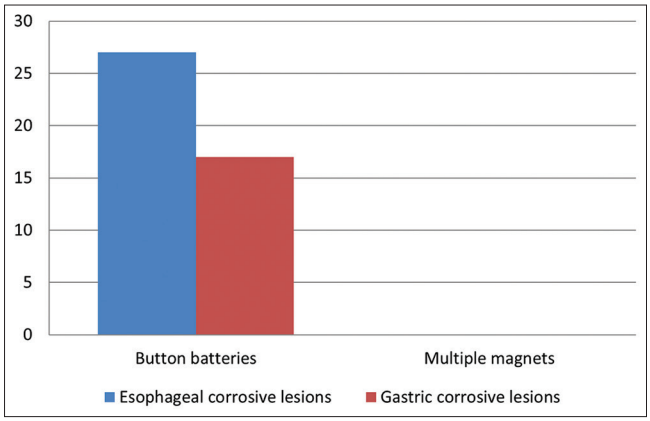


Figure 5: Comparison between button batteries and multiple magnets regarding GIT corrosive lesions

upper GI endoscopy under general anesthesia when endoscopically reachable. All procedures were done by the author, a pediatric gastroenterologist. The findings noticed during the endoscopy were recorded and statistically analyzed. The cases presented late with GIT perforation were referred to the pediatric surgery department for surgical management.

Statistical analysis

Data were fed to the computer and analyzed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp) Qualitative data were described using numbers and percentages. The Kolmogorov-Smirnov test was used to verify the normality of distribution Quantitative data were described using range (minimum and maximum), mean, standard

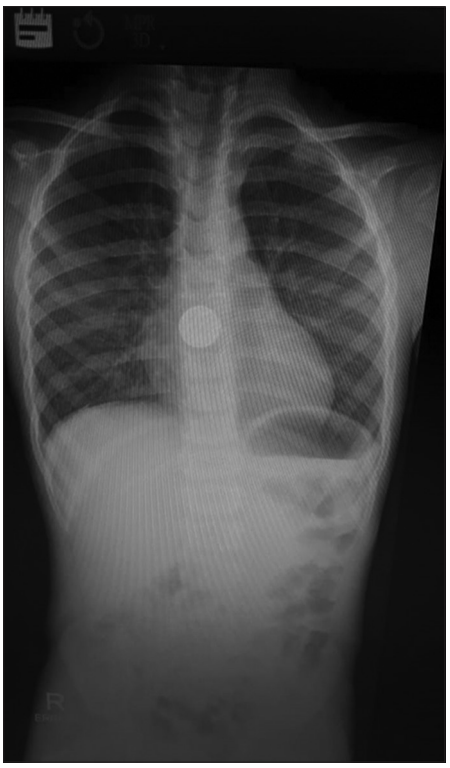


Figure 6: X-ray: Button battery affected in the esophagus

deviation, median. The significance of the obtained results was judged at the 5% level.

The used tests were:

1. Chi-square test: For categorical variables, to compare between different groups
2. MannWhitney test: For abnormally distributed quantitative variables, to compare between two studied groups
3. One-way analysis of variance (ANOVA): The one-way ANOVA is used to determine whether there are any statistically significant differences between the means of three or more independent (unrelated) groups
4. Two-sample t-test: two-sample t-test (also known as the independent samples t-test) is a method used to test whether the unknown population means of two groups are equal or not.

Ethical consideration

The study will be approved by the research scientific ethical committee in the Institute of Postgraduate Childhood Studies.

Ethical consent

Written informed consent will be obtained from the patients' parents or legal guardians after an explanation of the nature and aim of the study and its benefits for their children and adolescents and to the whole community as well as the expected risks that the candidates are subjected to if they participate in the study.

Figure 7: Endoscopic esophageal lesion due to affected battery

Privacy and confidentiality of the subjects

The entire patients' recorded data will be highly confidential. Patients' blood samples will be discarded after performing the required investigations and will not be used for any other purposes.

Ethical points

During the interview, the respondent of the children was simply informed about the aims of this study and the fact that it is done to improve the health status and education of all population. Written consent was obtained from the respondent who accompanied the child. The study followed the ethical standards of the national liver institute- Menofiya university- Egypt, committee (IRB00003413).

Results

There were 151 children enrolled in the study, classified into two groups. The first group constitutes ninety children with BB (Figures 7 and 8), the other group sixty children with multiple magnets ingestion. In addition to one patient with both multiple magnets and battery ingestion which are extracted endoscopically from the stomach without complication. BB detected in the upper GIT in the esophagus, stomach, and duodenum in 70 patients were extracted endoscopically. Other 20 patients where the batteries were detected distal to duodenum were observed till the discharge of batteries was confirmed. In patients with multiple magnets, the magnets were in the upper GIT in 46 patients while found distal to the duodenum in 14 patients.

Figure 8: Battery after endoscopic extraction

In this study, male children were 89 (59.3%) (Figure 2) while female children were 61 (40.7%), their ages ranged from 7 months to 12 years with a mean age was 24.56 ± 24.94 months (Figure 3). The ingestion of FB was witnessed by the mother in most cases

(76%), or the child of suitable age gave the history of ingestion to three patients. The duration from ingestion to endoscopic extraction was variable.

Figure 9: X-ray showed multiple magnets plus battery ingestion

The previous table shows the mean age of different groups, BB' mean age is 4.1 and Multiple magnets are 3.4 with no significance in different groups, as shown in (Table 1).

Table 1: Comparison between button batteries and multiple magnets regarding the sex of patients

Sex	Button batteries		Multiple magnets		p-value
	n = 90		n = 60		
	n	%	n	%	
Male	52	57.77	37	61.66	0.198
Female	38	42.23	23	38.34	

The statistical test used: Chi-square test
$p \leq 0.05$ considered statistically significant (95% confidence interval).

The main presenting symptoms in the BB group were vomiting in 21 patients (23.3%), chest pain or abdominal pain in 11 patients (12.2%), drooling in 9 patients (10%), cough in 7 patients (7.7%), and melena in two (2.2%). No symptom was encountered in 40 patients (44.4%) patients.

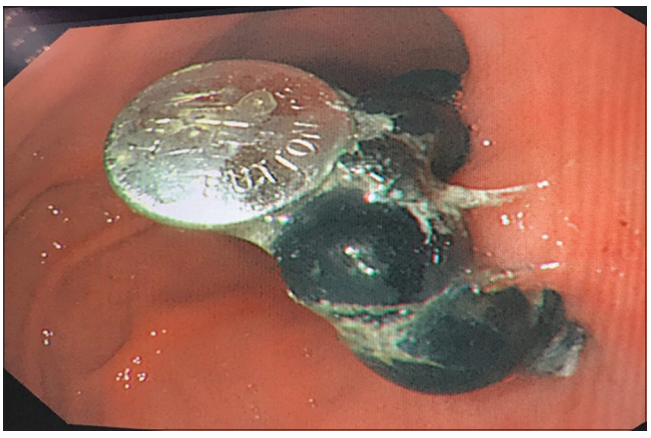


Figure 10: Multiple magnets plus battery in the stomach

Second group, multiple magnets ingestions (Figures 10 and 11) were asymptomatic in 12 patients, mild abdominal pain in 29, colic in 2 patients, while 9 patients presented with symptoms and X-ray findings of GI perforation presented as entero-enteric fistula in 4 patients and gastro-colic (Figure 12) fistula in 5 patients, in which the management was continued by the pediatric surgery team. All patients who were admitted with multiple magnets detected in upper GIT detected by X-ray (Figure 9), in those upper GI endoscopic extraction done as soon as possible according to our protocol, they did not get any complication.

Figure 11: Multiple magnets plus battery after endoscopic extraction

Patients were referred to our unit for endoscopic extraction of the batteries. The time interval between the ingestion and endoscopic extraction ranged from 2 h to >48 h, the delay usually due to the delayed referral of the patient.

In this study, there was no patient of the first group who ingested BB presented with GIT perforation (Figure 4). However, the variable degree of esophageal burn (Figure 5) detected by upper GI endoscopy in 27 patients (Figure 7), the lesion was over 5 cm in 17 patients with esophageal lesions, including the whole circumference in two patients, leading to esophageal stenosis. Those two patients were kept on the nasogastric tube, which was inserted endoscopically for feeding, started proton pump inhibitors (PPI), then endoscopic balloon dilation was done. Gastric erosion detected in 17 patients improved on 2 months' course of PPI.

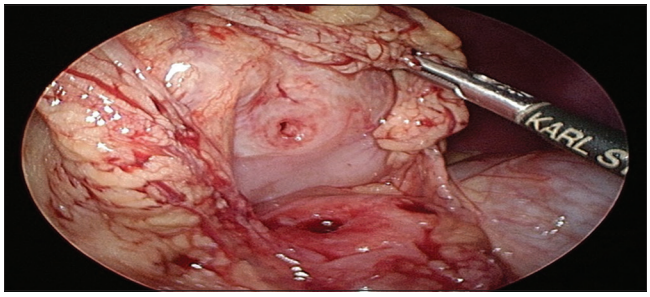


Figure 12: Gastro colic Perforation due to multiple magnets ingestion

Patients were classified according to the duration between ingestion till the endoscopic procedure into 2 groups:

1. Early intervention group where endoscopy was done within 6 h after ingestion
2. Delayed intervention where endoscopy was done beyond 6 h of ingestion

3. The delayed endoscopic intervention was mainly due to delayed referral from the primary center
4. Early extraction <6 h done in 113 patients while endoscopic extraction done in >6 h to 2–3 days in 37 patients
5. BB >20 mm seen in 59 patients, while BB <20 mm seen in 31 patients. The duration of impaction more than 6 h and size of BB >20 mm were the main two factors affecting the severity of esophageal lesions
6. Multiple magnets detected in our study ranged from 7 to 15 small magnets
7. BB were endoscopically extracted with Roth Net in 43 patients, retrieval basket in 18, and foreign body forceps in nine patients. All multiple magnets were extracted endoscopically with Roth Net.

BB were extracted endoscopically from the esophagus in 41 patients (11 from the upper one-third of the esophagus while the remaining 30 were extracted from the lower one-third at the cardia), BB found in the stomach were extracted endoscopically in 29 patients. There were 20 patients with BB seen distal to duodenum kept under observation until confirmation that batteries were discharged.

All of our patients were mentally stable, no deaths were reported in our study. Excellent and safe endoscopic extraction of BB done in all infants and children without endoscopic complications.

Discussion

A foreign body in children is a common pediatric gastroenterology emergency, dangerous ingested objects like batteries, multiple magnets can lead to serious complications. In our study, 90 patients included as BB ingestion, it was observed that the frequency of BB ingestion was increased due to the widespread usage of electronic devices.

Children with magnet ingestion in this study were 60, all of them ingested neodymium magnets which have attractive power 5 times or more compared with the conventional magnets, so the risk of complications was high [11]. This study revealed that the presenting symptoms in BB were vomiting, chest pain or abdominal pain in 11 patients, drooling, cough in seven patients, and melena in two. No symptom was encountered in 40 patients (44.4%) patients, this is the indifference with Ettyreddy *et al*., this may be due to the large series of our study compared to his study [12]. In the multiple magnets ingestion groups, patients were asymptomatic or had mild symptoms as mild abdominal pain and colic, only 9 patients presented with symptoms, and X-ray findings of GI perforation (Table 2) presented as entero-enteric fistula in 4 patients and gastro-colic fistula in 5 patientsthis is in difference to other studies, those, especially those who reported only case studies [13].

Table 2: Comparison between button batteries and multiple magnets regarding GIT perforation

Button batteries		Multiple magnets		p-value
n = 90		n = 60		
n	%	n	%	
GIT perforation				
0	0	9	15	< 0.01

The statistical test used: Chi-square test, P ≤ 0.05 considered statistically significant (95% confidence interval).

There is no GI perforation of the BB group, but inflammation, necrosis, and burn of esophageal mucosa were reported in addition to esophageal stricture post corrosive esophagitis secondary to BB ingestion (Table 2). No tracheoesophageal fistula or esophageal perforation was reported in this study secondary to BB ingestion. This may be due to early intervention by a Pediatric GI endoscopist.

In the BB group (N: 90 patients), corrosive lesions in the esophagus were observed in 27 patients (30%) while gastric corrosive lesions were seen in 17 patients (18.88%) (Table 3) with total caustic lesion seen in 44 patients (48.88%), while such lesion not detected in multiple magnets group which was statistically significant $p < 0.001$ (Table 2). Lesions related to the battery can be explained by different mechanisms, the release of alkaline solution leads to liquefaction necrosis. Inflammation and ischemia are secondary to pressure necrosis if lodged in a certain site for a long duration. Electrical charges can cause mucosal burn, Brumbaugh *et al*., concluded that battery could cause mucosal damage without a leak in an animal model. Finally, leakage of heavy metals released from the fragmented battery leads to corrosive injury [14].

There were no reported post-endoscopic extraction complications in our study, also no serious complications were reported for the next 4 weeks follow-up post-ingestion, this is the indifference with Akilov *et al*., who reported death from aorto-enteric fistula 19 days after removal of the battery [15]. In the current study (multiple magnets ingestion groups) there were 9 patients (15%) of multiple magnets group presented with GI perforation which was statistically significant compared to the BB group (Table 4), 4 patients got entero-enteric fistula while 5 patients had

Table 3: Comparison between button batteries and multiple magnets regarding GIT corrosive lesions

Button batteries		Multiple magnets		p-value
n = 90		n = 60		
n	%	n	%	
Esophageal corrosive lesions				
27	30	0	0	< 0.001
Gastric corrosive lesions				
17	18.88	0	0	

The statistical test used: Chi-square test, P ≤ 0.05 considered statistically significant (95% confidence interval), GIT: Gastrointestinal tract.

a gastro-colic fistula. Multiple magnets can squeeze the intestinal loops by attracting power of the magnets with subsequent bowel ischemia and necrosis leading to subsequent fistula or bowel perforation. Other studies reported a high incidence of perforations as high as 50% for Abbas *et al*.'s study versus 15% of our study. This difference can be explained because he studied 38 cases of magnets ingestion, from those only 8 patients with multiple magnets so the difference of the number of patients enrolled in both studies and the high number of cases in our study can explain this difference [16].

Table 4: Comparison between multiple magnets and button batteries groups regarding age

Studied variables	Button batteries	Multiple magnets	p-value
	n = 90	n = 60	
Mean of age (years)	4.1 ± 3.2	3.4 ± 3.8	0.186

The statistical test used: Two-sample t-test
$p \leq 0.05$ considered statistically significant (95% confidence interval).

Patients with multiple magnets detected by X-ray beyond the area reached by upper GI endoscopy, kept under observation with close observation of vital signs, following signs of complications, frequent X-ray and Polyethylene Glycol, if complicated with signs of perforation, fistula or other surgical complications, the patient will be transferred for surgical intervention as soon as possible.

The indication for surgical referral and intervention depends on the time of presentation, location, numbers of magnets, and associated abdominal symptoms. The late presentation or incidental finding of the magnet during radiological investigation always indicates the late detection of the magnets which raise the high specious of bowel perforation and fistula formation which indicate early surgical intervention. Accidentally discovered multiple magnets ingestion exceeded 48 h in children presented with a picture of intestinal perforation, constipation, or acute abdomen (peritonitis). Once the surgical intervention is needed the laparoscopic choice should be considered with possibilities of open conversion, as the magnet can lead to perforation with spillage of stool in the whole abdomen causing the laparoscopic progress not possible. In case of bowel perforations, always keep in mind that the number of wholes should be even, not to miss any whole without closure. The surgical management of multiple magnets extraction with bowel perforation will vary from simple extraction with perforation sites closure to bowel diversion with stoma formation.

Conclusion

This study put alarm that multiple magnets ingestion carries a high risk of GI perforation in comparison to battery ingestion. Invitation to ban on the sale of products with high-powered neodymium magnets, such as Buckyballs and Buckycubes, and to keep BB difficult reachable by children. In addition to encouraging urgent endoscopic management of suspected BB or multiple magnets ingestion.

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