Ingestion of Multiple Magnets by Children: Diagnosis and Management When Ingestion is not Witnessed

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AIM: Foreign body ingestion, particularly that of magnets, is a significant issue for children aged 6 months to 3 years due to their prevalence in toys and household items. Most ingested foreign bodies pass naturally, but 10%–20% of such cases require endoscopic removal, and <1% require surgery.

CASE PRESENTATION: A 2-year-old girl presented with abdominal pain, nausea, and vomiting. Abdominal ultrasonography revealed numerous non-specific mesenteric lymph nodes. Plain abdominal radiography identified multiple high-radiopacity foreign bodies, 4.5 mm in diameter.

RESULTS: We performed an emergency laparotomy and removed 24 spherical magnets through an intestinal breach.

CONCLUSIONS: Over the past decade, the incidence of magnet ingestion in children has increased notably, largely owing to the presence of small high-strength neodymium magnets in toys. Legislative actions, including recalls and bans, have effectively reduced ingestion cases; however, challenges, such as the resale of banned products and insufficient public awareness, persist. This case report addresses the concerns of this ongoing trend and suggests easy preventive measures to improve the safety of children.

Keywords: multiple magnet ingestion; multiple foreign body ingestion; laparotomy; pediatric surgery; intestinal perforation; prevention; legislative actions

Introduction

Foreign body (FB) ingestion is a serious issue that primarily affects children between the ages of 6 months and 3 years and can lead to life-threatening bowel injuries, especially when it comes to magnets [1]. Currently, the widespread use of small magnets in toys and household items, sold as desk toys and 'stress relievers' that contain hundreds or more small magnetic balls (<6 mm in size), cubes, and cylinders, has made such FBs more accessible [2]. In children who swallow multiple magnets, medical history and physical examination may not reliably indicate the presence of magnets, particularly when the ingestion is not witnessed, and radiological findings may not always conclusively determine whether one or more magnets have been ingested. Ingestion is normally brought to medical attention by a child's caregivers after being witnessed or reported. Only 10%–20% of ingested FBs require endoscopic removal for management, and <1% require surgery [3]. 'Ball magnets' are made of materials such as neodymium iron boron or samarium cobalt, which are 5–10 times stronger than traditional ferrite magnets and can attract multiple layers of intestinal tissues, leading to intestinal obstruction, transmural erosion, perforation, fistulation, and peritonitis [4]. Clinical management and the risk of complications depend on the location and type of FB. We herein report a complex clinical case presented at our hospital, in which rapid surgical intervention was necessary to prevent intestinal necrosis and widespread peritonitis. Despite the unwitnessed nature of FB ingestion, it is common in children and warrants consideration in the differential diagnosis of acute abdominal pain in pediatric patients. A prompt diagnosis is essential to avoid serious complications. Despite increasing awareness regarding such clinical emergencies, we need to intensify our efforts to educate families and toy manufacturers about the potentially fatal consequences of FB ingestion. Clinicians and caregivers should work together to promptly prevent and identify such deceptive medical issues.

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Case Report

Patient History

A 2-year-old girl was transferred to our emergency department with a 2-day history of abdominal pain, nausea, and 15 episodes of vomiting in the last 24 hours. In the previous 48 hours, there was no evacuation of the foreign body, fever, diarrhea, or evidence of possible ingestion of FBs (Table 1).

Table 1. Graphic summary of the evolution of symptoms and medical signs of our patient.

Symptoms	Present at admission	Developed during observation
Abdominal pain	++	++++
Nausea	++	++++
Emesis	++++	++++
Fever		+
Diarrhea		

Table 1: The '+' symbol indicates a scale of severity observed: '+' means the sign/symptom is present; '++' means mild; and '++++' means severe. The patient had no diarrhea.

Table 2. Laboratory exams at presentation.

Blood test	Values	Unit of Measurement – (References)
Leukocytes	**19.05**	10^3/μL - (5.5–15.0)
Percentage of leukocytes	10.5	% - (40.0–57.0)
Neutrophils	**16.48**	10^3/μL - (2.0–8.0)
Percentage of neutrophils	**86.5**	% - (30.0–55.0)
Haemoglobin	12.8	g/dL - (10.5–15.5)
Platlets	**495.0**	10^3/μL - (150.0–450.0)
CRP (C-reactive protein)	0.31	mg/dL - (<0.5)
Natraemia	137.0	mEq/L - (136.0–145.0)
Chlorides	**97.0**	mEq/L - (98.0–107.0)
LDH	**371**	U/L - (120.0–300.0)
Azotaemia	**20.0**	mg/dL - (5.0–18.0)
Plasma uric acid	**7.0**	mg/dL - (2.4–5.7)
Aspartate aminotransferase	**34**	U/L (<32)

Table 2: The table describes the laboratory parameters found out at presentation. The "**bold character**" indicates the out-of-range parameters. CRP, C-reactive protein; LDH, lactate dehydrogenase.

Her medical records indicated that she was born at term with a birth weight of 3400 grams after a normal pregnancy, and she had a previous hospitalization at 6 months of age for poor growth, mild gastro-oesophageal reflux, and coronavirus disease 2019 infection with pulmonary involvement.

Laboratory Findings at Presentation

Upon admission, blood tests and complete abdominal ultrasonography were performed. Ultrasonography revealed numerous sub-centimetric, non-specific lymph nodes in the mesenteric area but no other significant findings. Blood tests revealed leukocytosis (19.05×10^3/μL) and neutrophilia (16.48×10^3/μL), common in pediatric gastroenteritis and acute abdominal inflammatory processes, while C-reactive protein was negative (0.31 mg/dL). Platelets, chloride, lactate dehydrogenase, azotemia, plasma uric acid, and aspartate aminotransferase levels were abnormal, suggesting a possible pre-septic evolution (Table 2).

Re-Evaluation, Diagnosis, and Treatment

Initially, we kept the patient fasting and administered parenteral fluid therapy. Owing to worsening abdominal symptoms, a re-evaluation was required. The patient was mournful and restless with contracted diuresis, generalized tenderness, and guarding. Abdominal ultrasonography showed a 7-mm layer of fluid in the right parietocolic gutter, thickened and hyperechoic locoregional adipose tissue, small bowel loops with a traction aspect in the paraumbilical region, and lymph nodes that were larger than normal. The mesenteric vascular structures could not be evaluated (Fig. 1A–C).

Plain abdominal radiography revealed multiple small-calibre (4.5 mm) high-radiopacity FBs in the mesogastric area and marked gaseous distension of small intestine loops with an inverted 'U' appearance and thickened folds, but no sub-diaphragmatic air (Fig. 2A).

Surgical Findings and Intervention

An emergency supra- and sub-umbilical median laparotomy was performed. The small intestine was exteriorized, revealing a markedly distended ileal loop caused by the volvulus from the magnetic FBs. We found a parietal perforation between the FBs, approximately 80–90 cm from the ligament of Treitz; however, there was no vascular distress (Fig. 2B,C). Intestinal de-torsion and a small enterotomy were performed to remove 24 spherical magnets (each sized 0.5 cm) (Fig. 2D). Manual palpation revealed no other FBs. Intraoperative radiography confirmed the absence of

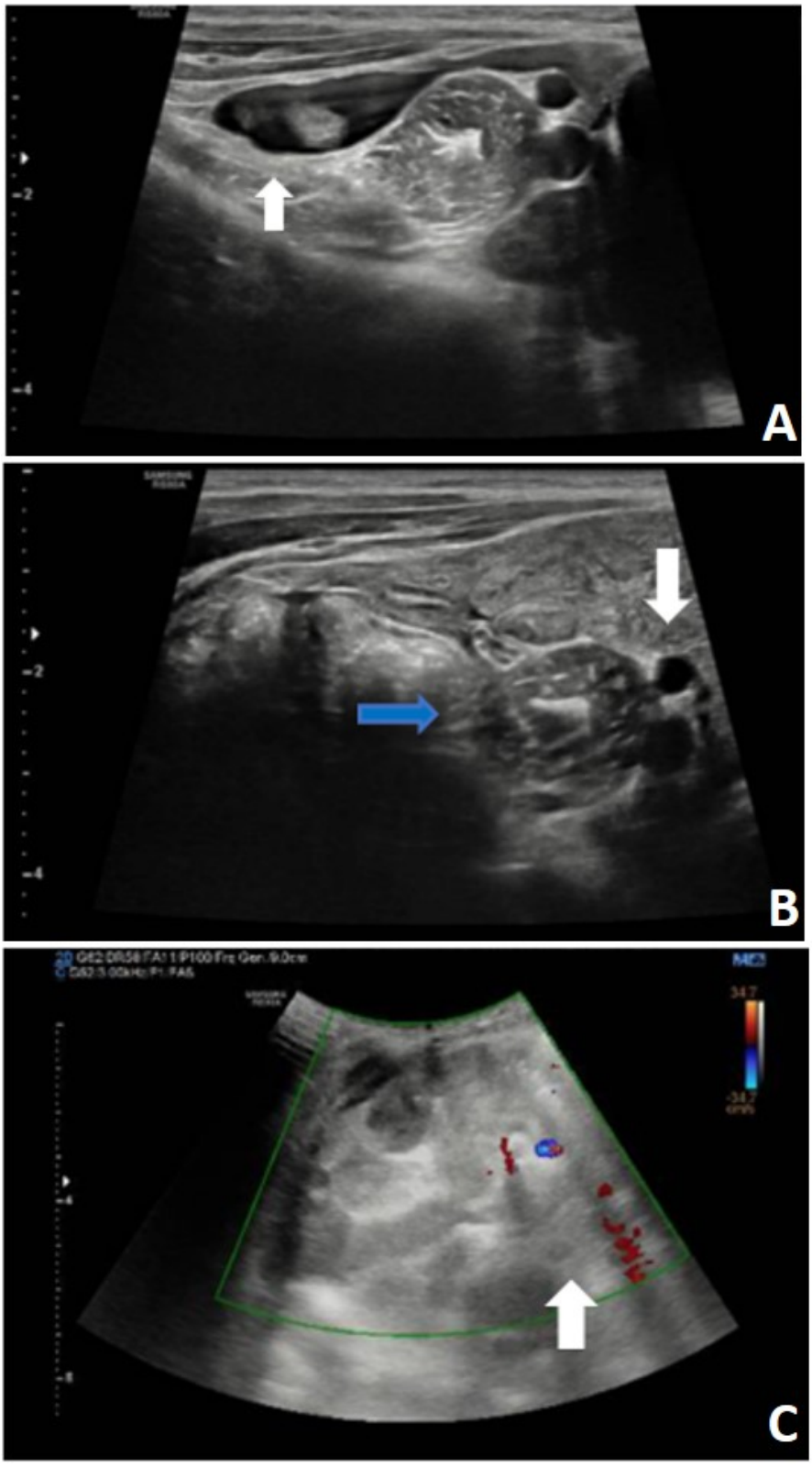

Fig. 1. Abdominal ultrasonography. (A) The arrow indicates the fluid layer in the parieto-colic gutter with thickening and hyperechogenicity of the locoregional adipose tissue. (B) The 'blue arrow' points at a small bowel loop and traction aspect to the right of the meso in the para-umbilical region, while the 'white arrow' indicates multiple lymph nodes increased in size. (C) The arrow indicates poor sampling of the vascular signals of the mesenteric fan in abdominal ultrasonography.

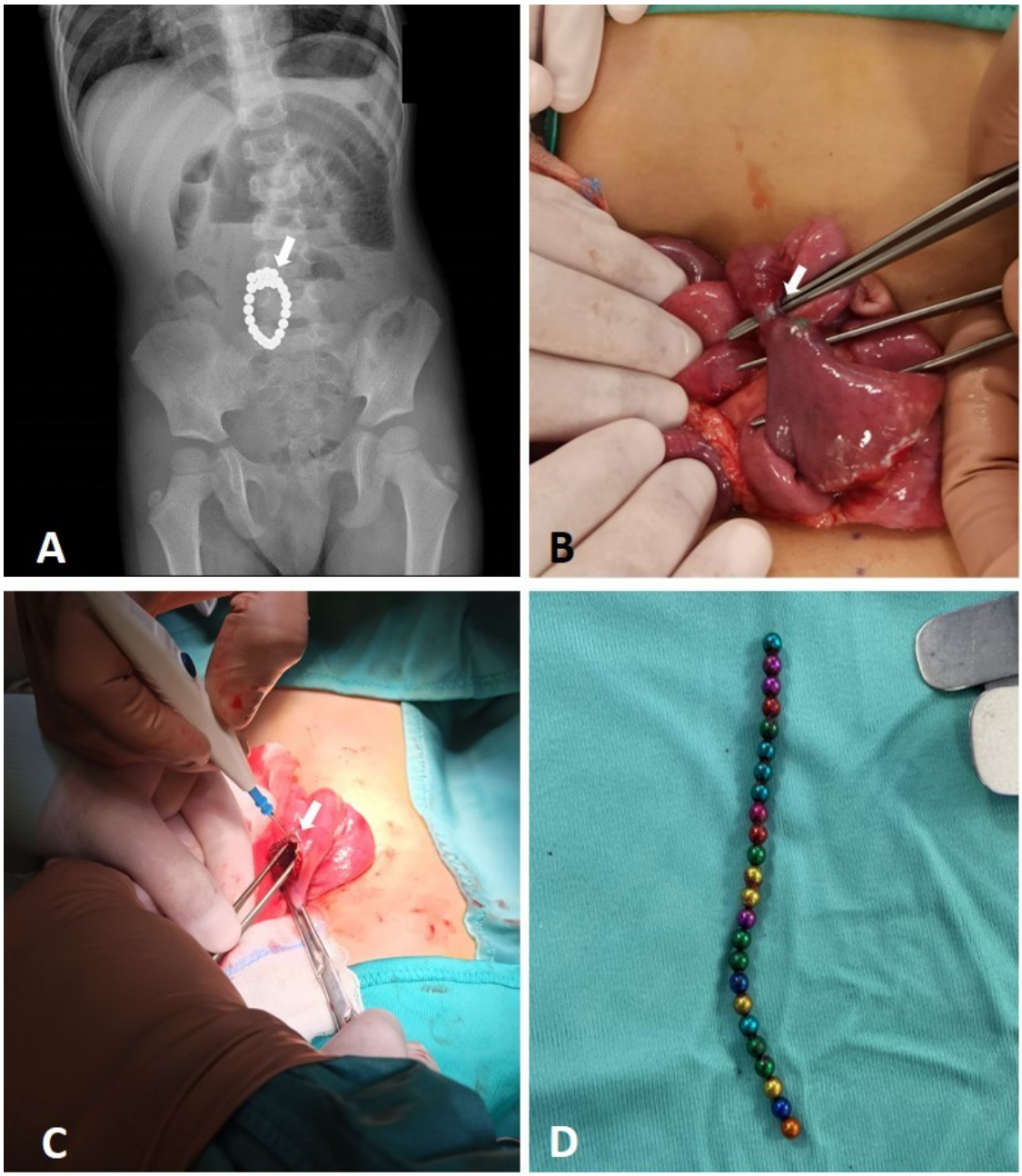

Fig. 2. Intraoperative findings. (A) The arrow indicates multiple small-calibre high-radiopacity foreign bodies in the mesogastric area and gaseous distension of small intestine loops with an inverted 'U' appearance. (B) Manual separation of the intestinal walls between the magnets reveals a parietal perforation (indicated by the arrow) at the contact area, approximately 80–90 cm from the ligament of Treitz. (C) Enterotomy with monopolar cautery through the proximal perforation (indicated by the arrow) and removal of the foreign bodies. (D) The 24 spherical magnets were extracted through the intestinal breach.

any residual FBs (Fig. 3). We sutured the enterotomy site and checked for intestinal transit from the ligament of Treitz to the ileocecal valve, noting no further perforations.

Outcome and Follow-up

On postoperative day 7, the child's recovery was uneventful and complete. The patient had a positive clinical course following hospitalization for volvulus and intestinal perforation. Owing to the irregular bowel habits observed during the hospital stay, a gastroenterologist prescribed treatment for coprostasis, which resolved the issue. At the 1.5-year follow-up after the surgical intervention, the patient showed no complications and was in excellent health.

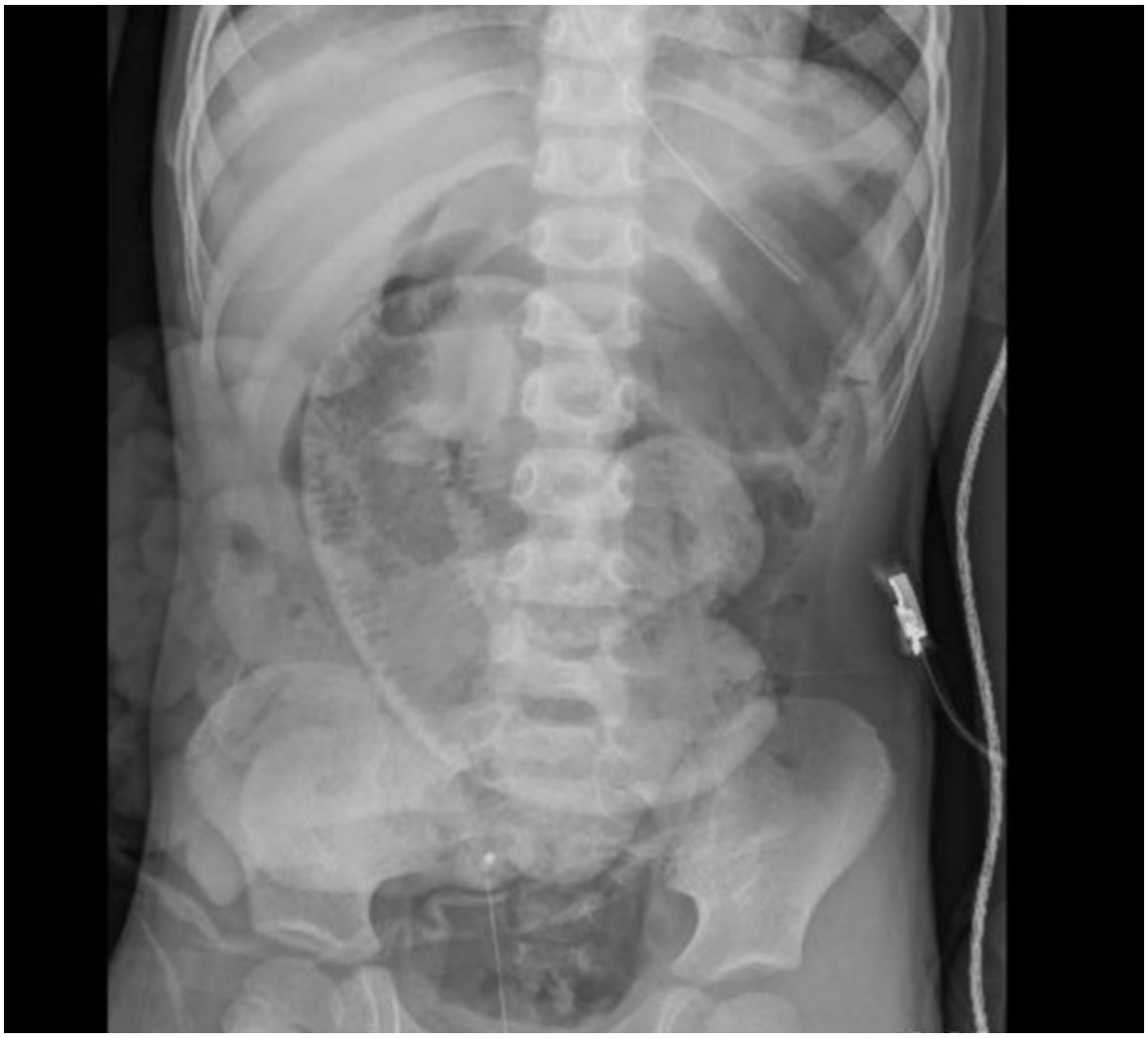

Fig. 3. An intraoperative radiograph performed after the extraction of the magnets showing no residual foreign bodies.

Discussion

Over the past 10 years, there has been a discernible increase in the number of children who present with symptoms consistent with the ingestion of multiple magnets. Children are the most vulnerable group. It is more common in extremes of ages, but especially among the pediatric age group, with a wide spectrum of clinical problems and surgical complications [5, 6]. The largest FB surveillance registry in Europe reports an annual incidence of non-food FBs among European Union children aged 0–14 years, with a fatality rate of 1%. Approximately 10,000 are inorganic and 2000 involve toys [7]. As toddlers play, they may place FBs in their mouths without being observed by adult observers. Any attempt to talk, laugh, or sing can lead to inadvertent swallowing or aspiration of the FB. The classic diagnostic history of FB aspiration may go unnoticed without an adult witness [5].

Magnet ingestion caused an 8.5-fold increase (75% average annual increase) in emergency department visits in the USA from 2002 to 2011 [8]. Researchers first established in 2002 that using neodymium magnets could damage the bowels [9]. Moreover, the increasing rate of magnet ingestion and the observed complications were related to the production of neodymium magnets in 2008. Neodymium allows companies to produce smaller (approximately 3 mm) and stronger magnets. In response to this increased risk, some countries, such as the USA, have forbidden the commerce of such magnets since 2010, recalling packages containing small magnets that have been made available for older children. Despite the passage of years, more recent studies conducted in France and a report published by Lemoine *et al*. [10] highlight that magnet ingestion is still a major concern. As mentioned previously, a single swallowed magnet typically exits the body on its own and rarely requires endoscopic removal. The number of magnets ingested strictly correlates with the risk of intestinal wall compression, pressure necrosis, fistula formation, or perforation, necessitating rapid surgical intervention to treat these conditions. Patients who ingest numerous magnets and exhibit signs of intestinal blockage require immediate surgical intervention.

Talvard *et al*. [11] reported in their case series that 88% of children who ingested multiple magnets (and even two children (12.5%) who ingested only one magnet) required removal, either endoscopically (33%) or surgically (58%). Owing to the prevalence of rare-earth magnets in children's toys, doctors and pediatric surgeons may find themselves dealing with this situation, which does not always receive appropriate medical attention [12, 13]. There is a significant delay in hospitalization and treatment, as demonstrated by the findings of a study conducted by Oestreich [14] that analyzed 128 cases of numerous magnets being ingested. The lack of information parents and healthcare providers have about toy components and manufacturers' failure to label toys that use specific batteries may be to blame. Several measures can be taken to reduce the risk of severe complications, including educating general practitioners and the general population about the risks and need for prompt hospital referral in the event of accidental ingestion [15]. European guidelines recommend urgent upper gastrointestinal endoscopy to remove multiple magnets from the stomach before they pass into the small bowel.

Research suggests that children with psychological disorders, such as autism, attention deficit hyperactivity disorder, or psychosis, are more likely to ingest multiple magnets. Children with psychiatric conditions were older than healthy children, with mean ages of 7.5 and 4.7 years, respectively. Rarely, when ingestion seems intentional, we must not forget that magnets can be confused with small candies [11].

Implementation of public health measures to prevent accidental magnet ingestion in children remains unclear. There is a strong relationship between the incidence of magnet ingestion and legislative laws [16]. The Consumer Product Safety Commission (CPSC) in the USA, and Health Canada in Canada used their legislative powers to promote public safety. The death of a 2-year-old boy in Washington State after swallowing magnet pieces (Magnetix; Rose Art Industries Inc., Livingston, NJ, USA) was the first event leading to the recall of the magnet set by the USA CPSC [17].

They used voluntary or mandatory recalls and CPSC-approved standards for high-powered magnet sets to protect children and teenagers [15]. A study conducted in Canada 2 years before and 2 years after the recall found that the incidence of magnet ingestion had significantly decreased [18]. A nationwide educational campaign in Israel achieved a 35% reduction in the incidence of FB aspiration in children aged >3 years [19]. A significant number of magnet ingestion cases were reported in Saudi Arabia until the Defective Products Recall Center banned magnet sets from the market in February 2020 (reference number: 20020-20023). Following the ban, the number of cases dropped dramatically at both the local and national levels. However, the unnoticed resale of these magnets led to a steady increase in the number of cases a year after the ban [16].

Preventive efforts should include public health education and close monitoring of children by parents and caregivers during play. Despite worldwide advances in imaging and endoscopic technologies, the high risk of mortality associated with FBs in the aerodigestive tract underscores the importance of preventive measures. Health education for mothers at antenatal clinics and student curricula should incorporate education on preventive measures. In addition to limiting the production of rare-earth magnetic toys, it is critical to educate parents and families extensively about the specific dangers associated with ingesting these magnets through school educational programs, social media platforms, and public media channels. Standardised diagnostic and therapeutic approaches may reduce or prevent serious complications [20].

In our clinical report, we found no history of magnet ingestion or psychological disorders, and misdiagnosed the patient's symptoms as gastroenteritis owing to a minor abdominal ache at the onset of clinical presentation. This case study highlights the importance of professionals and parents maintaining an understanding of potentially fatal illnesses. In contrast to the main cases presented in the literature, our patient's initial diagnosis and treatment were misleading because there was no reasonable suspicion of FB ingestion.

Initially, the patient's medical history and background did not align with the final diagnosis, which led to evaluation and treatment of gastroenteritis. As the ingestion occurred unwitnessed, the management and diagnosis of this case were delayed. Despite the case's resolution without major complications, such subtle ingestion can provide valuable lessons. First, we must consider that the delay in the differential diagnosis and the eventual discovery of the 24 magnets required more extensive surgical intervention, with longer recovery and hospitalisation. Timely diagnosis could have permitted a simpler endoscopic procedure, while avoiding invasive treatment. Unfortunately, without witnesses, identifying the origin of the abdominal pain was challenging. This lack of initial information complicates the diagnostic process and delays recognition of the true cause. Such cases underscore the difficulty in diagnosing FB ingestion when no one observes the event, highlighting the need for high clinical suspicion and thorough investigation in similar scenarios. Unlike many case reports in the literature, including those concerning unwitnessed FB ingestion, this report aimed to emphasise the importance of a thorough diagnostic workup. Drawing from lived experiences, this study summarises and reviews existing legislative standards and global prevention campaigns. Additionally, it offers suggestions for national, hospital, and community initiatives as well as preventive measures within the home environment to stop this trend.

Public Health Initiatives, Strategies for Prevention, and Legislative Actions

As reported in the literature, we examined the initiatives carried out by countries such as Canada, the USA, and Saudi Arabia. Our group evaluated the implementation of suggestions and public health initiatives that can be undertaken to reduce the risk of FB ingestion in children and associated complications. Continuous education, stringent regulations, and active surveillance are the keys to protecting children from this preventable hazard. The first step in reaching a large audience should include awareness campaigns and the launch of nationwide educational programs for parents, caregivers, and health professionals to elucidate the dangers of magnet ingestion and promote immediate medical attention. Social media and television can serve as platforms for nationwide educational campaigns to disseminate information. Incorporating classes based on the risks of FB ingestion, including magnets, into school curricula (primarily for children attending day-care) and antenatal classes for expectant parents may improve the safety of children. Setting up a strong surveillance system to track and report cases of magnet ingestion through a central database for health professionals could provide important data that would help identify trends and determine the efficacy of interventions. Organizations and parenting groups can combat community engagement by spreading awareness and implementing preventive measures. Nonetheless, the risks can be reduced by encouraging parents and caregivers to supervise children during play and regularly check toys for loose or detachable parts.

Health professionals can design a free medical app that offers real-time guidance on the actions to take in the case of suspected ingestion. This app can reduce delays in seeking medical attention in various scenarios such as the ingestion of magnets, batteries, or other FBs. A medical smartphone application can function as an educational resource, informing parents about the dangers of certain toys and household items, including safety tips and preventive measures to minimize the risk of ingestion.

Hospitals should develop standardized protocols for diagnosis and treatment to ensure a rapid and effective medical response, including urgent upper gastrointestinal endoscopy for the retrieval of swallowed magnets before they pass into the small bowel.

Legislative action should ban high-powered magnets, especially in toys and products accessible to children, or at least implement strict regulations that enforce the recall of products containing small high-powered magnets. A centralized database that provides information on the most commonly used toys involved in the unsupervised ingestion of magnetic or non-magnetic FBs could provide evidence of products that require market withdrawal.

Selling companies can establish and enforce stringent safety standards for toys and other products to ensure that magnets are securely enclosed and cannot be easily detached. In addition, manufacturers should include clear warning labels on products containing small magnets, highlighting the risks of ingestion.

Finally, legislative actions should impose penalties on companies that fail to comply with safety standards or recall directives.

Conclusions

In the past decade, despite advances in medical technology, the number of children ingesting multiple magnets has increased, posing a significant mortality risk. Preventive education targeting parents, caregivers, and healthcare professionals is critical for timely intervention. Effective legislation has reduced magnet ingestion incidents; however, challenges such as the unnoticed resale of banned products and inadequate caregiver awareness persist. Therefore, continued vigilance and public health initiatives are necessary. Preventive measures, including education and supervision during play, are essential for mitigating risks. Although global initiatives are limited, widespread awareness campaigns, educational programs, centralised surveillance, and medical apps for real-time guidance can improve safety and enforce stringent standards. Standardised diagnostic and therapeutic approaches are recommended to enhance outcomes and address this preventable issue. Further research and preventive measures at both the household and governmental levels are crucial for effectively addressing this concerning trend.

Availability of Data and Materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

LC and SF designed the research study. LC, SF and IPA performed the research. AB, AA, VP and AI analyzed the data. LC and SF wrote the manuscript. All authors revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent for the publication of the case report was obtained from the patient's parents. Ethical approval for the study was waived by the Ethics Committee of Bambino Gesù Children's Hospital.

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Conflict of Interest

The authors declare no conflict of interest.

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