



Rare-Earth Magnet Ingestion–Related Injuries in the Pediatric Population: A Review

Abstract: Foreign-body ingestions are common among children and usually resolve with limited, if any, treatment. The ingestion of rare-earth magnets, however, commonly results in serious injury or death. These dangerous high-powered magnets can be found in the United States in a variety of consumer products, including magnetic toy sets designed for children and adults. The ingestion of one of such magnet is unlikely to cause significant harm. However, if multiple magnets are ingested, or if a magnet is ingested along with a metal object, the magnets are powerful enough to attract each other through the walls of the intestine, potentially resulting in significant internal damage. Rare-earth magnet ingestion cases are difficult to diagnose and the symptoms are not easy to differentiate from other causes of gastrointestinal illness or pain. However, delays in medical treatment can lead to serious injury or death. This review article describes the epidemiology of rare-earth magnet ingestion-related injuries and provides recommendations for diagnosis and treatment. Federal

regulatory efforts related to rare-earth magnets and other prevention strategies are also discussed.

Keywords: magnet; ingestion; foreign body; fatality; pediatric; child; injury; emergency

magnets, these powerful and often miniscule magnets are created from alloys of neodymium iron boron or samarium cobalt, and can be 5 to 10 times stronger than traditional magnets.^{3,4} Rare-earth magnets can be found in a variety of consumer products, including entertainment products designed for adults, such as

 Injuries related to the ingestion of rare-earth magnets may include bowel obstructions and perforations, intestinal fistulas, volvulus, peritonitis, necrosis, and sepsis. 

The ingestion of nonfood items is not uncommon among the pediatric population. The majority of foreign body ingestions resolve on their own, do not require surgery, and do not cause any lasting health effects.^{1,2} However, the ingestion of high-powered magnets can result in life-threatening injuries, permanent disability, or death. Known as rare-earth

those sold under the names of Buckyballs and Buckycubes (recalled in 2014),⁵ and toys for children, including Magnetix building sets and Polly Pocket magnetic play sets, both of which were voluntarily recalled in 2006.^{3,6,7} Although rare-earth magnets are small in size, frequently less than 6 mm in diameter, they are very powerful. The ingestion of a single rare-earth magnet

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is unlikely to cause significant harm; however, if multiple magnets are ingested, or if a magnet is swallowed along with a metal object, the magnets are strong enough to attract each other through the intestinal walls and can cause significant internal damage. Injuries related to the ingestion of rare-earth magnets may include bowel obstructions and perforations, intestinal fistulas, volvulus, peritonitis, necrosis, and sepsis.^{3,8}

Epidemiology of Magnet Ingestion-Related Injuries

All Types of Magnets

Between 2002 and 2011, an estimated 16 386 children younger than 18 years were treated in hospital emergency departments in the United States for possible magnet ingestion; however, these injuries are believed to be underreported. This study included all types of magnets, including non-rare-earth magnets.⁹ The source of ingested magnets is most commonly from children's toys or kitchen gadgets.^{9,10} The number of emergency department visits among children attributable to suspected magnet ingestion increased by as much as 8.5-fold from 2002 to 2011.^{9,11}

Foreign body ingestions have been reported among children of all ages; however, young children are usually at highest risk of ingesting nonfood items as a result of their tendency to explore their environment with their mouths. In the study by Abbas et al,⁹ most patients who ingested magnets were male and more than half of the children were younger than 5 years. Ninety-six percent of patients in the study by Abbas et al⁹ were examined and/or treated in the emergency department, without being admitted.

Rare-Earth Magnets

Rare-earth magnet ingestions have a different age distribution than traditional magnets and foreign bodies in general. A recent retrospective analysis of data collected by or reported to the US Consumer Product Safety Commission (CPSC) identified 72 cases of rare-earth magnet ingestion-related injuries among children 15 years or younger. In this

study, which may not be representative of all rare-earth magnet ingestions, the mean age of the injured child was 6.4 years with peaks at 2 to 4 years and 8 to 10 years.⁸ More than half of the injured children in the study sample were male (54.2%); however, all the injuries to children 12 years or older involved females.⁸ This is likely related to the fact that females were more likely to ingest magnets while using them to simulate piercings of the tongue or lip. Magnet-related faux piercing injuries were more common among older children (10-15 years old).⁸ Other causes of ingestion identified in this study included mistaking the magnets for candy (6.9%) and using teeth to separate 2 magnets or carrying magnets in the mouth (4.2%).⁸ In the majority of the cases (69.4%), the reason for the ingestion was not identified.⁸ Magnet ingestions also are seen in children with developmental delays who have a tendency to put things in their mouth.³ Other research has indicated that in some cases of rare-earth magnet ingestion, the magnets had become dislodged from the toys and in others the magnetic toys were ingested intact.³ There also have been a few reports of older children consuming magnets intentionally, for example, on a dare or to see what would happen.³

In the study by De Roo et al,⁸ the number of magnets ingested in each case ranged from 1 to 40. Among cases in which a clinical outcome was specified, the most common outcome was multiple perforation and necrosis (34.3%).⁸ Other clinical outcomes included magnet lodged in bowel (6.0%), perforation (6.0%), ulcer (4.5%), bowel obstruction (3.0%), fistula (3.0%), and volvulus (1.5%).⁸ Thirty-three percent of cases reported no adverse effects.⁸ Surgery was performed in 69.7% of cases for which medical treatment was reported, and 73.6% of cases were admitted to the hospital.⁸ There has been at least 1 known fatality in the United States related to the ingestion of rare-earth magnets.^{3,6} The cause of death of the 20-month-old male was volvulus, bowel necrosis, and sepsis, caused by the ingestion of nine 6-mm cylindrical magnets that had

become dislodged from an older sibling's magnetic building set.³

Diagnosis and Management

Rare-earth magnet ingestion cases are difficult to diagnose, especially in nonverbal children; the signs and symptoms are not easy to differentiate from other causes of gastrointestinal illness. Children who ingest magnets may be unable or unwilling to admit to their actions.³ Also, parents and caregivers may not be aware of the danger and, if they observe or are made aware of the ingestion, may expect that the magnets will pass through the body on their own. These scenarios could result in a potentially serious delay in medical care. Treatment delays related to rare-earth magnet ingestion are common and delays of up to 6 months have been documented.¹² Reasons for treatment delays include the presentation of ambiguous symptoms, such as vomiting, "flu-like" symptoms, fever, and dull abdominal pain, incorrect diagnosis, and patient withholding of information about the ingestion.^{8,13,14} Magnet ingestion incidents are frequently not witnessed by an adult.^{2,8}

When rare-earth magnet ingestion cases do present in the health care setting, medical professionals must be aware of the potential for serious complications and the need for rapid evaluation and management.^{13,15,16} Delays in treatment can increase the likelihood of multiple perforations and bowel necrosis.⁸ The North American Society for Pediatric Gastroenterology, Hepatology, and Nutrition (NASPGHAN) recommends that clinicians treating children ask patients and caregivers about the possibility of magnet ingestion when evaluating gastrointestinal complaints.⁴ Diagnosis can be aided with the use of a radiograph or ultrasound, but these evaluations may not be used due to the relatively rare nature of these cases, the lack of witnesses to the ingestion, and the presence of ambiguous symptoms.⁸ Some studies recommend radiography when children present with abdominal pain with no identified cause.^{13,17} De Roo et al⁸ found that medical imaging was performed in 65.3% of cases in their study, most

commonly in the form of radiographs (91.5%). It is important to note that radiological methods alone may not allow the health care provider to determine whether the identified objects are magnetic, if there are multiple magnets stacked together or only one, or whether the magnets are in different sections of the intestinal tract and attracted through the intestinal wall.^{3,10,18} One diagnostic strategy is to pass a compass near the abdomen to help determine if an ingested item is magnetic. This should be done in an area away from electronic equipment that may generate a magnetic field.³

If ingestion of multiple magnets is confirmed, early consultation with a gastroenterologist and/or surgeon is recommended.¹⁰ Treatment options for the investigation and removal of ingested magnets include the following: no treatment (if a single magnet is ingested and expected to pass without complications), use of motility agents, upper or lower endoscopy, laparotomy, gastrotomy, small bowel enterotomy, and removal of the magnets through the appendiceal stump.^{4,10} Endoscopic removal using a net retrieval device, snares, basket retrieval devices, or multiprong forceps is common.⁴ However, the magnetic force may be too strong to allow for the endoscopic removal of magnets that are attracted to each other through the bowel wall and open surgical removal may be required. In numerous cases of multiple magnet ingestion, bowel resection and repairs of perforations and fistula have been performed.⁴ Many children have also been treated for complications resulting from magnet ingestion, including peritonitis and erosion of gastrointestinal mucosa.^{9,10} The NASPGHAN has issued an algorithm to aid clinicians in the identification and management of rare-earth magnet ingestions (see the appendix).⁴

Federal Regulation of Rare-Earth Magnets

The CPSC first issued warnings about the dangers of high-powered magnetic toy sets for children in 2006.^{6,7} Although the toy manufacturers cited in the initial

warnings responded with recalls and redesigns of the toys in question, new children's toys containing high-powered magnets were subsequently introduced to the market.^{3,6,7,9} In 2009, sales of magnetic entertainment sets containing hundreds of rare-earth magnets in a single set began to increase significantly.¹⁹ Although most of these items were marketed to adults, they were also appealing to children and the number of reported cases of rare-earth magnet ingestion began to rise. De Roo et al⁸ found that half of the magnets ingested by children in their study came from toys designed for use by children (49.3%) and that the remainder were from products intended for adults (50.7%).

As the popularity of these high-powered magnetic products increased, so did the reported injuries to children associated with these products. In 2010, the CPSC received the first consumer incident reports involving magnet sets and began to collect and evaluate product samples.¹⁹ The following year, the CPSC determined that magnet sets marketed to children younger than 13 years were noncompliant with the ASTM International safety standard ASTM F963-11, *Standard Consumer Safety Specification for Toy Safety*.¹⁹ Specifically, the products appeared to be marketed to children, but did not meet the standard's requirements for magnets that are part of a child's toy.¹⁹ Notices of Noncompliance were issued to companies marketing high-powered magnetic products to children and other companies selling magnetic entertainment sets were advised to direct their marketing and labeling to adults.^{8,10,19} Most of the importers who were selling the magnet sets voluntarily withdrew their products from the market in 2012, and the CPSC initiated administrative action against the remaining 3 importers.¹⁹ The administrative complaints were settled with 2 of the companies in 2014 and recalls were issued for their products.^{5,19} One importer continues to sell magnet sets despite ongoing CPSC administrative action.¹⁹

In September 2012, the CPSC expanded their regulatory efforts by issuing a Notice of Proposed Rulemaking to ban all magnetic toy and entertainment sets containing more than one magnet small enough to fit

within a small parts test device, unless the magnets have a flux index of 50 kG² mm² or less.¹⁹ In September 2014, the CPSC promulgated the final rule to regulate the types of magnetic sets that can be sold in the United States, which came into effect in April 2015.²⁰

Preventing Rare-Earth Magnet Ingestion-Related Injuries

Because of the difficulty in diagnosing magnet ingestions and the serious injuries that may result without timely recognition and intervention, primary prevention is very important. The CPSC's recent regulation of rare-earth magnets is the most effective means of preventing injuries from their ingestion. Restricting the magnetic power of small magnets available to consumers will reduce the risk of serious injury by preventing the flow of these dangerous products into the retail market. Individuals who would like to report a rare-earth magnet ingestion or an incident involving another unsafe consumer product to the CPSC may do so by going to www.saferproducts.gov or calling the CPSC hotline at (800) 638-2772.

In addition to restricting their manufacture and sale, physicians, parents, and child caregivers should be made aware of the unique risks posed by the ingestion of rare-earth magnets. Despite recalls, warning labels, awareness campaigns, and recent restrictions on the sale of products containing these high-powered magnets, the previous popularity of these items indicates that these magnetic sets are likely to remain in countless homes across the country. It is estimated that only 10% of recalled children's products are properly corrected, replaced or returned.²¹ Given that there were millions of magnetic toy sets for children and desk sets for adults sold prior to the 2014 ban, there are no doubt millions of small high-powered magnets still in the hands of US consumers. Parents and child caregivers should be encouraged to dispose of any products containing rare-earth magnets that are small enough to fit within a small parts test device. Emphasis should be placed on the need to keep high-powered magnets out of

environments where children live and play. Children with developmental disabilities also may be more likely to ingest magnets and other foreign bodies. Magnets should not be used by individuals of any age to mimic piercings of the nose, tongue, or lip.

In addition to warning parents and child caregivers about the dangers posed by these items, families should also be made aware of the warning signs and symptoms of magnet ingestions and their tendency to mimic other gastrointestinal ailments. If a child has a known exposure to rare-earth magnets, magnet ingestion should be considered in the differential diagnosis if gastrointestinal symptoms develop. In case of suspected magnet ingestion, parents and child caregivers should be encouraged to seek immediate medical

attention, because delayed treatment may increase the likelihood of a serious medical outcome.

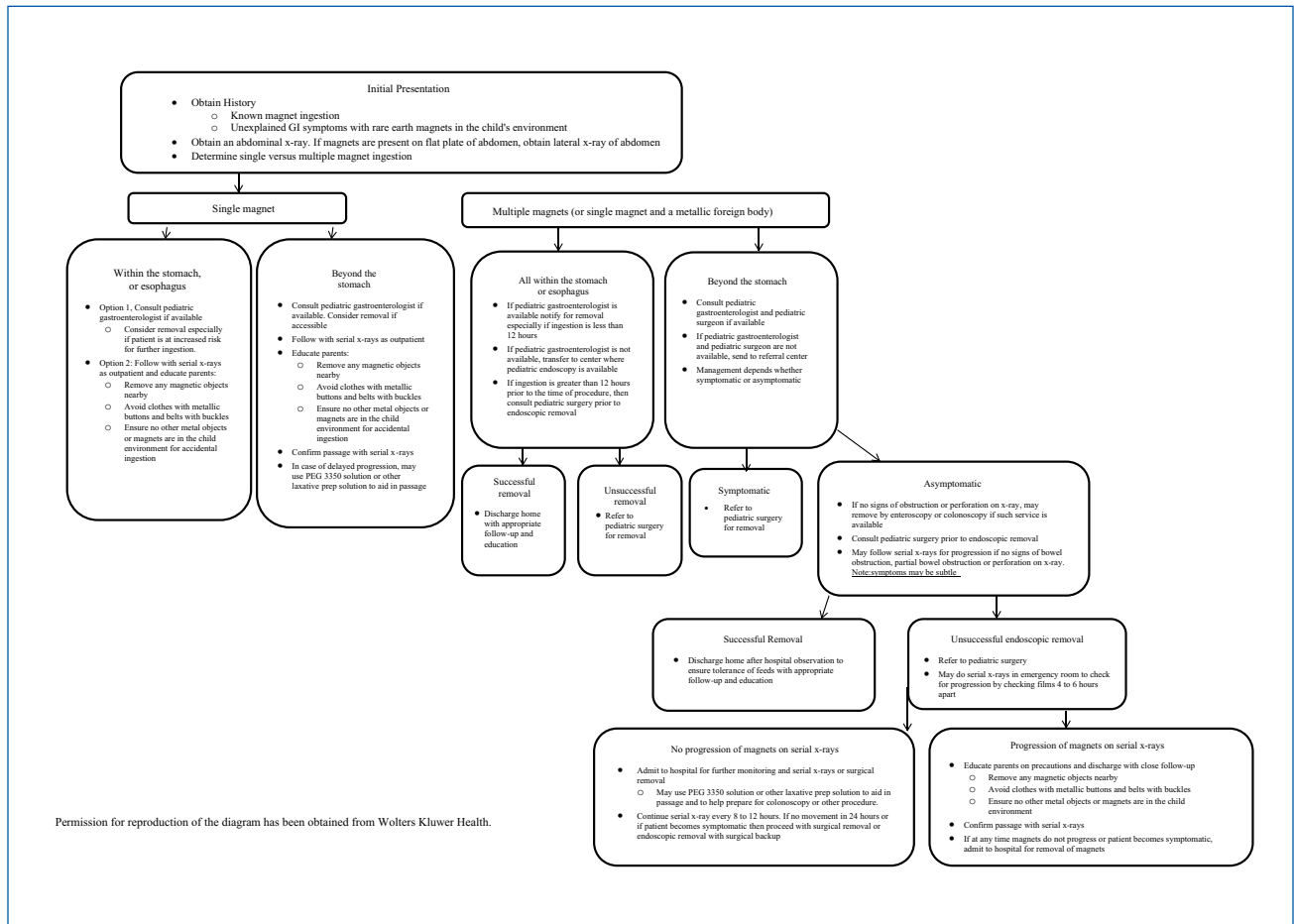
Conclusions

Rare-earth magnet ingestion cases pose a unique challenge to physicians, particularly when the patient has swallowed more than one magnet or when a rare-earth magnet has been ingested along with a metal object. These injuries may be difficult to diagnose as the symptoms frequently mimic other causes of gastrointestinal illness; however, rare-earth magnet-related injuries can be life-threatening and delays in diagnosis and treatment increase the risk for serious outcomes. Preventing rare-earth magnet-related injuries is important. Efforts

by manufacturers and importers to voluntarily remove potentially dangerous rare-earth magnet toy and entertainment sets from the market, along with recent actions by the US Consumer Product Safety Commission prohibiting the sale of high-powered magnetic sets containing small magnets, will help to reduce children's access to these hazardous consumer products. However, many rare-earth magnet toys and consumer products that are already in homes and offices are likely to remain accessible to children for years to come. Therefore, it is important that physicians, parents and child caregivers are aware of the dangers associated with the ingestion of multiple rare-earth magnets and the need for prompt medical attention if such ingestions are suspected.

Appendix

Management of rare-earth magnet ingestion by children.⁴



Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article. **AJLM**

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