



Surgical management of pediatric multiple magnet ingestions in the past two decades of minimal access surgery- systematic review of operative approaches

Romilly K. Hayward¹ · Amulya K. Saxena¹

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Abstract

Background Multiple magnet ingestion is increasingly reported in paediatrics and can cause significant morbidity. Various surgical approaches exist, though minimal literature compares outcomes between techniques. This review evaluates laparoscopic, laparoscopic-assisted, and open surgery with regard to outcomes.

Method Systematic review across MEDLINE, Embase, Scopus, and Web of Science identified reports of paediatric multiple magnet ingestion managed surgically between 2002 and 2022.

Results Ninety-nine studies were included, reporting data from 136 cases. Of these, 82 (60%) underwent laparotomy, 43 (32%) laparoscopic surgery, and 11 (8%) laparoscopic-assisted procedures. Sixteen laparoscopic cases were converted to open, often due to intraoperative findings including necrosis/perforation, or grossly dilated bowel. Bowel perforation occurred in 108 (79%); 47 (35%) required bowel resection, and 3 had temporary stoma formation. Postoperative recovery was uneventful in 118 (86%). Complications were reported following 15 (18%) open and 3 (7%) laparoscopic surgeries. No complications occurred following laparoscopic-assisted surgery. All post-laparoscopic complications were Clavien-Dindo (CD) Grade I. Following open surgery, 5 complications were CD grade I, 6 were CD grade II, and 4 were CD grade IIIb, requiring re-laparotomy. Median length of stay for open and laparoscopic-assisted procedures was 7 days, and for laparoscopic was 5 days ($p < 0.001$).

Conclusion Surgical management of multiple magnet ingestion often achieved uncomplicated recovery and no long-term sequelae. Whilst open laparotomy was the more common approach, laparoscopic surgery was associated with reduced length of stay and postoperative complications. Therefore, in experienced hands, laparoscopic surgery should be considered first-line, with the possibility of conversion to open if required.

Keywords Magnet ingestion · Paediatrics · Outcome analysis · Laparoscopy · Systematic review

Introduction

Incidence of multiple magnet ingestion in the paediatric population has increased drastically over the past few decades and is associated with high morbidity and potentially fatal outcomes [1–3]. While ingestion of a single magnet is unlikely to cause significant harm, attractive forces between

multiple magnets within the digestive tract can result in necrosis, perforations, fistulas and bowel obstruction [1].

A number of algorithms have been developed to determine the optimal approach to diagnosis and management of multiple magnet ingestion. In 2012, following a survey that highlighted a more prevalent and hazardous problem than previously appreciated, the North American Society of Pediatric Gastroenterology, Hepatology, and Nutrition (NASPGHAN) developed a comprehensive algorithm that aimed to more clearly define the roles of paediatric gastroenterologists and endoscopy [2]. While more detailed than previous algorithms, the role of surgical management, and optimal surgical approach, remained somewhat unclear.

Laparoscopic and open surgical approaches have been extensively compared and evaluated outside of the context

✉ Amulya K. Saxena
amulya.saxena@nhs.net

¹ Department of Paediatric Surgery, Chelsea and Westminster Hospital NHS Foundation Trust, Imperial College London, 369 Fulham Road, London SW10 9NH, UK

of multiple magnet ingestion with key advantages of laparoscopic procedures reported as reduced blood loss, postoperative pain, wound infections, length of stay, and recovery time [4–6].

There is, however, minimal literature comparing outcomes between these surgical approaches in the management of multiple magnet ingestion in the paediatric population. The aim of this study was to analyse and compare outcomes for laparoscopic, laparoscopic-assisted, and open-surgical approaches in multiple magnet ingestion with a focus on morbidity, perforation, and postoperative outcomes to determine the optimal approach to operative management.

Methods

Systematic search across MEDLINE, EMBASE, Scopus, and Web of Science was conducted in September 2023 using the search terms ‘multiple magnet’, ‘ingestion’, and ‘surgical’. Truncation and wildcards were applied to synonyms to include all relevant papers; synonyms were pooled with ‘OR’; ‘AND’ was used to combine search terms. An abstract screen was conducted, followed by a full-text screen.

Inclusion criteria were: (a) reports of cases of multiple magnet ingestion managed surgically in patients under 18 years of age, (b) published between the years 2002 and 2022, and (c) published in English. Exclusion criteria were: (a) unclear or incomplete case/cohort documentation such that either the operative approach or the number, age, and sex of patients could not be defined and (b) unavailability of full text.

Data was collected for age, sex, comorbidities, magnet type/size/location, preoperative management/imaging, length of time from ingestion to surgery, surgical approach, conversions, sepsis, perforation, follow-up, morbidity and mortality. The study was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement 2020 (Fig. 1). The systematic review protocol was registered at the International Prospective Register of Systematic Reviews (PROSPERO) registration number CRD42023461706.

Results

The literature search revealed 410 articles, of which 174 reported surgical management of multiple magnet ingestion in paediatric patients, and 99 met the inclusion criteria.

A total of 136 children were analysed, of which 91 (67%) were male. Age ranged from 9 months to 17 years with a median age of 4 years (IQR 2–8 years). There were 14 children with relevant physical or psychiatric comorbidities including autism spectrum disorder (ASD) (n=4), attention

deficit hyperactivity disorder (ADHD) (n=3), pica (n=2), developmental delay (n=4), adjustment disorder (n=1), and Fragile X (n=1).

The most frequently reported symptoms included abdominal pain (n=98, 72%), vomiting (n=83, 61%), constipation (n=14, 10%), fever (n=14, 10%), abdominal distension (n=13, 10%), and diarrhoea (n=7, 5%). Bowel obstruction was reported in 27 (20%), peritonitis was reported in 22 (16%), and 1 child was septic on admission. Asymptomatic presentation was reported in 19 (14%).

The most common type of magnets ingested included balls/beads (n=76, 56%), rods (n=18, 13%), discs (n=18, 13%), and ‘rattle’/‘singing’ magnets (n=9, 7%). Magnet type was unspecified in 22 (16%). Median number of magnets ingested was 5 (IQR 2–12). The maximum number of magnets ingested was 70. The number of magnets ingested was not specified for 9 cases (7%). Most ingestions were unwitnessed (n=102, 75%).

Surgical management was entirely open in 82 (60%) (laparotomy n=81 [7–69], mini-laparotomy n=1 [70]). In 43 (32%) the procedures began laparoscopically, of which 27 were entirely laparoscopic [7, 8, 66, 67, 69, 71–87] and 16 (37%) were converted to open (laparotomy n=12 [68, 88–97], mini-laparotomy n=4 [66, 98]). Reasons for conversion to open were: (a) to achieve removal of all magnets (n=5) [66, 96–98]; (b) concern of free perforation through multiple loops of bowel (n=1) [90]; (c) magnets sticking to the camera rod and obstructing vision (n=1) [68]; (d) unclear aetiology of small bowel obstruction (n=1) [92]; (e) intraoperative findings including necrosis and/or perforations (n=4) [89, 93, 94, 98], grossly dilated small bowel (n=2) [68, 88], impending gastrocecal fistula (n=1) [95], and dense matted small bowel (n=1) [91]. Laparoscopic-assisted surgery was performed in 11 (8%) [82, 83, 93, 98–103], with removal achieved most often through extension of the umbilical port site incision.

Table 1 describes a breakdown of case characteristics by surgical approach. Sex, age, number of magnets, witnessed ingestions, and time from ingestion to surgical intervention (reported in 60 cases) were similar across groups.

Figure 2 depicts the increase in case reports of multiple magnet ingestion requiring surgical management over the past two decades broken down by surgical approach.

Magnets were located in the small bowel in 115 (85%), large bowel in 44 (32%), and stomach in 27 (20%). The most common intestinal sites specified included the ileum (n=56, 41%), jejunum (n=32, 24%), and cecum (n=21, 15%). Magnets were either partially or completely extraluminal in 9 (7%) and were removed from the appendix via appendectomy in 4 (3%) (magnets located in appendix n=2; magnets milked to the appendix for removal n=2).

Table 2 describes patient outcomes broken down by surgical approach.

Fig. 1 PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only

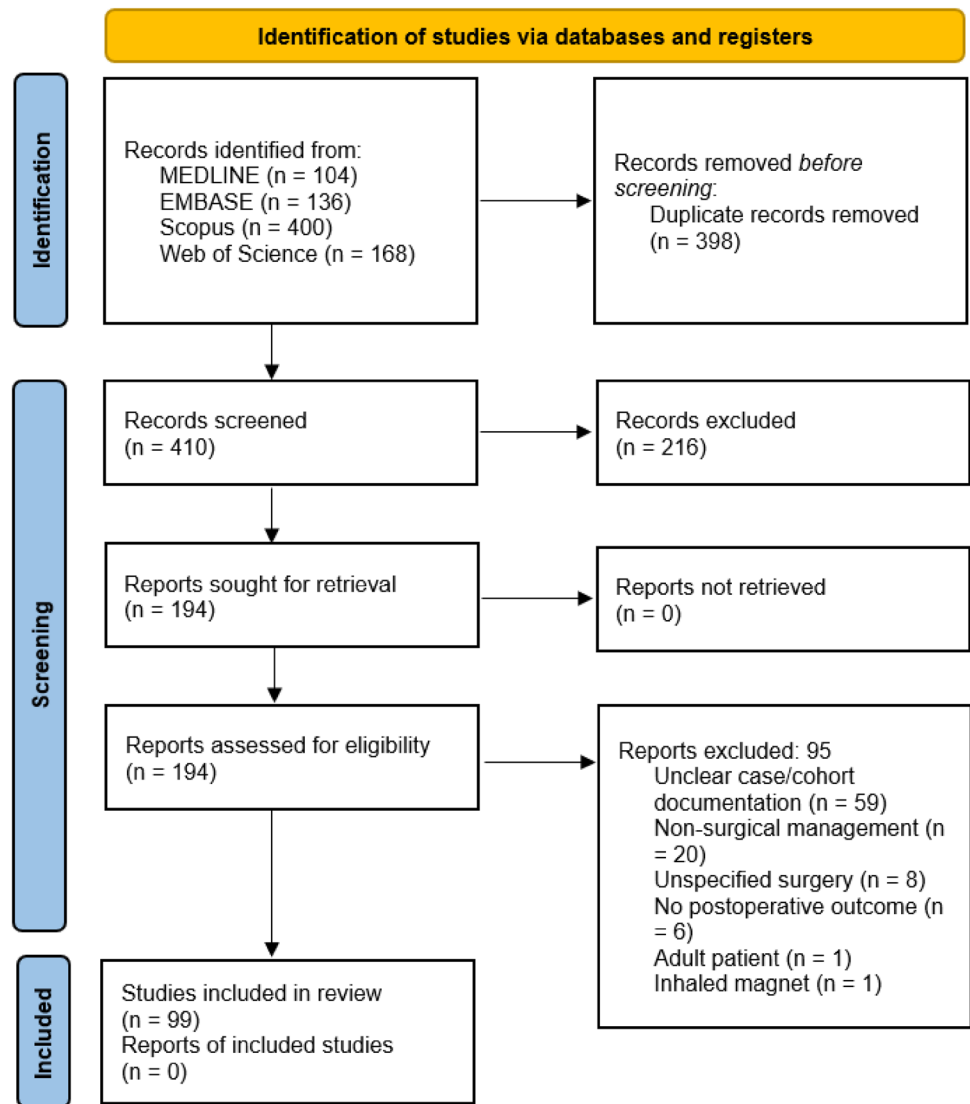


Table 1 Comparison of patient outcomes between different surgical approaches

Operation	Open (n=82)	Laparoscopic (n=43)	Laparoscopic-assisted (n=11)	p value
Male (n)	56 (68%)	28 (65%)	7 (64%)	0.911 [†]
Age (years)	4 (2.0–7.0)	5 (3.0–9.0)	3 (2.5–8.5)	0.248 [§]
Number of magnets	5 (2.5–14.0)	4 (2.0–7.0)	14 (3.5–16.5)	0.053 [§]
Witnessed ingestion (n)	17 (21%)	14 (33%)	3 (27%)	0.344 [†]
Time from ingestion to surgical intervention (days)	n=337 (4.0–18.0)	n=23 4 (2.5–8.0)	n=4 4.5 (3.8–18.8)	0.529 [§]

p values calculated using

[†]Chi-squared test

[§]Kruskal–Wallis test

Values are median (IQR) or number (proportion)

Bowel perforations and/or fistulas were reported in 108 (79%) (69/82 open procedures (84%), 30/43 laparoscopic procedures (70%) (17/27 entirely laparoscopic (63%),

13/16 laparoscopic converted to open (81%)), and 9/11 laparoscopic assisted procedures (82%). Multiple perforations were reported in 96 (71%). Perforation of the small

Fig. 2 Trends in number of cases reporting surgical management of multiple magnet ingestion over the past two decades

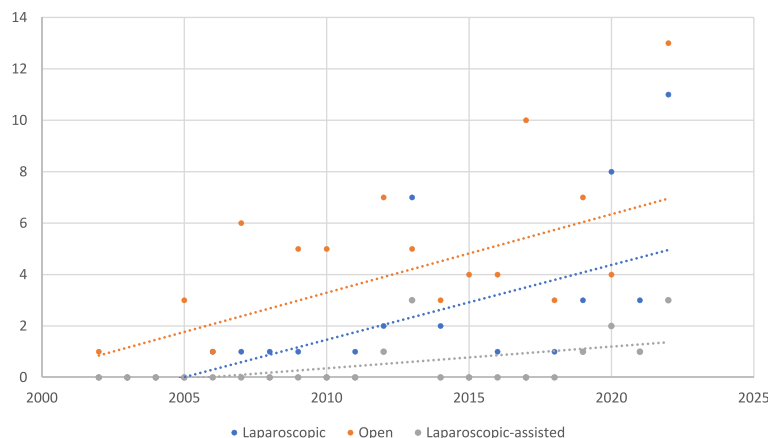


Table 2 Comparison of patient outcomes between different surgical approaches

Operation		Open (n = 82)	Laparoscopic (n = 43)	Laparoscopic-assisted (n = 11)	p value
Perforation (n)		69 (84%)	30 (70%)	9 (82%)	0.165 [†]
Postoperative complication (n)	None	67 (82%)	40 (93%)	11 (100%)	0.083 [†]
	CD1	5 (6%)	3 (7%)	0 (0%)	0.675 [†]
	CD2	6 (7%)	0 (0%)	0 (0%)	0.127 [†]
	CD3b	4 (5%)	0 (0%)	0 (0%)	0.257 [†]
Post-op LOS (days)		7 (5.8–9.3)	5 (3–7)	7 (4–8)	<0.001 [§] *

* $p < 0.001$

p values calculated using

[†]Chi-squared test

[§]Kruskal–Wallis test

Values are median (IQR) or number (proportion)

CD Clavien Dindo Classification Grade

bowel was reported in 94 (69%), large bowel in 36 (26%) and stomach in 19 (14%). The most common sites of perforation specified included the ileum (n = 52, 38%), jejunum (n = 32, 24%), and cecum (n = 20, 15%). Bowel necrosis without perforation was reported in 10 (7%) and volvulus occurred in 6 (4%).

Bowel resection was required in 47 (35%) (34/82 open procedures (41%), 10/43 laparoscopic procedures (23%) (6/27 entirely laparoscopic (22%), 4/16 laparoscopic converted to open (25%)), and 3/11 laparoscopic-assisted procedures (27%). 3 patients (2%) required temporary stoma formation (all of whom underwent entirely open procedures) of which one was reversed at postoperative day 21, one planned for reversal at 6 months, and one planned for reversal at an unspecified timepoint.

Postoperative recovery was uncomplicated in 118 cases (86%): 67/82 open procedures (82%), 40/43 laparoscopic procedures (93%) (24/27 entirely laparoscopic (89%), 16/16 laparoscopic converted to open (100%)), and 11/11 laparoscopic-assisted procedures (100%).

Complications occurred in 18 cases. Of these, 8 (44%) were Clavien Dindo classification (CD) grade I including: ileus (n = 5), bowel obstruction (n = 1), wound infection (n = 1), wound infection and bowel obstruction (n = 1). Complications were CD grade II in 6 cases including: abdominal abscesses requiring interventional radiology (IR) drainage (n = 2), wound infection with dehiscence requiring vacuum dressing (n = 1), prolonged ileus requiring total parenteral nutrition (TPN) (n = 1), high output jejunostomy requiring TPN (n = 1), and prolonged antibiotic treatment for peritonitis (n = 1). Complications were CD grade IIIb in 4 cases including wound infection requiring re-laparotomy (n = 2), bowel obstruction requiring resection and adhesiolysis (n = 1), and missed fistula causing bowel obstruction requiring re-laparotomy (n = 1). No lethal outcomes were reported following surgical management.

Of the 27 laparoscopic cases, 3 (11%) had postoperative complications (all CD grade I). Of the 82 open cases, 15 (18%) had postoperative complications (CD grade I: n = 5, CD grade 2: n = 6, CD grade 3b: n = 4). No complications

were reported following procedures that began laparoscopically and were converted to open or following laparoscopic-assisted procedures.

Postoperative length of stay (LOS) was reported in 99 cases. Median LOS was 7 days (IQR 5–8). For entirely open procedures, median LOS was 7 days (IQR 5.75–9.25), for laparoscopic procedures median LOS was 5 days (IQR 3–7) ($p < 0.001$). For laparoscopic-assisted procedures, median LOS was 7 days (IQR 4–8).

Discussion

The results of this study demonstrate favourable outcomes following surgical management of multiple magnet ingestion in the paediatric population with a majority of patients reported to have uncomplicated postoperative recovery with no long-term sequelae. In line with previous reviews [2, 104, 105], the incidence of multiple magnet ingestion increased over time and the majority of patients (60%) underwent open surgery while laparoscopic procedures accounted for 32%, and laparoscopic-assisted 8%.

The majority of patients (79%) suffered perforation as a result of multiple magnet ingestion and 35% required bowel resection. Only 3 patients required stoma formation, all of which were planned for reversal.

The results of this analysis demonstrate an entirely laparoscopic approach to be favourable in this patient population, as it is associated with a shorter length of stay and reduced incidence and severity of postoperative complications when compared to open procedures. All complications that occurred following laparoscopic procedures were CD grade I, while following open procedures, 40% of complications were CD grade II and 27% were CD grade IIIb requiring re-laparotomy.

A previous case series of eight children who ingested powerful rare-earth magnets reported the successful use of endoscopy ($n = 3$), colonoscopy ($n = 1$), and laparoscopy ($n = 4$) with no requirement for open procedures [85]. Likewise, Wooten et al. reported a case where laparoscopy proved both diagnostic and therapeutic for malrotation with associated fistula and volvulus following ingestion of multiple magnets [95].

Opposing literature has recommended an open approach, proposing laparoscopic removal to be more challenging in cases of magnet ingestion owing to the magnets adhering to the instruments [106, 107]. The results of this study however demonstrate the majority of laparoscopic procedures to be successful, with only one occasion in which the magnets stuck to the camera rod and obstructed vision [68]. In this case, conversion to open surgery was successful in retrieving the magnets and the patient was discharged after seven days with no complications noted

over four months of outpatient follow-up. These conclusions are in line with previous studies that lend favour to laparoscopic procedures as a first-line surgical treatment for magnetic foreign body ingestion [108–110].

Laparoscopic procedures however are not without limitation, and laparoscopic-assisted surgery has been proposed to offer a potential balance between the improved postoperative outcomes associated with minimally invasive techniques and the longer operating times, steep learning curve, and high costs that present barriers to the implementation of such techniques in clinical practice [111]. The earliest report of laparoscopic assisted management included in this review was published in 2012 and the low number of cases available for analysis limits the ability to draw definitive conclusions as to its associated outcomes. Despite this, it can be noted that of the 11 patients who underwent laparoscopic-assisted procedures, none suffered postoperative complications and no conversions to open laparotomy were reported, lending support to this approach as a potentially favourable surgical option, though further analysis of larger cohorts is undoubtedly required.

When determining the optimal surgical approach, it is well recognised that consideration should be given, not only to previously associated outcomes and individual patient factors, but also to the operating surgeon's preferred technique and relevant expertise, which play vital roles in such matters [112].

Conclusion

The incidence of multiple magnet ingestion requiring surgical intervention has increased over the past two decades, though consensus on the optimal approach is yet to be reached and requires ongoing review of associated outcomes. Whilst the majority of cases thus far have been managed through open laparotomy, this review demonstrates a laparoscopic approach to be both feasible and potentially advantageous, associated with shorter length of stay and reduced postoperative complications. Therefore, in experienced hands, laparoscopic surgery should be considered as first-line management in this population, with the possibility of conversion to open surgery if required.

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Author contributions RH (data curation, formal analysis, investigation, methodology, project administration). AKS (conceptualization, methodology, supervision and review and editing).

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Data availability All data underlying the results are included in this article as references to published articles, or are available from the corresponding authors on reasonable request.

Declarations

Conflict of interests The authors have no competing interests to declare that are relevant to the content of this article.

Ethics approval For this type of study ethical approval is not required.

Informed consent For this type of study formal consent is not required.

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