

# Multicenter investigation of pediatric alimentary tract magnets ingestion in China

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# Abstract

**Purpose:** To describe the incidence and management of alimentary tract Buckyball ingestion in Chinese pediatric patients, and discuss the precautionary measures through a multicenter investigation. **Methods:** Medical records of 74 pediatric patients from 9 large Chinese hospitals were included in this study. Questionnaires were distributed online, and medical records were reviewed. Follow-up was through telephone and outpatient service. **Results:** Among the 74 cases were 50 boys (68%) and 24 girls (32%). The median age was 36 (22, 77) months, with a range of 7 months to 11 years old, and it showed two peaks. The annual case number showed a sharp increase, and the total case number in the last 2 years (2017 and 2018) showed a greater than 9-fold increase when compared with the first 2 years (2013 and 2014). The majority of ingestions were unintentional, with only 3 patients deliberately swallowing the Buckyball. The median time of ingestion until the onset of emergent symptoms was 2 (1, 5) days, and varied from 4 hours to 40 days. 21 patients had no symptoms, and the remaining cases presented with abdominal pain, vomiting, fever, abdominal distension, excessive crying, melena, and the ceasing of flatus and defecation. Gastroscopy, colonoscopy, laparoscopic surgery and laparotomy surgery were adopted according to the algorithm from the North American Society of Pediatric Gastroenterology, Hepatology and Nutrition (NASPGHAN). Gastrointestinal mucosa erosion, ischemia and necrosis, perforation, and abdominal abscess, ileus and fistula was found in the patients. The median number of Buckyballs ingested was 4 (2, 8), with a range from 1 to 39. During the follow-up period of 6 (1, 15) months, 3 patients had ileus, and one underwent a second operation. The remaining 71 patients were uneventful. None of the 74 patients reported a second swallowing of foreign bodies. **Conclusions:** The incidence of pediatric alimentary tract magnets ingestion in China is still increasing. Management of such patients should follow the algorithm from NASPGHAN. Precautionary measures toward the issue should be taken from three levels, namely the national administration, producer, and consumer. **Keywords:** Pediatric, Alimentary tract, Magnetic foreign body, Buckyball

## Introduction

Alimentary tract foreign body ingestion is common in children, especially in neonates and infants [1]. Research showed that 80% of the ingestions cause no harm, with the foreign body being passed out of the alimentary tract without incident [2]. However, magnetic foreign bodies are a special type of foreign body, as they can cause severe injuries to the gastrointestinal tract, and even be life-threatening. When swallowed alone, or when multiple magnetic foreign bodies are swallowed together, they tend to discharge spontaneously. However, if they are ingested separately, with or without another metal foreign body, they could attract each other across layers of intestines, and cause ischemia, pressure necrosis, perforation and volvulus of the intestines, leading to a severe onset.

Buckyball, also known as a magic magnetic ball, is a special kind of toy, which is made of rare-earth magnets. Unlike traditional magnets, Buckyball is small in volume but powerful in magnetism, and easily swallowed by children. The severity of pediatric injuries from Buckyball ingestion in the United States had been investigated by NASPGHAN, and the algorithm for the diagnosis and treatment was published in

2012 [3, 4]. Faced with an increase in medical problems of this nature, the United States government held a mandatory recall for the magnetic toy in 2014, and the incidence has sharply declined since then [5]. However, unlike the United States, Buckyballs have recently become more popular in China, and there is a positive correlation between its popularity and the number of pediatric gastrointestinal Buckyball injuries in emergency departments. To date, no large-scale case study has analyzed or summarized the incidence and severity of gastrointestinal Buckyball injuries in Chinese pediatric patients.

Thus, the purpose of the study is to describe the incidence and management of alimentary tract Buckyball ingestion in Chinese pediatric patients, and discuss the precautionary measures toward the issue through a multicenter investigation.

## Methods

### Patients

Medical records from January 2009 to March 2019 of 74 pediatric patients who were under the age of 18 years old, diagnosed with alimentary tract Buckyball ingestion, admitted to emergency department, and underwent endoscopy or surgical intervention were included in this study. The patients were from 9 large Chinese hospitals, among which 8 were children-specialized hospitals, including Beijing Children's Hospital, Zhengzhou Children's Hospital, Xi'an Children's Hospital, Children's Hospital of Hebei Province, Anhui Provincial Children's Hospital, Jiangxi Provincial Children's Hospital, Children's Hospital of Nanjing Medical University, and Wuhan Children's Hospital. The remaining hospital was a comprehensive hospital, the First Affiliated Hospital of Zhengzhou University.

### Data collection

Questionnaires were distributed online, medical records of the patients were reviewed retrospectively and special attention was given regarding the age, gender, clinical manifestations, treatments, number and site of Buckyball, and address of the patients. Post-surgery follow-up was through telephone and outpatient service.

### Statistical analysis

All the data was analyzed using SPSS for Windows version 17.0. Normal distribution data was presented by (mean  $\pm$  standard deviation), non-normal distribution data was presented by median (first quartile, third quartile), and categorical variables were presented by frequencies and percentages.

## Results

74 pediatric patients with alimentary tract Buckyball injury were included in the study. Among the cases were 50 boys (68%) and 24 girls (32%), with an obvious gender prevalence towards boys (Fig 1 A). The age was 36 (22, 77) months, ranging from 7 months to 11 years old, and it showed two peaks, the first

between 1 and 3 years old, and the second between 6 to 11 years old (Fig 1 B). During the investigation period, the first case occurred in 2013. There was a sharp increase in the annual case number (Fig 1 C) and the total case number in the last 2 years of our study (2017 and 2018) showed a greater than 9-fold increase when compared with the first 2 years (2013 and 2014). Hebei Province had 23 cases, which was the highest number of recorded cases among all the provinces included in our study. Beijing and Henan Province followed with 12 cases (Fig 1 D). All 74 patients had no diagnosed psychological disorder or allotriophagia. Only 3 of them had specific reasons for swallowing the foreign body; a neonatal boy was fed the buckyballs by his older cousin for his own amusement, a school aged boy ingested the balls deliberately to demonstrate his bravery, another girl swallowed the Buckyballs because she mistook them for candy. The remaining 71 patients were playing with the Buckyballs and accidentally swallowed them.

The time of ingestion until the onset of emergent symptoms was 2 (1, 5) days, and varied from 4 hours to 40 days. 21 patients had no symptoms, but their parents or guardians had been alerted to the fact that they had swallowed the Buckyballs and sought medical help at the hospitals; other patients had abdominal pain, vomiting, fever, abdominal distension, excessive crying, melena, and the ceasing of flatus and defecation (Table 1). Radiological examination could primarily display Buckyballs' numbers and location (Fig 2 A-C), which guided for better treatment. The patients underwent gastroscopy, colposcopy, laparoscopic surgery and laparotomy surgery depending on the NASPGHAN algorithm (Table 2). During the surgery, gastrointestinal perforation (Fig 3A), ischemia and necrosis of gastrointestinal wall, abscess, ileus, fistula (Fig 3B-D) and gastrointestinal mucosa erosion were found (Table 3). The number of Buckyballs was 4 (2, 8), with a range from 1 to 39.

During the follow-up period of 6 (1, 15) months, three patients had ileus after laparotomy surgery, and one of them underwent a second operation to relieve intestinal obstruction. The remaining 71 patients had no abdominal distension, adhesive intestinal obstruction, or tardive perforation incident. None of the 74 patients reported a second swallowing of Buckyballs or other magnetic foreign bodies in the post-surgery course.

## Discussion

Alimentary tract foreign body ingestion is common in pediatrics, especially in neonates and toddlers [6]. Among them, more than 80% need no intervention and the foreign body will pass out uneventfully. Only 20% call for further attention, and less than 1% required surgery [7]. Treatments are different for different categories of foreign bodies. The wait-and-see strategy can be used in the ordinary foreign body, such as coins, jewelries, and small toys. However for the remaining 20% of patients who have fish bones, jujube pits, batteries, or magnets ingestions, active intervention is needed. Unlike other foreign bodies, ingested magnets can attract each other across bowel loops, and cause gastrointestinal wall ischemia, pressure necrosis or perforation [8-9]. Other studies also described intestinal obstruction from internal hernia and volvulus of intestine, fistula formation [10], and hemorrhage when the mesenteric was involved [10]. Midget J reported a twenty-month old boy who had ingested magnets, causing intestinal necrosis and abdominal sepsis, which led to death [11-12]. Additionally, Waters AM [13] reported another case of death

due to the hemorrhage from an esophago-aortic fistula induced by ingestion of magnets. Thus, the risk of ingestion of magnets remains higher than the ingestion of ordinary foreign bodies.

Rare-earth magnet, made from NdFeB (neodymium iron boron), a newly developed magnetic material, has a maximum magnetic energy force 5 to 10 times than that of the ordinary ferrite [12, 14-15], suggesting that the tiny rare-earth magnet can produce a huge magnetic force. It was primarily developed for industrial manufacture such as electrical machinery, medical apparatus and instruments, in order to decrease the volume of production and enlarge its properties. However, in recent years, it has been largely used in toy production. Buckyball, made of this type of magnet and mostly consisting of 216 magnets all 5mm in size, is a colorful toy that is cheap to afford. It is also able to activate thinking skills and motivate creativity (Fig 4 A-B). Although it was developed only for people older than 14 years of age for entertainment and stress release (Fig 4 C-D), it has been given to children of all ages.

An earlier study revealed that from 2003 to 2009, 38 cases of magnetic foreign body ingestion were identified, of which 8 cases were multiple magnets ingestion, and the number continues to grow [16]. Another investigation in 2013 reported that during 2002 and 2011, there had been more than 22,000 pediatric magnetic foreign body ingestion cases in America, and the investigation showed a 5-fold increase comparing the first and the last 2 years [4]. In the year 2014, Buckyballs and high-powered magnets were mandatorily recalled by the consumer product safety commission in the United States, and since the recall, a significant decrease was reported in multiple mini-magnet ingestion [5]. However, unlike the United States, our results (Fig 2 C) reveal that alimentary tract Buckyball injuries are still increasing sharply in China annually, with no trend of decline.

Our investigation showed the peak age of the children who ingested the magnets was between 1 and 3 years old, and between 6 to 11 years old (Fig 1 B), which was consistent with De Roo AC's study in 2013 [17]. This may be explained by the fact that toddlers explore the world with their mouths and may accidentally swallow the Buckyballs when playing, and as a means for school aged children to boast of their bravery, as reported by one patient in this study. However, 71 of the 74 patients ingested the Buckyballs unintentionally, a finding consistent with the reports from De Roo AC [17] and the NASPGHAN [6]. Other special reasons such as psychological disorders or allotriophagia [15, 16] were not found in this study. The ingestion displayed an obvious male predominance at any age period (Fig 1 A), which was in accordance with other reports [18]. This may be attributed to the mischievous and curious nature of boys.

Beyond the rising popularity of Buckyball, severe injuries occurred. Since it was first introduced to the market in 2009 [14, 19], the number of irreversible injuries has increased because of its powerful magnetic force [20]. Unlike ordinary magnets, Buckyballs can attract each other even through 6 layers of intestinal walls [21], with an average distance of 3.5cm [22], and this strength increases when multiple Buckyballs are ingested [22]. Symptoms were not specific, and were dependent on the time of presentation and location of the Buckyballs, but more than half of the patients (40/74) presented with abdominal pain. Richard Sola Jr concluded that abdominal pain was one risk factor for emergency surgery [23]. Other complications, such as ischemia and necrosis, gastrointestinal perforation (Fig 3 A),

abscess, ileus, and gastrointestinal fistula (Fig 3 B-C) also proved to be critical. Diagnosis and treatment algorithm were published by the NASPGHAN in 2012 [3], and patients in this study who were managed according to the algorithm attained satisfactory results.

Although treatment is of great significance, prevention is much more important. China should take measures for prevention of Buckyballs ingestion, and these suggestions listed should be followed. Firstly, on the national administration level, the production and trade of Buckyballs as well as other high-powered magnetic toys should be stopped [15]. The serious complications that could arise should also be publicized and reinforced by various media means. Secondly, on the production level, a national policy should be implemented, targeted towards pediatric toy productions. The magnetic toy size should be enlarged and the material used to make such toys should either revert back to the ordinary magnet that has low magnetic energy product [24] or use a magnetic force lowered to the flux index of 50kG2 [12]. Warning labels should be much more prominent. Thirdly, on the consumer level, parents and caregivers should be made aware about the potential risk of the toy [11, 19, 24]; and children younger than 14 years old or who have psychological disorders and allotriophagia should refrain from playing with it. Parents should monitor their children more closely when playing with magnetic toys and also educate them about the right way to play with such toys [4, 25]. Additionally, children should be taught not only about the side effects of ingesting foreign objects, but also to stop instigating harmful ingestion among their peers. When evaluating the complaints of unexplained abdominal pain, clinicians should inquire specifically about the possible ingestions that a child might have made [15].

## **Conclusion**

The incidence of pediatric alimentary tract magnetic foreign body ingestion in China is still increasing. Management of such patients should follow the NASPGHAN algorithm. Precautionary measures toward the issue should be taken from three levels, namely the national administration, producer, and consumer.

## **Declarations**

### **Acknowledgment**

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## Availability of data and materials

The data is available from the corresponding author on reasonable request.

## Authors' contributions

Kai Wang conceived and designed the study, helped with the data collection, and drafted the initial manuscript. Dan Zhang, Xianling Li, Zengmeng Wang, Guangjun Hou, Xinjian Jia, Huizhong Niu, Shiqin Qi, Qingqiang Deng, Bin Jiang, Hongqiang Bian, and Heying Yang helped with the data collection. Yajun Chen conceived and designed the study, helped with data collection, and revised the manuscript. All authors read and approved the final manuscript.

## Ethics approval and consent to participate

This study was reviewed and approved by the Ethics Committee of Beijing Children's Hospital. We retrospectively reported the data without providing any individual details.

## Consent for publication

All the authors have approved the manuscript and agree for publication.

## Competing interest

The authors declare that they have no competing interest.

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## Tables

**Table 1.** Clinical manifestation

Symptoms onset (n)	Symptoms	Number	Frequency (%)
No (21)	—	21	28.38
Yes (53)	Abdominal pain	40	54.05
	Vomiting	36	48.65
	Fever	11	14.86
	Abdominal distension	3	4.05
	Fiercely crying	3	4.05
	Melena	2	2.07
	Flatus and defecation stopped	1	1.35

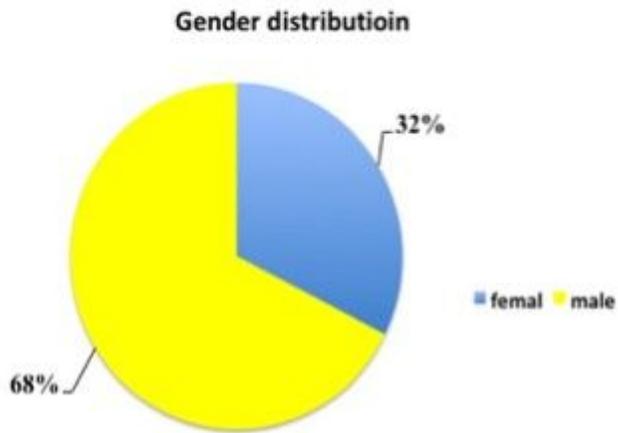
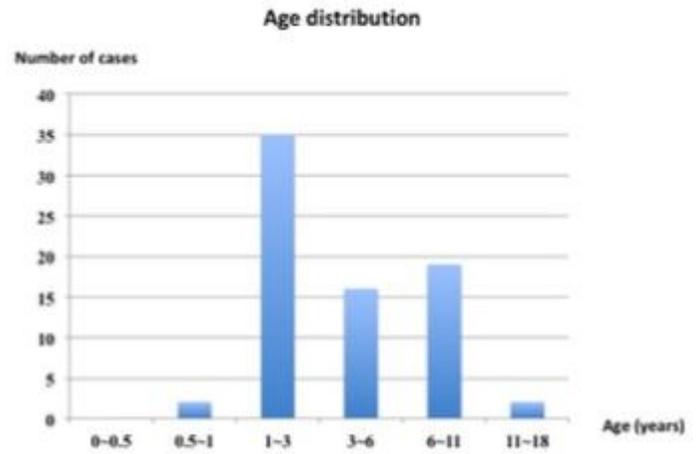
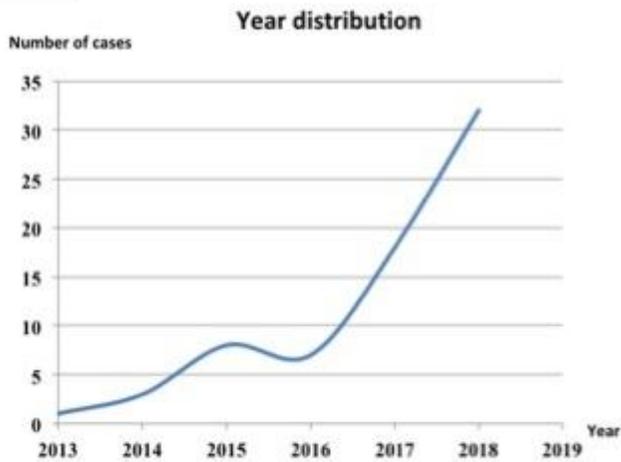
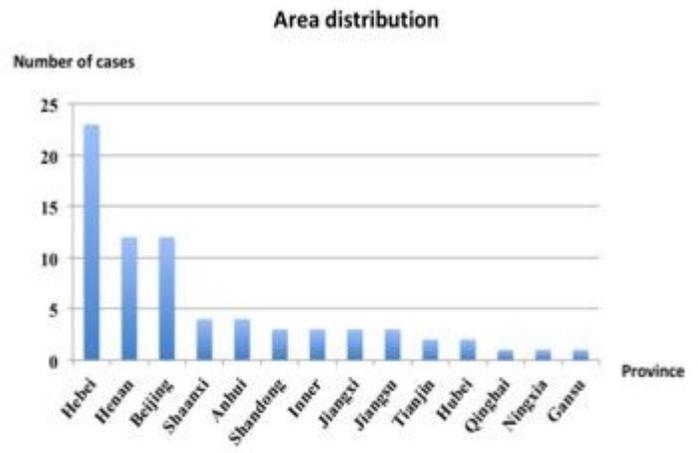
**Table 2.** Treatment procedures

Treatment procedures	Total number	Number of success
Gastroscopy	16	7
Coloscopy	1	0
Laparoscopic operation	6	5
Laparotomy	51	51

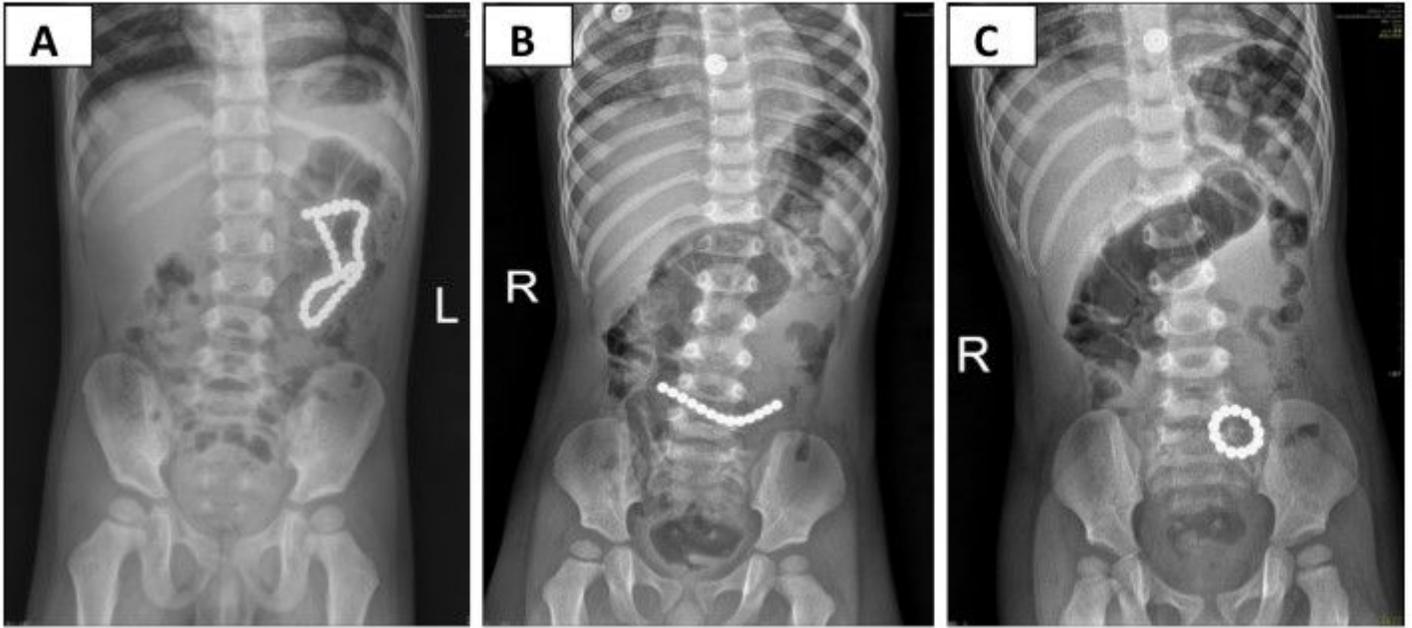
**Table 3.** Findings during operation

Findings	Number	Frequency (%)
Gastrointestinal perforation	38	51.35
Ischemia and necrosis of gastrointestinal wall	14	18.92
Abscess	7	9.46
Ileus	6	8.11
Fistula	2	2.70
Gastrointestinal mucosa erosion	28	37.84

## Figures

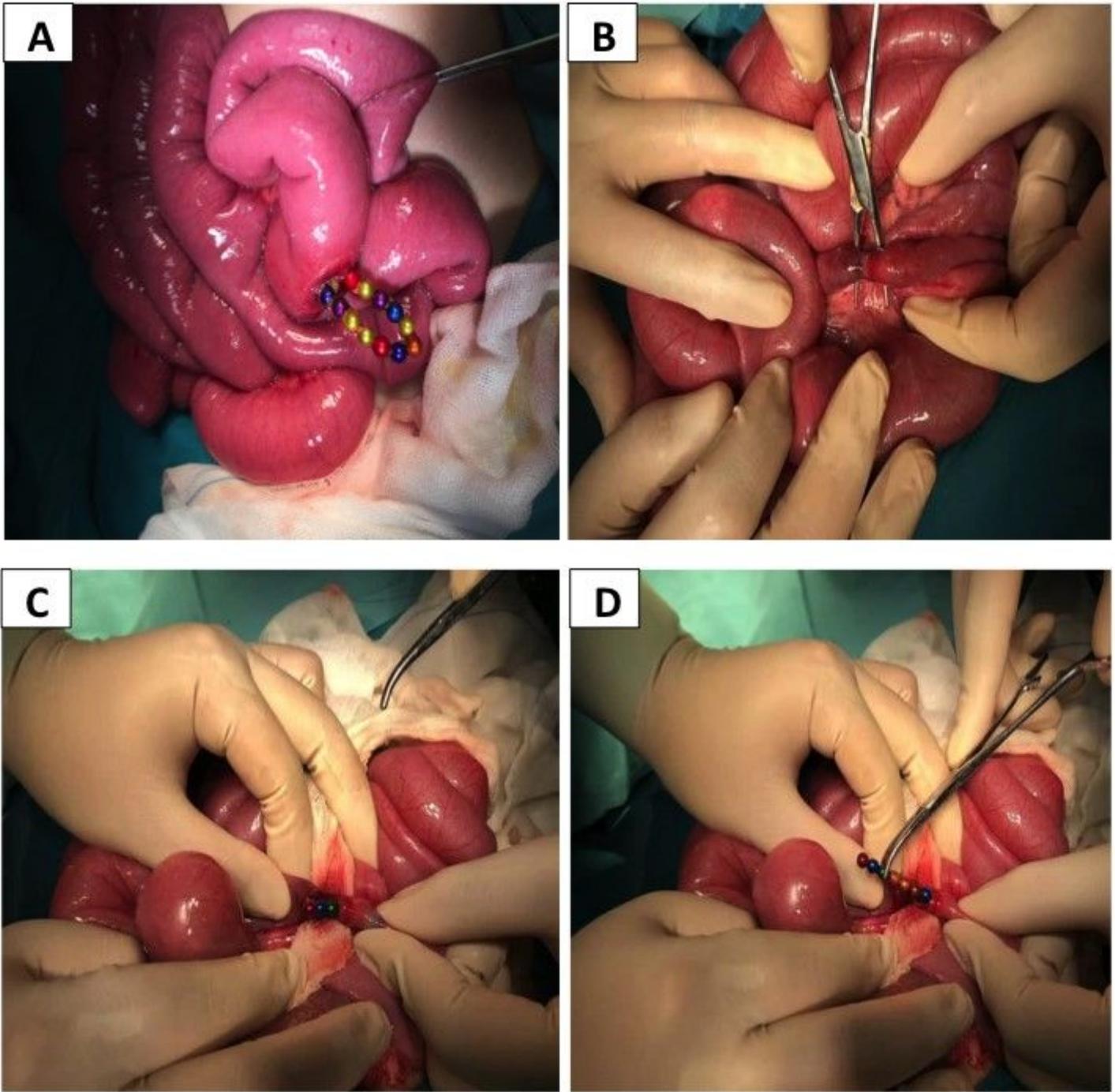
**A****B****C****D****Figure 1**

Results showed the gender (A), age (B), year (C) and area (D) distribution of Buckyball injuries



**Figure 2**

Radiology results of Buckyballs ingested. The maximum of 39 Buckyballs ingested (A). Another patient ingested 13 Buckyballs, which showed line type on the first day (B), and turned to annular type on the following day (C)



**Figure 3**

Exploration results during surgery. Buckyballs caused intestinal perforation (A) and fistula (B-D)

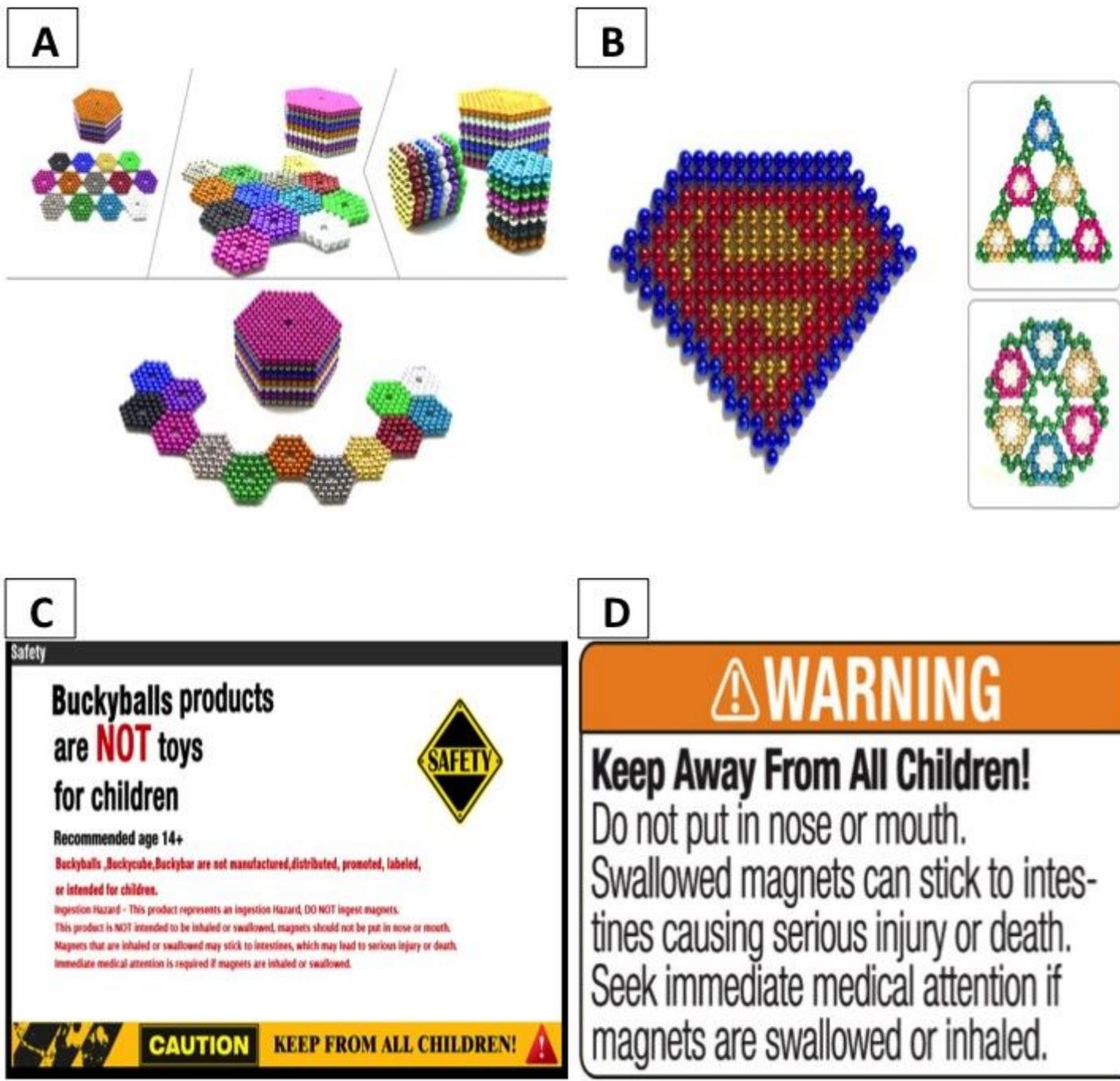


Figure 4  
 Buckyballs with different shapes and colors, and the warning labels that showed the accessible age was upon 14 years old. (Pictures were from the following website. <http://www.the-buckyballs.com/g/white-buckyballs-neocube-cheap> <http://www.buy-buckyballs.net/page/safety>)