Quality Improvement Study

Medicine®

OPEN

A computed tomography phantom study of foam earplugs

Uncommon but potentially hazardous foreign body ingestion in children

Li-Sheng Hsu, MD[a,b,c,*], Ju-Bei Yen, MD[c,d], Shie-Shan Wang, MD, PhD[c,e,f], Chien-Lin Liao, BS[a]

Abstract

Ingestion of a foreign body is common among children. However, ingestion of foam earplugs (FEPs) has not been reported previously. A 7-month-old female infant presented with small bowel obstruction, which was finally proved to be a case of FEP ingestion.

Computed tomography (CT) phantom study was performed to examine the imaging features of FEPs. We studied the following dry and fully wet FEPs, FEPs squeezed in pure water to varying degrees, and FEPs with different degrees of compression in the dry and wet states from day 0 to 6 and all scanned with a CT scanner.

The density of a dry FEP is −843.5 ± 4.5 Hounsfield units (HU) and it increases to 0.76 ± 9.3 HU when fully wet. The densities of FEPs ranged from −844.2 to 1.0 HU with different water/air ratios, and some showed a heterogeneous geographic pattern. The densities of FEPs increase due to compression and gradual water absorption.

FEPs can be potentially hazardous objects to children. Owing to the special foam structure of the FEP, it can mimic a fatty lesion if the density ranges from −100 to −50 HU; moreover, it can hide in the water if fully wet. However, it should not be mistaken as air, as the density of a dry FEP is −843.5 HU, and the contour can be observed if the window level is set appropriately. Because of its soft texture, the surgeon should be careful not to miss an FEP during the operation. Moreover, radiologists should be familiar with the CT features of FEPs so that they can be identified before surgery.

Abbreviations: CT = computed tomography, FEP = foam earplug, HU = Hounsfield units, PU = polyurethane.

Keywords: computed tomography, foam earplug, foreign body, phantom study, plastic bezoar, polyurethane foam, small bowel obstruction

1. Introduction

Common foreign bodies ingested by children include coins, magnets, disk batteries, bezoars, fish or chicken bones, buttons, pins, pen or bottle caps, and marbles. Potential small bowel complications owing to the ingestion of foreign bodies include bowel obstruction, perforation, fistula, bleeding, abscess formation, and peritonitis.[1] Ingestion of some uncommon foreign bodies remains a challenge to both clinicians and radiologists. Foam earplugs (FEPs) made of polyurethane (PU) are commonly used for noise reduction. Their texture is soft, and they can recover their original shape after the removal of compression (memory foam).[2] First, we report a rare case in which an infant ingested an FEP that mimicked a lipoma, as its density was similar to the density of fat, and caused small bowel obstruction. Based on this case, we performed a computed tomography (CT) phantom study to evaluate the CT features of FEPs for diagnosis in the future.

In October 2015, a 7-month-old girl was admitted to the pediatric ward in our hospital because she had vomited after her meals 6 times in 1 day. Abdominal radiography showed distended loops of the small bowel (Fig. 1A). Sonography did not reveal any target lesion but intussusception was still suspected. CT scan showed a low-attenuation lesion (size, 9.6 × 25.7 mm; CT number, −120.1 ± 12.8 Hounsfield units [HU]) in the terminal ileum with small bowel obstruction and whole colon collapse (white arrows in Fig. 1B, C). Presence of a foreign body in the small bowel, lipoma, and ileoileal intussusception were all considered. Barium enema did not reveal intussusception but we noted a suspicious ovoid filling defect in the terminal ileum (black arrows in Fig. 1D).

Laparotomy was performed owing to the persistent symptoms; however, no intussusception was noted. The surgeon only performed manual decompression of the obstructed small bowel. One day after surgery, an FEP was found in her diaper (Fig. 2). She was discharged from the hospital 2 days after surgery.

To understand the imaging features and possible changes in the FEPs in the gut, we designed a CT phantom study; we hope that

Editor: Somchai Amornyotin.

The authors have no funding and conflicts of interest to disclose.

[a] Department of Diagnostic Radiology, Chang Gung Memorial Hospital, [b] Department of Physical Education, Health and Recreation, National Chiayi University, Chiayi, Taiwan, [c] Chang Gung University College of Medicine, Taoyuan, Taiwan, [d] Department of Pediatrics, [e] Department of Pediatric Surgery, Chang Gung Memorial Hospital, Chiayi, [f] Graduate Institute of Clinical Medical Sciences, Chang Gung University, Taoyuan, Taiwan.

[*] Correspondence: Li-Sheng Hsu, Department of Diagnostic Radiology, Chang Gung Memorial Hospital, Chiayi Branch, Puzi City, Chiayi County, Taiwan (e-mail: gv107392@yahoo.com.tw).

Medicine (2016) 95:35(e4701)

Received: 8 April 2016 / Received in final form: 27 July 2016 / Accepted: 27 July 2016

http://dx.doi.org/10.1097/MD.0000000000004701

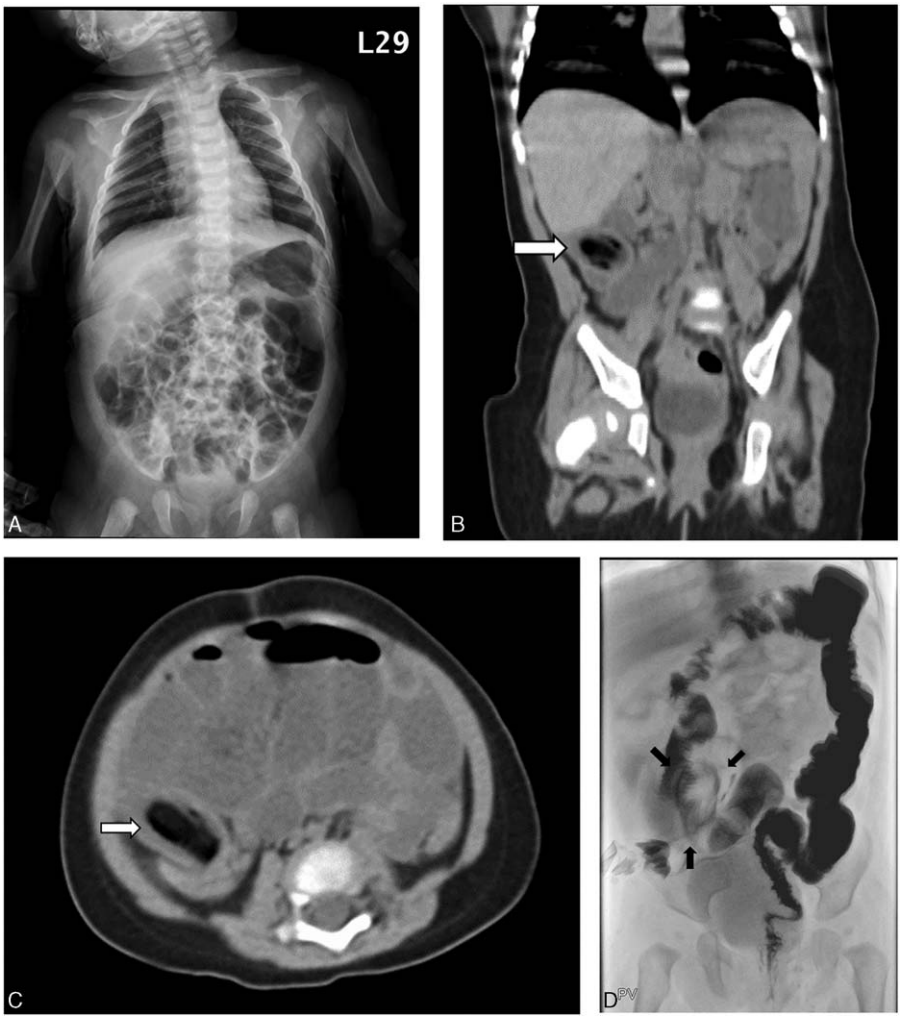

Figure 1. Imaging findings of the 7-month-old girl who presented with small bowel obstruction. (A) Abdominal radiography showing diffuse dilatation of the small bowel loops. (B, C) A low-attenuation lesion (size, 9.6 × 25.7 mm; CT number, −120.1 ± 12.8 HU) in the terminal ileum with small bowel obstruction and whole colon collapse (white arrows). (D) A suspicious ovoid filling defect in the terminal ileum (black arrows). CT = computed tomography, HU = Hounsfield units.

our results will be useful in the field of diagnostic imaging in the future.

Figure 2. The foam earplug (FEP) found in the diaper.

2. Materials and method

The study was approved by the Chang Gung Medical Foundation Institutional Review Boards. MAX-1 Pre-shaped FEPs (Honeywell, San Diego, CA) were used as phantoms for tests. They were scanned with a CT scanner (SOMATOM Sensation 64, Siemens Medical Solutions, Forchheim, Germany) at 120 kVp. The images were reconstructed with 3D reformations, and the average CT numbers were measured with a region of interest area of about 5 mm^2.

In order to determine the CT number ranges for FEPs in the human body, a dry FEP and a fully wet FEP (squeezed in pure water by fingers) were scanned.

Six FEPs were squeezed to different degrees with fingers to simulate the changes due to bowel motility and content.

Because the FEPs can be compressed and absorb water in the bowel loops over time, 5 holes were cut in a foamcore frame, and 5 FEPs with different degrees of compression were placed into the holes (height of each of the FEPs: 5, 10, 15, 20, and 25 mm,

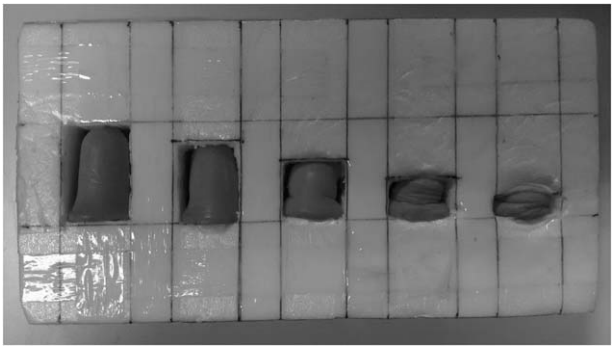

Figure 3. The foamcore frame with 5 foam earplugs (FEPs).

respectively) (Fig. 3). There was no compression when the height was 25 mm, and the maximum compression was noted when the height was 5 mm. The FEPs were scanned in a dry state; then, they were immersed into a water bottle without squeezing and scanned daily from day 0 to day 6.

3. Results

The density of a dry FEP is -843.5 ± 4.5 HU (Fig. 4A) and a dry FEP can be identified by its contour. The density of a fully wet FEP increases to 0.76 ± 9.3 HU and is almost hidden in the water (white arrows in Fig. 4B).

The CT numbers of FEPs are from -844.2 to 1.0 HU and 2 on the right side show heterogeneous geographic patterns (Fig. 4C).

Five FEPs in the foamcore with different degrees of compression were scanned in the dry and in the wet states from day 0 to day 6 (Fig. 4D). The CT numbers of FEPs increase due to compression and gradually absorbed water. The changes in CT numbers of the half-compressed FEPs (10, 15, and 20 mm) are more significant compared to those of the noncompressed (25 mm) and maximum-compressed ones (5 mm) (Fig. 5).

4. Discussion

Among cases of bezoar, plastic bezoar-related cases are rare. In previous studies, the ingested plastics included foam,[3–9] glove,[10,11] spray foam,[12] plastic wire,[13] bread clip,[14] and polystyrene resin.[15,16] Moreover, in most cases, the material is PU, polystyrene, polyethylene, and vinyl. These cases are generally associated with mental disorders such as psychiatric disorders, pica, mental retardation, or dementia. Most patients need endoscopy or laparotomy for treatment.[3–16]

Few studies have the CT features of plastics. Henrikson et al evaluated different kinds of plastics by CT; they included 8 kinds of plastics and the CT numbers ranged from –125 to 364 HU. Polypropylene, ultrahigh molecular weight polyethylene, high-density polyethylene, and polystyrene had negative CT numbers

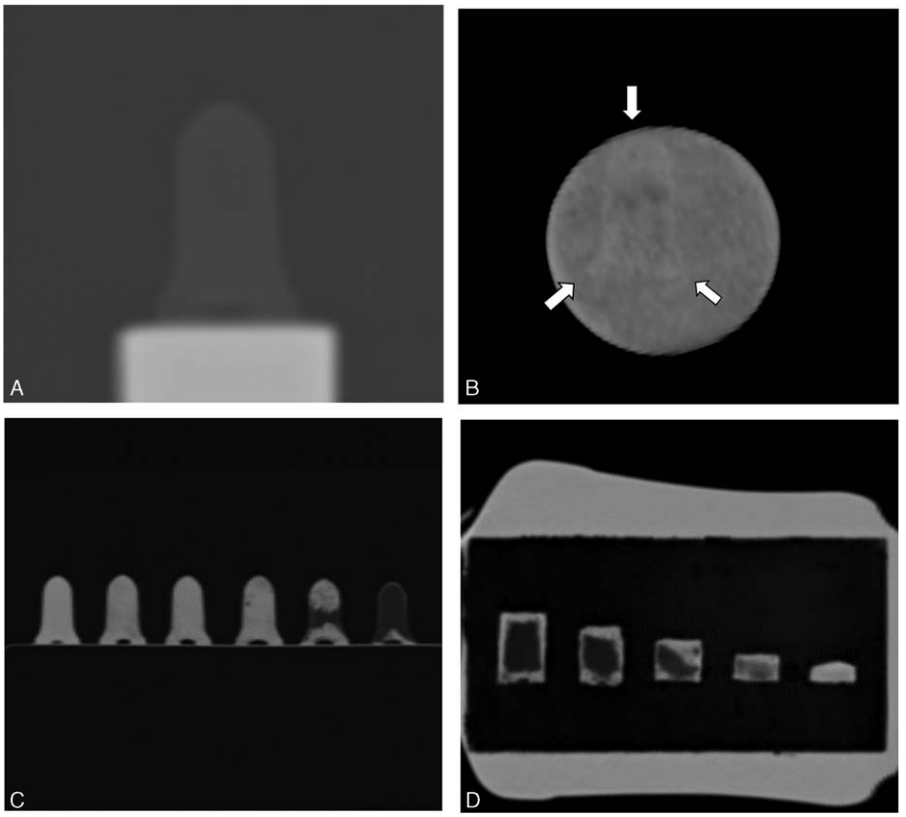

Figure 4. Phantoms evaluated by CT. (A) The CT number of a dry FEP is -843.5 ± 4.5 HU; it can be differentiated from air by the contour. (B) A totally wet FEP in the water bottle is almost hidden in the water (white arrows). The CT number is 0.76 ± 9.3 HU. (C) The figure panel shows 6 FEPs with different CT numbers (−844.2–1.0 HU); 2 on the right side show geographic patterns. (D) FEPs with different degrees of compression in a foamcore frame. CT = computed tomography, FEP = foam earplug, HU = Hounsfield units.

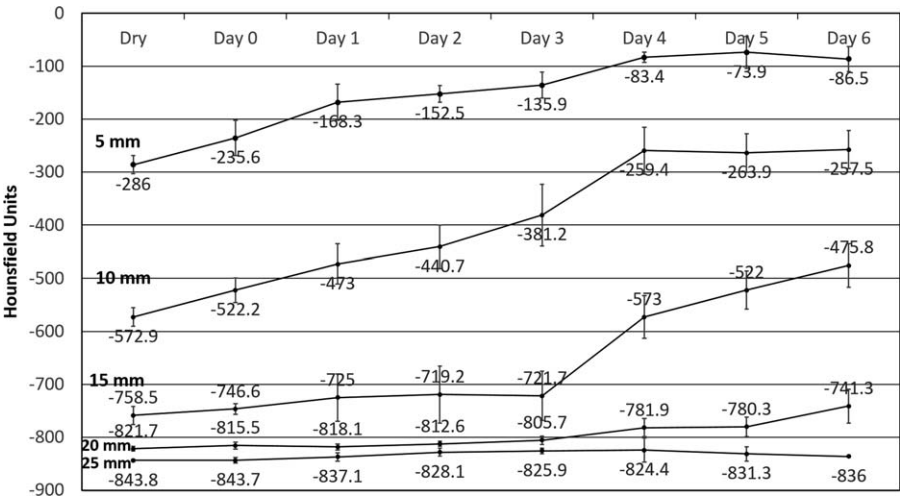

Figure 5. Changes in the CT numbers of FEPs with different degrees of compression (heights of each of the 5 FEPs: 5, 10, 15, 20, and 25 mm separately) in the dry and wet states from day 0 to day 6. Values are expressed as mean. Error bars show the mean and standard deviation. CT = computed tomography, FEP = foam earplug.

and nylon, polymethyl methacrylate, polysulfone, and acetal had positive CT numbers.[17]

PU is a kind of polymer composed of organic units joined by urethane links. PU is used in the production of seats, insulation panels, seals, gaskets, wheels, tires, adhesives, sealants, and surface coatings. PU foam is made using small amounts of blowing agents, such as carbon dioxide or pentane when urethane polymerization occurs to give less dense foam. Additionally, PU foam has the advantages of better cushioning, energy absorption, and thermal insulation.[18] There have been several cases regarding the ingestion of PU foam from cushions of sofas, couch, or car seats.[3–9,12,18] Most of the cases are noted in pica patients and they need to undergo surgery to treat the bowel obstruction. Moreover, the ingested PU foam mostly presents as intraluminal filling defects with a mottled appearance on CT scans.[3,4,7–9,12]

An FEP is a common device that is meant to be inserted in the ear canal to protect the user's ears from noises or the intrusion of foreign bodies. It is made of PU, and has a special foam structure, called memory foam. An FEP can recover its original shape after the removal of compression.[2]

According to the tests, the CT number of a dry FEP is -843.5 ± 4.5 HU because of the presence of gas in the foam structure. In the totally wet state, its density can increase to 0.76 ± 9.3 HU, which is similar to the density of water. If water distribution is uneven, heterogeneous geographic patterns can be noted. An FEP can mimic fatty lesion if the density ranges from -100 to -50 HU; it can hide in the water if fully wet. However, it may not be mistaken as air as the CT number of a dry FEP is -843.5 HU, which is higher than the density of gas, and the contour can be observed if the window level is set appropriately.

The CT numbers increase from -844.7 to -286.3 HU with different degrees of compression in a dry FEP. However, in the human body, it may not be able to achieve high or maximum compression. In the static state, the CT numbers increased gradually over time, but the numbers may increase more rapidly owing to bowel movement and compression. Half-compressed FEPs can absorb water more rapidly than noncompressed (25 mm) and maximum-compressed (5 mm) ones. In noncompressed FEPs, the foam structure is mainly occupied by air, and in the maximum-compressed ones, there is little space to absorb water.

In previous studies, the ingested PU foam usually presented as intraluminal filling defects with a mottled appearance, similar to that noted for bezoars in the bowel loops. However, the CT features of our case are quite different. This is because the air spaces in the PU foam from cushions of sofas or car seats are much larger than those in the FEP; it is impossible to see the tiny air spaces in the FEP. The CT density of the FEP reflects the summation of the CT density of PU foam, water, and gas as a result of the partial volume effect.[3,5,7,8]

To the best of our knowledge, no case of FEP ingestion that caused small bowel obstruction has been reported thus far. Initially, we did not consider the likelihood of foreign body ingestion because the patient's parents denied the possibility. They probably used FEPs for reducing noise due to the infant's crying. Although a case of FEP ingestion has not been reported before, FEPs can be potentially hazardous objects to children. In addition, if the FEP cannot be identified before surgery, the surgeon may miss it during surgery because the FEP's texture is very soft and a reoperation may be performed. Hence, it is important that radiologists are familiar with the CT features of such objects so that they can identify them before performing a surgery.

A limitation of this study is that the phantom study cannot completely reflect the real changes in FEPs in the human body. However, we used static and dynamic, passive and active phantom studies to simulate the different compression ratios of FEPs caused by bowel motility and the range of CT numbers according to water/gas ratio in different bowel conditions.

5. Conclusions

Although rare, ingestion of FEPs can be potentially hazardous in pediatric cases because FEPs are widely used globally. The CT features of ingested FEPs are quite different from those of ingested PU foam in pica patients. When features indicate the presence of a low-attenuation lesion (when the density is equal to or slightly lower than that of fat) inside the body, ingestion of plastics should be taken into account besides considering fat-containing lesions.

Owing to the special foam structure of the FEPs, the density may change because of the water/gas ratio, water distribution, and time elapsed after contact with water. A wet FEP can hide in water as well as mimic fatty lesions depending on its water content, but misidentification of FEPs as air can be avoided if the density is measured, the window level is properly set, and the contour is carefully observed. Radiologists should be familiar with the features of FEPs to avoid misdiagnosis before surgery.

References

[1] Grassi R, Faggian A, Somma F, et al. Application of imaging guidelines in patients with foreign body ingestion or inhalation: literature review. Semin Ultrasound CT MR 2015;36:48–56.

[2] Wikipedia contributors. Earplug. Wikipedia, The Free Encyclopedia. July 2, 2016, 18:54 UTC. Available at: https://en.wikipedia.org/w/index.php?title=Earplug&oldid=728038666. Accessed July 18, 2016.

[3] Chiu B, Ciaccio C, West MA. Intestinal obstruction from furniture cushion foam bezoar. Surgery 2005;138:956–8.

[4] McAlinden MG, Potts SR. Sponge bezoar: a rare cause of abdominal pain. Ulster Med J 1999;68:36–7.

[5] Misra SP, Dwivedi M, Misra V. Endoscopic management of a new entity-plastobezoar: a case report and review of literature. World J Gastroenterol 2006;12:6730–3.

[6] Agrawal V, Joshi MK, Jain BK, et al. Plasticobezoar-another new entity for Rapunzel syndrome. Indian J Pediatr 2009;76:229–30.

[7] Medani M, Myers E, Kenny B, et al. Small bowel obstruction secondary to migration of a fragment of lithobezoar: a case report. Cases J 2009;2:9155.

[8] Altepeter T, Annes J, Meller J. Foam bezoar: resection of perforated terminal ileum in a 17-year-old with sickle beta+ thalassemia and pica. J Pediatr Surg 2011;46:E31–2.

[9] Chandramohan SM, Rajkumar R, Duraisamy B, et al. Esophago-gastric 'foam-bezoar'–report of a new entity. Trop Gastroenterol 2014;35:128–30.

[10] Kamal I, Thompson J, Paquette DM. The hazards of vinyl glove ingestion in the mentally retarded patient with pica: new implications for surgical management. Can J Surg 1999;42:201–4.

[11] Huang TC, Chiu HH, Liao YC. An unusual cause of small bowel obstruction: a plastic glove. Clin Gastroenterol Hepatol 2009;7:e9–10.

[12] Girardin M, Giostra E, Dumonceau JM. Endoscopic removal of a gastric bezoar consisting of self-expanding spray foam used for insulating window frames. Endoscopy 2011;43(Suppl 2 UCTN):E372–3.

[13] Verma VK. Plastic bezoars-a unique introduction in bezoars family. Indian J Surg 2013;75(Suppl 1):51–3.

[14] Tang AP, Kong AB, Walsh D, et al. Small bowel perforation due to a plastic bread bag clip: the case for clip redesign. ANZ J Surg 2005;75:360–2.

[15] Metlay LA, Klionsky BL. An unusual gastric bezoar in a newborn: polystyrene resin and Candida albicans. J Pediatr 1983;102:121–3.

[16] Koneru P, Kaufman RA, Talati AJ, et al. Successful treatment of sodium polystyrene sulfonate bezoars with serial water-soluble contrast enemas. J Perinatol 2003;23:431–3.

[17] Henrikson GC, Mafee MF, Flanders AE, et al. CT evaluation of plastic intraocular foreign bodies. AJNR Am J Neuroradiol 1987;8:378–9.

[18] Wikipedia contributors. Polyurethane. Wikipedia, The Free Encyclopedia. July 11, 2016, 14:22 UTC. Available at: https://en.wikipedia.org/w/index.php?title=Polyurethane&oldid=729335321. Accessed July 18, 2016.