Imaging Foreign Bodies: Ingested, Aspirated, and Inserted

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Foreign bodies can gain entrance to the body through several mechanisms, ie, ingestion, aspiration, and purposeful insertion. For each of these common entry mechanisms, this article examines the epidemiology, clinical presentation, anatomic considerations, and key imaging characteristics associated with clinically relevant foreign bodies seen in the emergency department (ED) setting. We detail optimal use of multiple imaging techniques, including radiography, ultrasonography, fluoroscopy, and computed tomography to evaluate foreign bodies and their associated complications. Important imaging and clinical features of foreign bodies that can alter clinical management or may necessitate emergency intervention are discussed. [Ann Emerg Med. 2015;66:570-582.]

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INTRODUCTION

Foreign bodies are a common cause of emergency department (ED) visits and can gain entry into the human body through a variety of methods, including ingestion, aspiration, and purposeful insertion. According to the National Hospital Ambulatory Medical Care Survey, there were approximately 535,000 ED visits with foreign body–related primary diagnosis in the United States in 2010.[1] ED providers are usually the first point of contact for patients who experience foreign body–related accidents and therefore have an important role in coordinating care. To ensure accurate diagnosis of the foreign bodies and their associated complications, ED providers need to be cognizant of the appropriate imaging modalities and specific techniques available for both diagnostic and follow-up evaluation of foreign bodies. This review will discuss the epidemiology, clinical presentation, anatomic considerations, and appropriate imaging strategies for each foreign body's entry mechanism, which may involve radiographs, ultrasonography, fluoroscopy, or computed tomography (CT). Key imaging characteristics, including size, shape, density, anatomic location, and clinical features of foreign bodies that can change management or necessitate emergency interventions, will also be discussed.

Background

Radiography is the major workhorse used in initial and follow-up imaging of foreign bodies. When foreign bodies are evaluated on radiographs, it is important to recognize that radiopacity and radiographic visibility are 2 different concepts. Radiopacity is an intrinsic feature of an object that depends on its ability to absorb (attenuate) or scatter X-ray photons.[2] Radiographic visibility depends on the X-ray attenuation characteristics of the object, its surrounding structures, and the overlying and underlying structures that X-ray photons have to pass through to reach the detector. In a simple experiment, Halverson and Servaes[2] demonstrated that plastic toys (generally perceived to be radiolucent) were visible on radiographs when placed in a basin without water (surrounded by air). However, the toys gradually became less visible and eventually disappeared on radiographs as the depth of water in the basin increased. By the same logic, a foreign body that is radiographically visible in the airway may not be visible when it is embedded in soft tissue; a foreign body that is radiographically visible in the foot may not be visible when it is embedded in the abdomen where soft tissue thickness is greater. Therefore, radiographic visibility of an object can depend not only on its size and radiopacity but also on its anatomic location, the patient's body habitus, and the surrounding anatomic structures. In clinical practice, an object is described as radiopaque when it is relatively more radiopaque than the surrounding tissue.

Although plastic and organic foreign bodies (such as wood) are generally radiolucent on radiographs, stone foreign bodies are usually radiopaque. A common misconception held by physicians about glass foreign bodies is that only leaded glass is radiopaque on radiographs.[3] In fact, the radiodensity of glass

Editor's Capsule Summary

What is already known on this topic
Imaging studies are helpful in the detection of ingested, aspirated, and inserted foreign bodies.

What question this study addressed
This systematic review discusses the ability of different imaging studies to detect foreign bodies in particular locations, according to the location and physical properties of the foreign body.

What this study adds to our knowledge
Radiographs, ultrasonography, and computed tomography scans are all recommended options, depending on the clinical scenario.

How this is relevant to clinical practice
Evidence-based imaging recommendations are made according to the suspected foreign body and its suspected location.

does not depend on lead content, but rather on its density.[4] Therefore, all glass foreign bodies are radiopaque, but with various degree of radiodensity. Metal foreign bodies are almost always radiopaque, with the exception of thin aluminum metal, which has a lower radiodensity and a lower sensitivity for detection on radiographs.[5]

It may be necessary to take into account radiographic magnification when measuring the size of foreign bodies if an exact measurement is surgically or medically warranted. Several studies report mean magnification ranging from 13.7% to 21.7% in pelvic radiographs and 18.5% to 21.7% in lateral cervical radiographs.[6-8] Such magnification depends on the distance between the object being measured and the radiograph cassette and varies because of technique and patient body habitus.[9] The measurements made on radiographs represent the upper bound measurements of the actual size. Calibration technique that involves placing objects of known size in the same plane of interest has been shown to be effective in reducing the magnification of measurements made on radiographs.[8]

Ultrasonography is generally an excellent modality for evaluating superficially embedded small or radiolucent foreign bodies, but also can assist in identifying inserted foreign bodies within the genitourinary system. Although the results of an ultrasonographic examination can be operator dependent, the advantages of ultrasonography include portability and its ability to detect foreign bodies and to provide detailed anatomic evaluation without radiation. For more superficial foreign bodies, a high-frequency (7 to 12 MHz) linear transducer is recommended. This probe provides high resolution, with corresponding sacrifice in depth of penetration. A lower-frequency (3 to 5 MHz) curved transducer can be used for deeper imaging.[10] Depending on the composition, a foreign body has variable echogenicity with either posterior shadowing (dark shadows deep to the structure) or ring-down artifacts (bright echogenic lines extending posteriorly) (Figure E1*A* to *E*, available online at http://www.annemergmed.com).[11] Although wood, plastic, and stone foreign bodies generally demonstrate posterior shadowing, glass and metal foreign bodies demonstrate ring-down artifacts. If the foreign bodies contains air (eg, wood), "dirty shadowing" may be observed, which is a more heterogeneous shadowing produced by sound-reflecting material (ie, gas).

Fluoroscopy uses real-time radiography to collect information about the dynamic functionality of the organ system of interest. For example, it can be used to evaluate esophageal motility in the setting of dysphagia and movement of the diaphragm in the setting of diaphragmatic paralysis, and it can also be used to evaluate leakage or fistula arising from the gastrointestinal tract with oral or rectal water-soluble contrast. For the best results, fluoroscopy requires the patient's ability to follow commands and readily change position. It also requires the presence of the interpreting radiologist throughout the examination.

After radiography, CT is usually the next step to evaluate for radiolucent foreign bodies and foreign body–related complications because of its ability to provide volumetric information and detailed spatial resolution of anatomy and pathology. Hounsfield units are a standardized CT measurement of density, with lower values corresponding to less radiodense materials; the Hounsfield units scale is centered at 0 (water), with index material values of –1,000 (air), +40 (blood), and +1,000 (bone). Because of its porous nature and intrinsic composition, wood foreign bodies may contain tiny air bubbles and oils, and thus can mimic air and fat on CT and often have negative Hounsfield units (eg, Hounsfield units of dry and fresh pine=–650 and –24, respectively).[12-15] As the wood foreign body absorbs more water from its surroundings, it may become more dense on CT, mimicking soft tissue (Figure E1*F*, available online at http://www.annemergmed.com).[13] Hounsfield unit values of plastic foreign bodies are of intermediate value (100 to ≈500) and can vary, depending on the composition and density.[14] Hounsfield unit values of stone foreign bodies are higher, usually greater than 1,000 (eg, sandstone ≈1,600, limestone ≈2,800).[14,16] The Hounsfield unit value of glass varies, depending on the density, ranging from approximately 500 for windowpane glass to greater than 2,000 for bottle and car window glass.[16] On CT, the Hounsfield unit value for metallic foreign bodies is generally greater than 3,000, except for aluminum, which has a value in the 700s to 800s.[13,14,16] Although both stone and glass appear hyperdense on CT (Figure E1*G*, available online at http://www.annemergmed.com), they do not exhibit streak artifacts (Figure E1*H*, available online at http://www.annemergmed.com) like metal does, which can sometimes obscure the evaluation of adjacent structure on CT. Table 1 serves as a reference for imaging characteristics of commonly encountered foreign body materials discussed above under different imaging modalities.

It is estimated that esophageal foreign bodies are responsible for approximately 1,500 deaths annually in the United States.[17] Although the majority of ingested foreign bodies pass through the gastrointestinal system without complications, approximately 10% to 20% of ingestions require intervention.[17,18] However, in the setting of intentional foreign body ingestion, the rates of endoscopic and surgical intervention are higher, at 63% to 76% and 12% to 16%, respectively.[19,20] Pediatric patients account for the majority of foreign body ingestion cases, with peak incidence occurring between aged 6 months and 6 years, and are often accidental.[21] In adult patients, intentional foreign body ingestion is more frequently observed with psychiatric illness, intellectual disability, substance dependence, incarceration (seeking secondary gains), and body packing (Table 2).[22,23]

Adult patients with esophageal foreign body impaction can present with dysphagia, odynophagia, chest pain, pharyngeal discomfort, nausea, or vomiting. In severe esophageal obstruction, which is an indication for emergency intervention, patients may present with hypersalivation associated with aspiration and coughing. In the younger pediatric population, who are often unable to provide a detailed history, drooling, choking, refusal to eat, coughing, and respiratory distress should raise the index of suspicion for foreign body ingestion.[23] Patients with ingested foreign bodies that have passed the gastroesophageal junction are often asymptomatic. If there are any clinical symptoms, they are largely dependent on the physical and chemical properties of the ingested material and may manifest as abdominal pain, melena (sharp or corrosive object), obstruction (large object), or drug-related toxidrome (ruptured drug packages) (Table 2).

The most common location for ingested foreign body impaction is within the upper esophagus, at the level of cricopharyngeus muscle (Figure E2, available online at http://www.annemergmed.com), which accounts for approximately 75% of all foreign body impaction cases.[24] Although foreign bodies at or above the cricopharyngeus muscle necessitate otorhinolaryngology consultation, below the cricopharyngeus muscle they are removed either by endoscopy (by gastroenterologists) or surgery, if necessary.[21] Other common locations of esophageal foreign body impaction include the level of the aortic arch, left main bronchus, or gastroesophageal junction (Figure 1). Once objects have made their way through the gastroesophageal junction, they usually have no problem progressing through the remainder of the gastrointestinal tract. In total, less than 10% of impaction occurs distal to the gastroesophageal junction.[24] Depending on the size and shape of the foreign bodies, other potential regions of foreign body obstruction in the gastrointestinal tract include the pylorus, duodenal C-loop, and ileocecal valve (Figure 1).[18,24-26]

Table 1. Summary imaging characteristics for commonly encountered foreign body materials.

Materials	Radiographs	Ultrasonography	CT
Wood	Radiolucent	Hyperechoic structure with posterior shadowing[11] Dirty shadowing if there is significant amount of air content	HU* can be negative (because of air) and can gradually increase as wood absorbs more water (eg, HU of dry and fresh pine=–650 and –24, respectively).[3,12-15]
Plastic	Radiolucent	Hypoechoic structure with posterior shadowing[11]	HU is of intermediate value (100–≈500) and can vary slightly, depending on composition and density[14]
Stone	Radiopaque	Hyperechoic structure with posterior shadowing[11]	Hyperdense object without streak artifact High HU, usually >1,000 (eg, sandstone ≈1,600, granite ≈2,100, slate ≈2,200, marble ≈2,300, limestone ≈2,800)[14,16]
Glass	Radiopaque	Hyperechoic structure with ring-down artifact[11]	Hyperdense structure without streak artifact HU variable and depends on density (eg, windowpane glass ≈500, bottle glass ≈2,100, car window ≈2,700)[14,16]
Metal	Radiopaque (except for thin aluminum)[3,5]	Hyperechoic structure with ring-down artifact[11,14]	Hyperdense structure with streak artifact HU >3,000 (except for aluminum, which has HU ≈700–800)[13,14,16]

HU, Hounsfield units.
*HUs are a standardized CT measurement of density, with lower values corresponding to less dense materials; the HU scale is centered at 0 (water), with index material values of –1,000 (air), +40 (blood), +1,000 (bone), and +3,000 (metal).

Table 2. Clinical and imaging pearls for foreign body ingestion.

Risk factors	Young children, psychiatric illness, intellectual disability, substance dependence, prisoners, drug trafficking[22,23]
Clinical presentation	Esophageal FB: dysphagia, odynophagia, chest discomfort, pharyngeal discomfort, nausea, vomiting, hypersalivation with aspiration and coughing[23]
	FB distal to GE junction: abdominal pain, melena (sharp or corrosive FB), obstruction (large FB), or toxidrome (ruptured drug packets in body packers)
	Children: drooling, refusal to eat, coughing, or choking
Imaging considerations	Initial evaluation: 2-view radiographs, nose-to-rectum radiographs if physical examination and history fail to localize FB in younger pediatric patients
	Negative radiograph results should not preclude further evaluation with CT or endoscopy in the setting of high clinical suspicion
	CT can increase the sensitivity of detecting radiolucent FB (eg, fish bone)[27] and FB-related complications, and localize the FB with finer anatomic details
	Oral contrast examination should be avoided before endoscopy[21]
Clinically important imaging findings	Sharp FB or button battery in the esophagus or any FB causing symptoms of complete esophageal obstruction requires emergency endoscopic removal[21]
	Sharp FB in the esophagus or duodenum, long FB (>6 cm in length) at or above proximal duodenum, magnets within reach by endoscopy warrant urgent endoscopic removal[21]
	Imaging finding of complications such as pneumomediastinum, pneumoperitoneum, or intra-abdominal abscess requires surgical consultation

FB, Foreign body; *GE*, gastroesophageal.

For a majority of radiopaque ingested foreign bodies, 2-view radiographs are sufficient as the initial evaluation. For pediatric patients, a focused imaging evaluation based on the patient's symptoms, physical examination, and history should be performed to reduce unnecessary radiation. Only in cases in which localization remains difficult after obtaining history and physical examination may "nose-to-rectum" imaging be considered (Figure E2*A*, available online at http://www.annemergmed.com). On radiographs, it is necessary to note the location, size, shape, and number of the foreign bodies ingested, as well as any detectable associated complications.

Many commonly swallowed objects can be radiolucent and may be invisible on radiographs, such as thin fish or chicken bones, plastic, wood, and thin aluminum objects (such as carbonated soft drink tabs). Therefore, negative-result radiographs, in the setting of high clinical suspicion for foreign body ingestion, should not preclude further evaluation with either CT or endoscopy.[21] Endoscopy allows diagnosis and intervention simultaneously in the setting of negative radiograph results with persistent esophageal symptoms. CT may be helpful in delineating the specific location of foreign bodies in finer detail and improves the sensitivity of detecting radiolucent foreign bodies and foreign body–related complications. The American Society of Gastrointestinal Endoscopy advises against the use of oral contrast examinations because of risks for aspiration and the potential negative effect on the quality of subsequent endoscopy.[21]

When a sharp foreign body is present within the esophagus, emergency endoscopic removal is indicated.[21] If the object has passed through the gastroesophageal junction but remains within reach of endoscopy (such as in the stomach or duodenum), urgent endoscopic retrieval is recommended as long as the object can be withdrawn safely (Figure 2).[21] Once sharp objects pass the duodenum, up to 35% of them can lead to perforation; therefore, they should be followed with daily radiographs to document passage.[21,25] Surgical removal is recommended if the patient becomes symptomatic or if sharp objects fail to progress after 3 days and are beyond endoscopic reach.[21]

In the setting of radiolucent foreign bodies, secondary radiographic signs, such as prevertebral soft tissue swelling on a lateral cervical spine radiograph, may suggest the presence of cervical foreign bodies (Figure 3). However, in the setting of negative radiograph results, CT may be helpful. It has been shown to have high sensitivity and specificity in detecting foreign bodies in the upper gastrointestinal tract and also in diagnosing fish bone impaction.[27] Complications caused by a sharp ingested object such as perforation, fistula, and phlegmon or abscess (Figure 4) can also be evaluated with CT. The addition of intravenous contrast allows better characterization of these complications, should they be present.

A specific sharp radiolucent foreign body of clinical relevance (and for which clinical history is paramount) is a plastic bread bag clip (Figure E3, available online at http://www.annemergmed.com), which poses a great diagnostic challenge because all cases reported in the literature have been invisible on both radiographs and CT.[28,29] The design of the clip makes it prone to complications such as small bowel perforation, obstruction, or gastrointestinal hemorrhage.[28,29]

In general, blunt objects in the esophagus require at least urgent endoscopic removal.[21] An exception to this rule is a coin, which is discussed in the next paragraph. However, when symptoms of severe esophageal impaction are present,

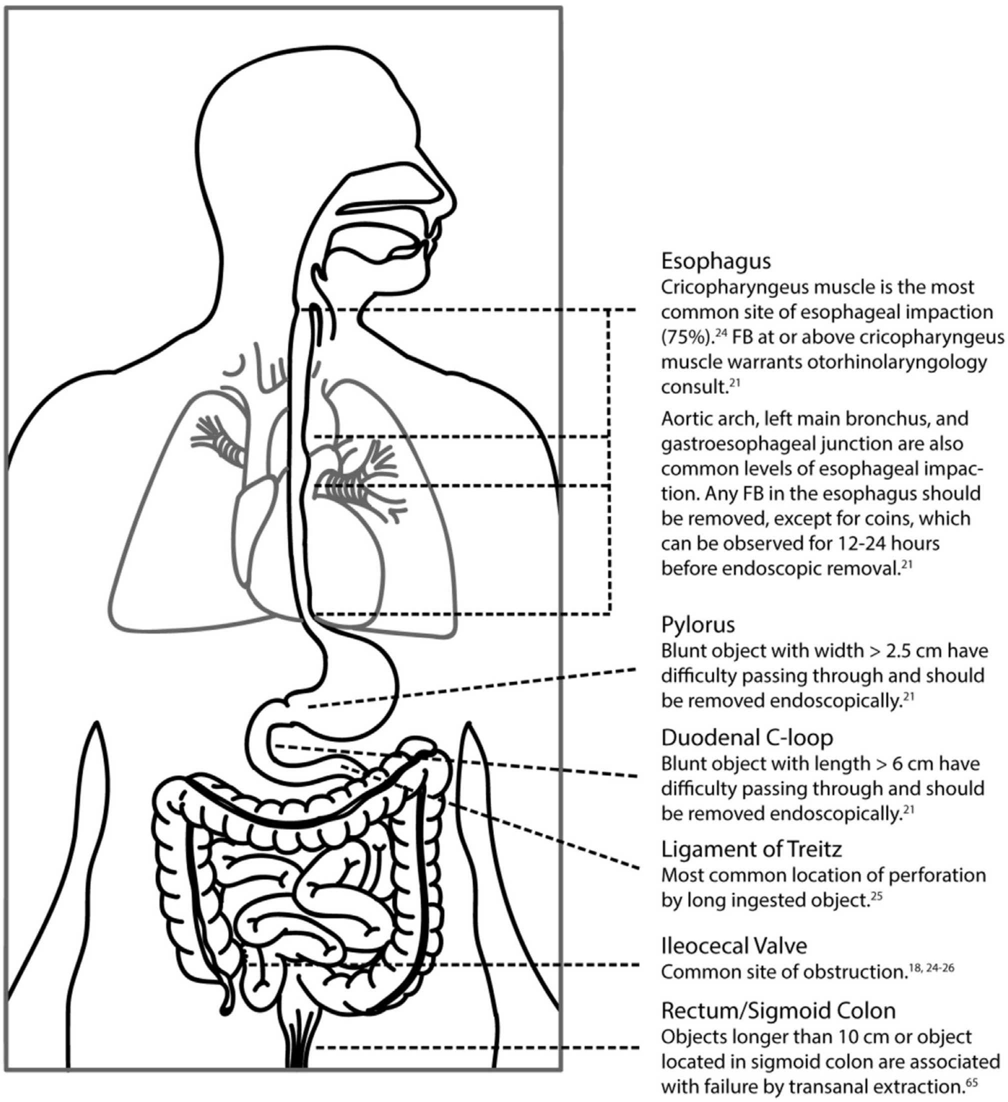

Figure 1. Clinically relevant anatomic sites in the gastrointestinal tract in the setting of ingested or rectal foreign bodies.

regardless of the type of foreign bodies involved, emergency endoscopic removal is warranted. Blunt objects with width greater than 2.5 cm often have difficulty passing the pylorus.[26] Despite limited data to support such recommendation, American Society of Gastrointestinal Endoscopy guidelines suggest endoscopic removal for blunt foreign bodies with width greater than 2.5 cm.[21] A conservative approach for blunt foreign bodies retained in the stomach consists of weekly radiographs until passage. Once the blunt objects pass the pylorus, they usually do not have trouble passing through the remaining gastrointestinal tract, unless the patient has distal narrowing or stricture as a result of previous surgery or pathologic conditions such as Crohn's disease. If the blunt object fails to pass the pylorus after 3 to 4 weeks, endoscopic removal is recommended. If the patient develops any symptom suggestive of peritonitis or if the object remains in the same location distal to the duodenum for more than 1 week, surgical intervention is indicated.[21]

According to a qualitative analysis conducted by Jayachandra and Eslick,[24] coins are the most commonly ingested foreign bodies and account for up to 70% of foreign body ingestion in the pediatric population. Coins lodged in esophagus can be observed for 12 to 24 hours before consideration of endoscopic removal as long as the patient remains asymptomatic (Table 3). Ingested coins are most commonly lodged near the level of cricopharyngeus muscle (Figure E1, available online at http://www.annemergmed.com).[24,25] Coinlike objects on radiographs must be differentiated from button batteries whenever possible because the latter in the esophagus require emergency endoscopic removal. Once passing the gastroesophageal junction, most coins eventually leave the

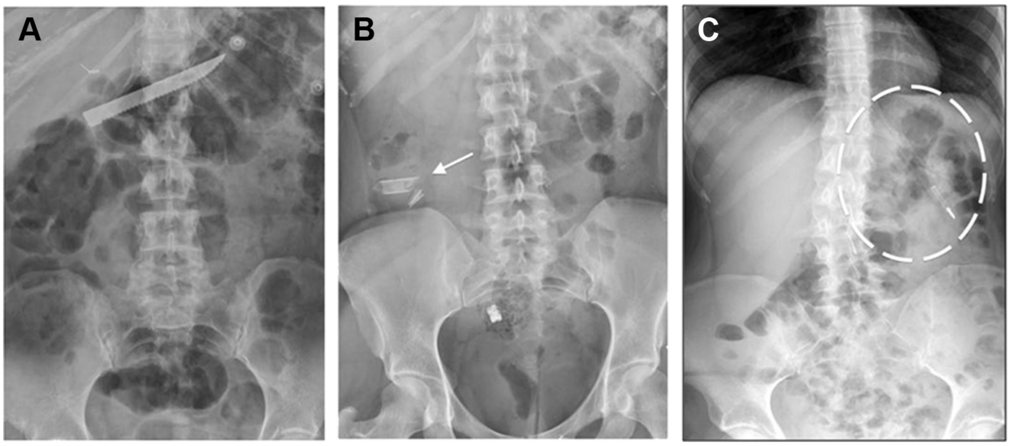

Figure 2. Sharp ingested foreign bodies. *A*, A woman repeatedly swallows a serrated knife. *B*, Swallowed broken glass crack pipe (white solid arrow). *C*, A patient with a psychiatric history and multiple previous FB ingestions presented to the ED after ingesting a ballpoint pen (white dashed circle). There is a metallic tip and associated spring, with a fainter plastic casing.

stomach and can be followed with weekly radiographs for up to 4 weeks before endoscopic removal.[21]

Blunt objects longer than 6 cm proximal to duodenum usually have difficulty passing the duodenal C-loop and warrant urgent endoscopic removal.[21,26] Palta et al[19] showed that 80% of 139 objects longer than 6 cm remained in the stomach at endoscopy. The most common site of perforation by long objects is near the ligament of Treitz.[25] Deliberate efforts are required to ingest long foreign bodies, such as toothbrushes, pencils, and utensils. Such incidents are often intentional and occur more frequently in patients with psychiatric illness.[23] Both short and long blunt objects share the same conservative management and imaging follow-up strategy as described previously (Table 3).

Unlike other blunt objects, button batteries in the esophagus require emergency endoscopic removal even without symptoms of severe impaction.[21,23-25,30-34] If untreated, esophageal button batteries are known to cause potentially fatal complications within hours after ingestion. Their major injury mechanisms involve generation of an electrolytic current that hydrolyzes local fluid and produces hydroxide, and leakage of caustic alkaline substance. Both can cause liquefaction necrosis and severe mucosal damage, leading to esophageal perforation, stricture, fistula, and possibly massive hemorrhage and death.[23,25,33]

After button batteries have passed through the esophagus, the majority of them progress without complications and can be followed with radiographs every 3 to 4 days. According to a data analysis performed by Litovitz et al,[33] of all the button batteries ingested, the larger (>2 cm) lithium button batteries are the ones found to cause major disabling and fatal complications. Endoscopic removal is recommended for large-diameter batteries (>2 cm) that remain in the stomach for longer than 48 hours on follow-up radiographs.[21] Once past the gastroesophageal junction, smaller button batteries are usually not retrieved unless the patient becomes symptomatic.

Button batteries may mimic coins on radiographs. Some helpful ways to differentiate the two are "halo" sign on frontal projection or "step-off" sign on lateral projection, which sometimes require extreme magnification to visualize (Figure E4, available online at http://www.annemergmed.com). If there is concern about button battery ingestion, specifically discussing this with the radiologist may be helpful for arriving at the correct diagnosis.

Not many data are available for cylindrical batteries because they are less frequently ingested and no major or fatal complications have been reported in the literature. Endoscopic removal is recommended by the American Society of Gastrointestinal Endoscopy when they are lodged in the esophagus or remain in the stomach for greater than 48 hours.[21]

When multiple magnets or a pair of magnetic and metal objects is ingested, there is a risk for bowel wall pressure necrosis caused by the attractive force between the 2 objects. Devastating complications such as fistula, perforation, obstruction, volvulus, and peritonitis have been reported.[35] It may be difficult to discern the number of ingested objects from radiographs. Multiple radiopaque objects that appear to be persistently in tandem or stacking on top of one another on serial radiographs should raise the index of suspicion for multiple magnets or magnet-metal pairs (Figure E5, available online at http://www.annemergmed.com). American Society of Gastrointestinal Endoscopy guidelines advise urgent endoscopic removal of any number of known ingested magnets. For magnets that are out of reach by endoscopy, close observation with serial radiographs to ensure

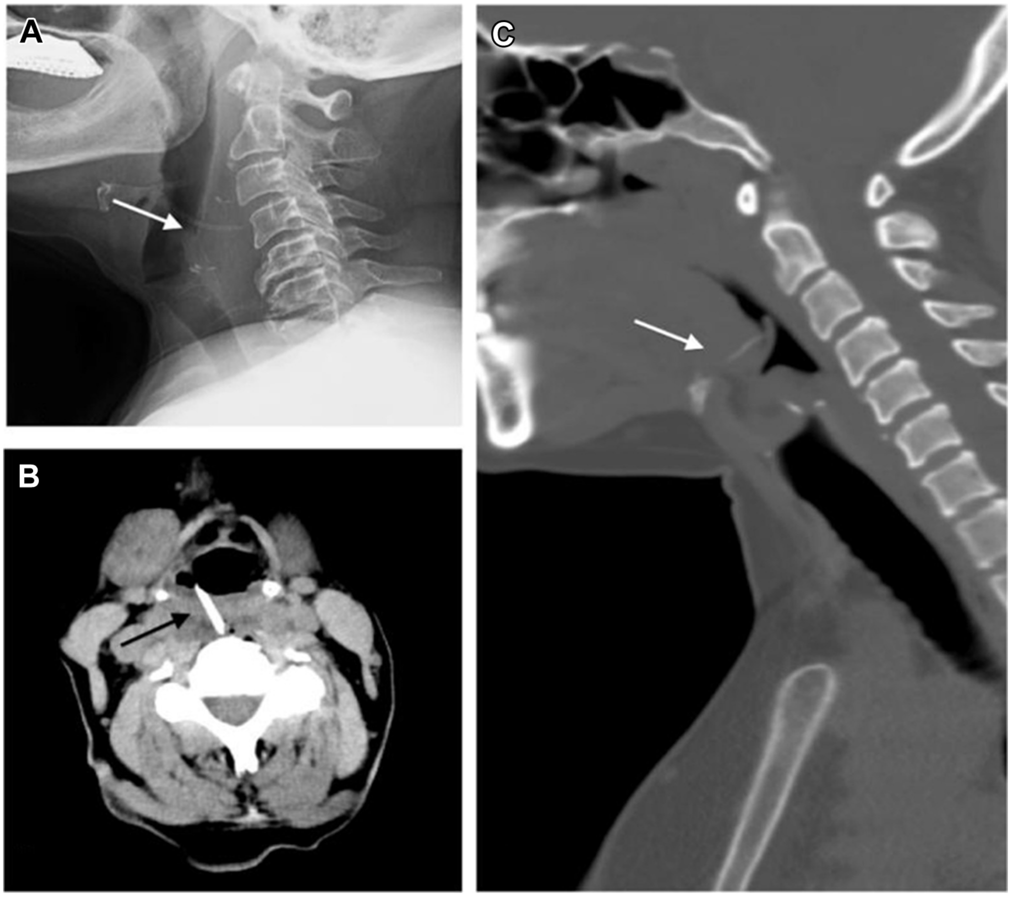

Figure 3. Patient who swallowed a chicken bone. Lateral neck soft tissue radiograph (*A*) demonstrates a faint radiopaque curvilinear structure (white solid arrow) anterior to C4, with prevertebral soft tissue swelling at the same level (helpful secondary sign even in absence of radiopaque FB). As a rule of thumb, prevertebral soft tissue swelling is present if soft tissues are thicker than half a vertebral body width at C3 or above or a vertebral body width at C4 or below. Axial CT view (*B*) of the same patient demonstrates a hyperdense chicken bone (black solid arrow). Sagittal view of a neck CT of another patient who swallowed a fish bone (*C*) demonstrates a faint radiopaque linear structure within the vallecula (white solid arrow), consistent with a fish bone, which would appear radiolucent on radiographs.

progression is recommended. Surgical consultation is indicated if the patient becomes symptomatic or if the multiple magnets or magnet-metal pairs appear immobile on serial radiographs.[21,23,36]

Ingestion of illicit drugs contained by condom, balloon, or plastic for drug trafficking (Figure E6, available online at http://www.annemergmed.com) is referred to as "body packing."[21,23] The ability of radiographs for detecting drug packages can be variable and dependent on the material of the containers, with false-negative rates as high as 23%.[37] CT with intravenous contrast (without oral contrast) has been shown to be a more reliable way for detecting intracorporeal drug packets.[37] Furthermore, the radiologist should be made aware that the indication for CT is to search for intracorporeal drug packets such that gastrointestinal lumen should be carefully inspected. The American Society of Gastrointestinal Endoscopy recommends against endoscopic removal of drug packets because of concerns for rupturing them during retrieval.[21] Surgical removal should be considered when drug packets fail to progress or when the patient develops symptoms from ruptured packets.[21]

According to the National Safety Council, foreign body aspiration represents the fourth leading cause of unintentional home and community death in the United States, with approximately 4,600 reported deaths in 2009.[38] The incidence of such aspiration demonstrates a bimodal distribution, with peaks at aged 1 to 2 years and older than 60 years.[38-40] Foreign body aspiration occurs less frequently in adults, accounting for only 20% of the cases.[41] Risk factors associated with it include altered mental status, loss of consciousness (because of a variety of reasons such as trauma, seizure, or anesthesia), age-related decline in swallowing mechanism, usage of certain medications that can impair cough reflex or swallowing

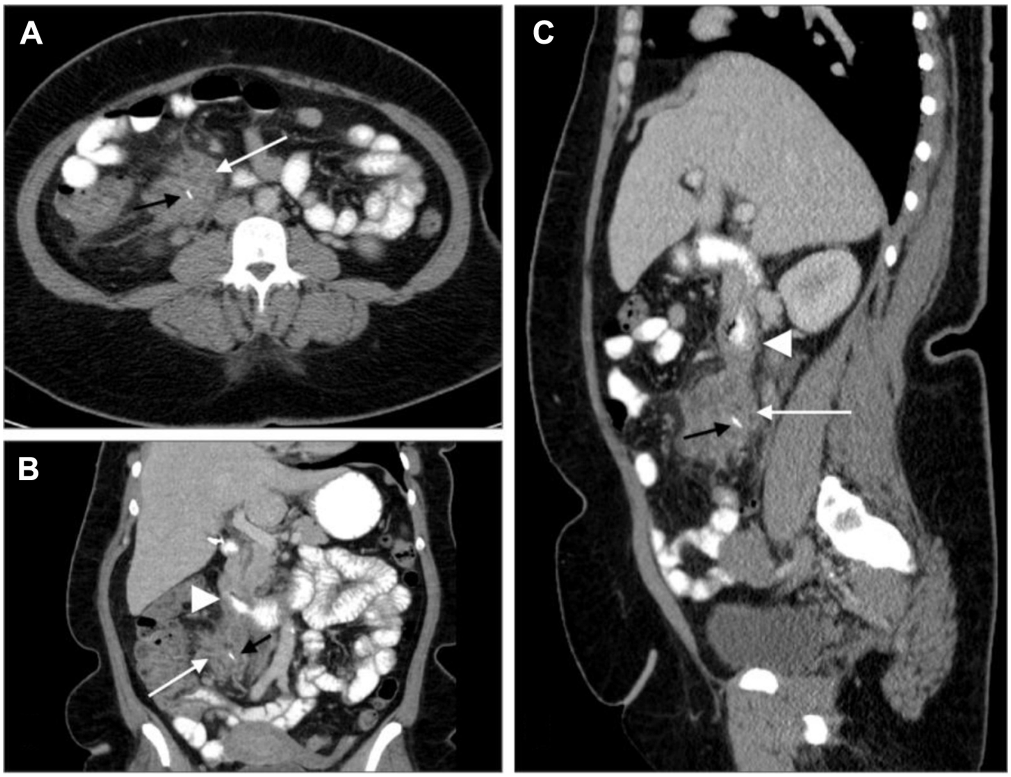

Figure 4. Patient who swallowed a chicken bone and presented several days later with severe pain. Axial (*A*), coronal (*B*), and sagittal (*C*) contrast-enhanced CT showing a heterogeneous phlegmon (white solid arrows in *A*, *B*, and *C*) inferior to, but contiguous with, the second-third portion of the duodenum (arrowheads in *B* and *C*). In the center of this collection, there is a thin hyperdense chicken bone (black solid arrows in *A*, *B*, and *C*).

(eg, anticholinergics, antipsychotics, anxiolytics), and neurologic diseases such as stroke, Alzheimer's disease, or Parkinson's disease (Table 4).[41]

The clinical manifestations of foreign body aspiration can vary, depending on the degree and duration of obstruction, as well as the size and location of the foreign body. Common acute symptoms reported in the literature for both pediatric and adult patients include choking, intractable cough, vomiting, wheezing, stridor, respiratory distress, tachypnea, chest pain, chest discomfort, and, in severe cases, breathlessness and cyanosis.[39,42-47] In adults, presentation can be as subtle as chronic cough, leading to delayed diagnosis and late complications such as recurrent pneumonia, hemoptysis, bronchiectasis, lung abscess, or empyema.[48] Severe airway injury, pneumonitis, and fibrotic stricture have also been reported in the setting of pill aspiration (Table 4).[49]

In adults, the most common site of obstruction is the right bronchial tree, mainly because of the more obtuse angle between the right main bronchus and trachea, and the slightly larger diameter of the right main bronchus compared with the left.[43,50] Although several pediatric studies that include older children show a preference for right-sided bronchial obstruction like the adult population,[40,42,43,45,51,52] such unilateral preference is not observed in studies that are composed of predominantly younger children.[39,44] More proximal tracheal airway obstruction, which occurs more frequently in the younger pediatric population because of smaller tracheal diameter, usually leads to more severe symptoms.[39,44,47]

Imaging should not delay intervention in the setting of life-threatening foreign body aspiration. Bronchoscopy and laryngoscopy are the criterion standard methods for diagnosing and treating such aspiration. For nonlife-threatening or suspected foreign bodies aspiration, 2-view chest and neck radiographs should be performed as the initial evaluation. Diagnosis of foreign body aspiration by imaging can be challenging because the majority of aspirated foreign bodies are radiolucent. In a retrospective review of pediatric foreign body aspiration cases, conducted by Eren et al,[51] nearly two thirds of 1,160 patients presented with negative radiograph results. Other studies have reported lower percentages (15.7% to 32%) of normal radiograph results.[41-44,46,53,54] Other commonly reported radiographic findings include atelectasis, hyperinflation of the affected lung, consolidation or pneumonia, mediastinal shift, and

Table 3. Summary of indications for intervention and recommendations for imaging follow-up for various types of ingested foreign bodies.[21]

FB Types	Endoscopic Removal	Surgical Removal	Imaging Follow-up
Any FB causing symptoms of complete esophageal obstruction requires emergency endoscopic removal			
Sharp FB	Emergency endoscopic removal if it is in the esophagus Urgent endoscopic removal if in the stomach	If symptomatic and beyond the reach of endoscopy or too dangerous to remove endoscopically If failure to progress after 3 days	Daily radiograph for up to 3 days Consider CT for radiographically invisible FB or evaluation of complications (eg, abscess)
Blunt FB	Urgent endoscopic removal if it is in the esophagus or if the FB is >6 cm in length and proximal to the duodenum If the FB is >2.5 cm in width and proximal to the duodenum If the FB fails to pass through the pylorus after 3–4 wk	If immobile and distal to the duodenum for >1 wk If symptomatic and distal to the duodenum	Weekly radiograph for up to 4 wk
Coins	If asymptomatic, observe for 12–24 h before considering endoscopic removal If proven to be button batteries in esophagus on imaging, emergency removal is required	If immobile and distal to the duodenum for >1 wk	Weekly radiograph for up to 4 wk
Batteries	Emergency endoscopic removal if button battery in the esophagus If larger (>2 cm) batteries remain in the stomach >48 h	If immobile or symptomatic and beyond reach by endoscopy	Once batteries past GE junction, initial follow-up radiograph at 48 h Once past the pylorus, repeated radiograph every 3–4 days
Magnets	Urgent endoscopic removal of all magnets within endoscopic reach	If magnets appear immobile on serial radiographs and beyond the reach of endoscopy, surgical consultation is recommended[23,25,36] If symptoms of obstruction or perforation[36]	Close follow-up with frequent serial radiographs to ensure mobility
Illicit drug packets	Not recommended because of risk of rupturing drug packets	If symptomatic (toxidrome) from ruptured drug packets If failure to progress	CT with intravenous contrast (without oral contrast) may be helpful in the setting of negative radiograph results[37]

radiopaque aspirated foreign bodies.[41-44,46,53,54] In the setting of normal radiograph results, additional expiratory views may help accentuate air trapping of the affected lung. However, the quality of the study relies heavily on the technique and the patient's cooperativeness. For younger patients who cannot follow directions, lateral decubitus views can be considered. However, the amount of data available to support the use of these specialized views is limited. Although some studies showed that expiratory views slightly increase the sensitivity of detecting aspirated foreign bodies in comparison with standard views (Figure 5*A* and *B*),[55,56] a recent study showed that decubitus view does not increase sensitivity and may increase false-positive rates.[55] Specialized views may be most helpful in limited circumstances, such as when a round foreign body completely or near completely blocks a unilateral main stem or lobar bronchus.

Though not routinely used, fluoroscopic dynamic evaluation of bilateral diaphragms has been shown to be effective for detecting unilateral bronchial foreign bodies.[44,52,57] During fluoroscopic evaluation, the side of the diaphragm that demonstrates diminished excursion in comparison to the contralateral side would suggest air trapping and possible obstruction. CT has also been shown to have higher sensitivity than radiographs in detecting radiolucent foreign bodies (Figure 5*D* through *F*) and can be performed to evaluate foreign body–associated complications.[41,44,47,53,58] Studies have also reported high sensitivity (100%) and specificity (81% to ≈100%) of 3-dimensional CT bronchoscopy for detecting aspirated foreign bodies.[59-63]

Organic food items are the most commonly aspirated foreign bodies in both adult and pediatric populations.[39,40,46,53,54] Studies report nut (particularly peanut) as the most commonly found aspirated item (up to 40%) by bronchoscopy in pediatric patients.[39,46,52] Some other commonly ingested items include fruit seeds, beans, fruit parts, plastic toys, pins, animal bones, and teeth (Figure 5*C*).[40,46,53-55,58]

Insertion (genitourinary and rectal) foreign bodies in the nasal cavity or outer ear, in the nontraumatic setting, usually can be directly examined with devices such as otoscopes during physical examination. Imaging is not the performed routinely as part of the initial evaluation. However, they can appear as incidental findings on imaging. In this review, we will focus on rectal and

Table 4. Clinical and imaging pearls for foreign body aspiration.

Risk factors	Young children, altered mental status, loss of consciousness (from trauma, seizures, or anesthesia), age-related decline in swallowing mechanism, usage of medications that impair cough reflex or swallowing (eg, anticholinergic, antipsychotic, anxiolytics), or neurologic disease (eg, Parkinson's disease, Alzheimer's disease)[41]
Clinical presentation	Acute FB aspiration: choking, intractable cough, vomiting, wheezing, stridor, tachypnea, respiratory distress, chest pain, chest discomfort, breathlessness, and cyanosis (severe cases)[39] Missed/chronic FB aspiration: chronic cough, recurrent pneumonia, hemoptysis, fever, lung abscess, or empyema Pill aspiration: airway injury, pneumonitis, or fibrotic stricture[49]
Imaging considerations	Imaging should not delay intervention (bronchoscopy or laryngoscopy) in the setting of life-threatening FB aspiration Initial evaluation (for nonlife-threatening cases): 2-view neck and chest radiographs Additional specialized views such as inspiratory/expiratory and bilateral decubitus may be most helpful in limited circumstances, such as when an FB completely or nearly completely blocks a unilateral main stem bronchus CT can be considered for evaluation of radiolucent FBs and their associated complications in nonemergency setting[41,44,47,53,58]
Clinically important imaging findings	Normal radiograph results do not exclude the possibility of aspirated radiolucent FB, which are often organic food items Atelectasis or hyperinflation of affected lung, consolidation/pneumonia, mediastinal shift, and radiopaque aspirated FB are common radiographic findings for FB aspiration

genitourinary foreign bodies, which typically require imaging evaluation.

The mean age of patients with rectal foreign bodies is approximately 45 years, with age ranging from 20 years to older than 90 years.[64] There is a strong male predominance, with a male:female ratio of up to 37:1.[64] Common causes for rectal foreign bodies include autoeroticism (most common), sexual assaults, self-treating fecal impaction, body stuffing (drug packets), and concealment of weapons (prisoners).[65,66] For genitourinary foreign bodies, autoeroticism is the predominant cause. According to a 2010 survey study for men who have sex with men, 10.7% of respondents had engaged in recreational insertion of a solid or liquid into the urethra.[67] In the setting of nonsexual rectal and urethral insertion, psychiatric illness can be a risk factor (Table 5).[65,68]

Common clinical manifestations of rectal foreign bodies include anorectal pain, anorectal bleeding, abdominal

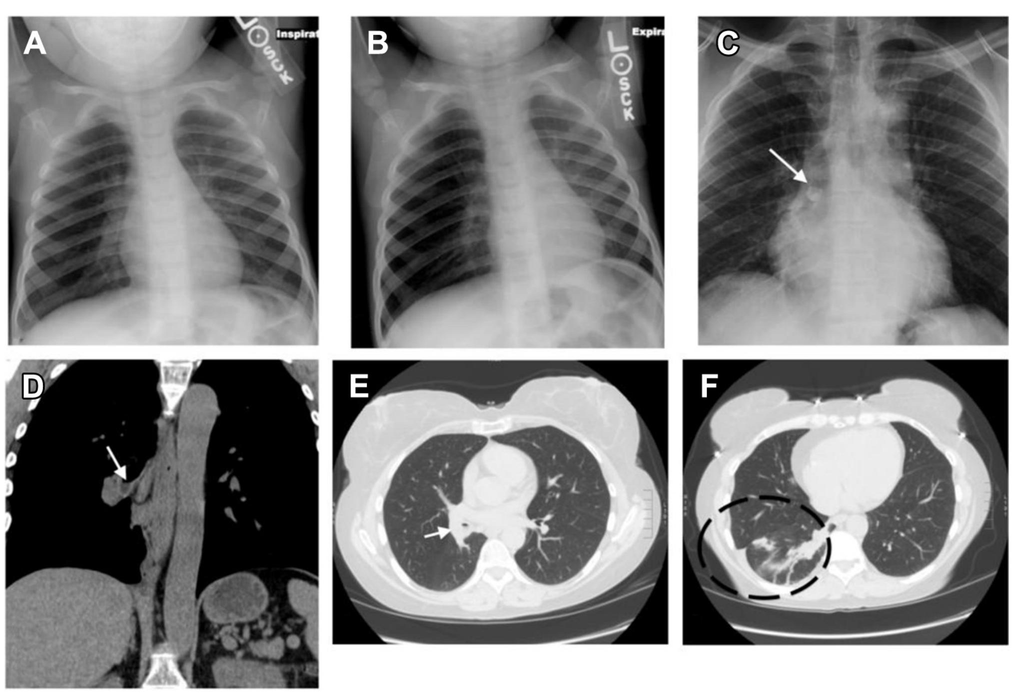

Figure 5. Peanut aspiration in a child. No radiopaque object was identified on frontal radiograph (*A*). On expiratory view (*B*), prominent air trapping was observed in the right lung, suggesting obstruction of the right main bronchus. A peanut was subsequently found in the right main bronchus by bronchoscopy. *C*, A radiopaque tooth in the bronchus intermedius (white solid arrow) on frontal chest radiograph. Coronal (*D*) and axial (*E*, *F*) noncontrast chest CT images of the same patient who aspirated a peanut. White solid arrows in *D* and *E* point to a filling defect in the bronchus intermedius (note the narrowed bronchus). Black dashed circle in *F* demonstrates postobstructive atelectasis. A peanut was subsequently found in the bronchus intermedius by bronchoscopy.

Table 5. Clinical and imaging pearls for foreign body insertion.

Risk factors	Autoeroticism, sexual assaults, self-treating fecal impaction, drug trafficking, concealment of weapons (prisoners), psychiatric and mental illness[65,66]
Clinical presentation	Rectal FB: anorectal pain, anorectal bleeding, abdominal or pelvic pain, obstruction, incontinence, acute abdomen Genitourinary FB: urinary frequency, dysuria, urinary tract infection, hematuria, vaginal bleeding, or abdominal or pelvic pain Presentation often delayed because of embarrassment
Imaging considerations	Imaging should be conducted before digital rectal examination or removal as a safety precaution to prevent unnecessary injury from touching sharp FB Initial evaluation: 2-view radiographs If suspecting perforation, additional upright chest radiograph can be performed to evaluate for pneumoperitoneum CT can be used to evaluate radiolucent rectal FB and possible complications Water-soluble contrast enema can be used to evaluate for perforation or fistula[65] Radiolucent FB in the bladder can be detected by ultrasonography with good sensitivity[70] Postextraction radiographs should be performed to evaluate for complications or any residual FB
Clinically important imaging findings	Pneumoperitoneum caused by bowel perforation should prompt emergency surgical consultation

or pelvic pain, obstruction, incontinence, and, sometimes, acute abdomen in the setting of perforation.[65,66,69] Symptoms of genitourinary foreign body insertion include urinary frequency, dysuria, urinary tract infection, hematuria, vaginal bleeding, or abdominal or pelvic pain (Table 5).[68] Patients with rectal and genitourinary foreign bodies often have delayed presentation to the ED because of embarrassment.

Initial imaging evaluation for rectal or genitourinary foreign bodies involves 2-view radiographs, which will help clinicians identify the shape, size, orientation, location, and type of the foreign body to develop a safe removal strategy. Imaging should be conducted before digital rectal examination as a safety precaution to prevent provider injury from sharp foreign bodies. For rectal foreign bodies, additional upright chest radiograph (as part of an acute abdomen series) is performed to evaluate for pneumoperitoneum, which is an indication for emergency surgical intervention (Figure E7*C* and *D*, available online at http://www.annemergmed.com). CT can be used to evaluate for suspected radiolucent rectal foreign bodies and abscess. Water-soluble contrast enema can be used to evaluate complications such as rectal perforation or fistula.[65] For genitourinary radiolucent foreign bodies, ultrasonography has been shown to have high sensitivity (93.8%) for detecting foreign bodies in the bladder.[70] Postextraction radiographs (along with endoscopy) are routinely performed to evaluate for complications and any residual foreign bodies.[66]

Myriad rectal foreign bodies have been reported, including sex toys, batteries, light bulbs, bottles, vegetables, fruits, cans, and drug packets.[65,66] A variety of urethral foreign bodies has also been reported in the literature, including intrauterine devices, sutures, pins, animal bones, wires, and ballpoint pens.[68,70] The majority of colorectal foreign bodies can be removed through a transanal approach. Predictors of failure by transanal extraction include objects longer than 10 cm, hard or sharp objects, objects located in the sigmoid colon, or those that have been retained for longer than 2 days.[65]

Understanding the clinical presentation, radiologic management, and imaging characterization of foreign bodies of different entry modalities is essential to accurate diagnosis and associated complications in the ED setting. Knowing the clinical implications of the size, shape, chemical properties, and anatomic location of foreign bodies is critical to medical decisionmaking. Certain seemingly benign foreign bodies (such as ingested button batteries and magnets) can cause devastating complications and should not be overlooked. If there is doubt, radiology consultation can be requested to develop an individualized imaging plan to accommodate each patient's specific clinical scenario.

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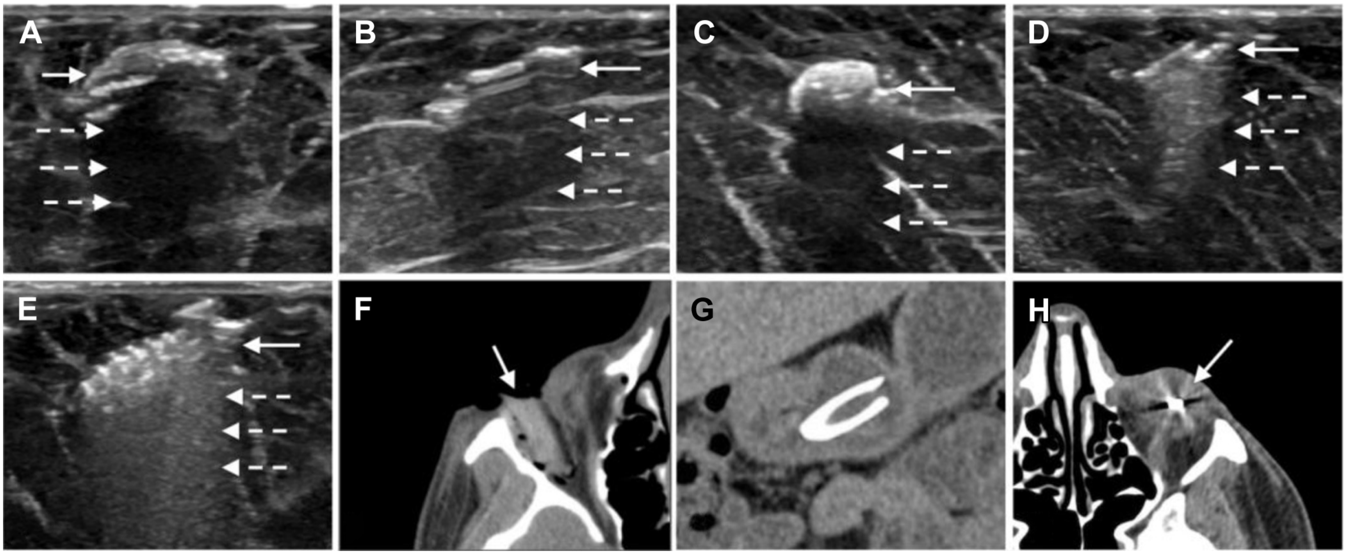

Figure E1. Ultrasonography (*A* to *E*) and CT (*F* to *H*) images of various materials. Wood (*A*), plastic (*B*), and stone (*C*) FBs appear as echogenic structures (white solid arrows) with posterior shadowing (white dashed arrows). Glass (*D*) and metal (*E*) appear as echogenic structures (white solid arrows) with ring-down artifacts (white dashed arrows). *F*, Intraorbital wood shrapnel (white solid arrow) can have soft tissue density after absorbing blood. With less water content, wood can also mimic air and fat density because of air content (image not shown). *G*, Ingested broken glass appears hyperdense without streak artifact. *H*, Metal appears hyperdense with streak artifacts on CT (white solid arrow).

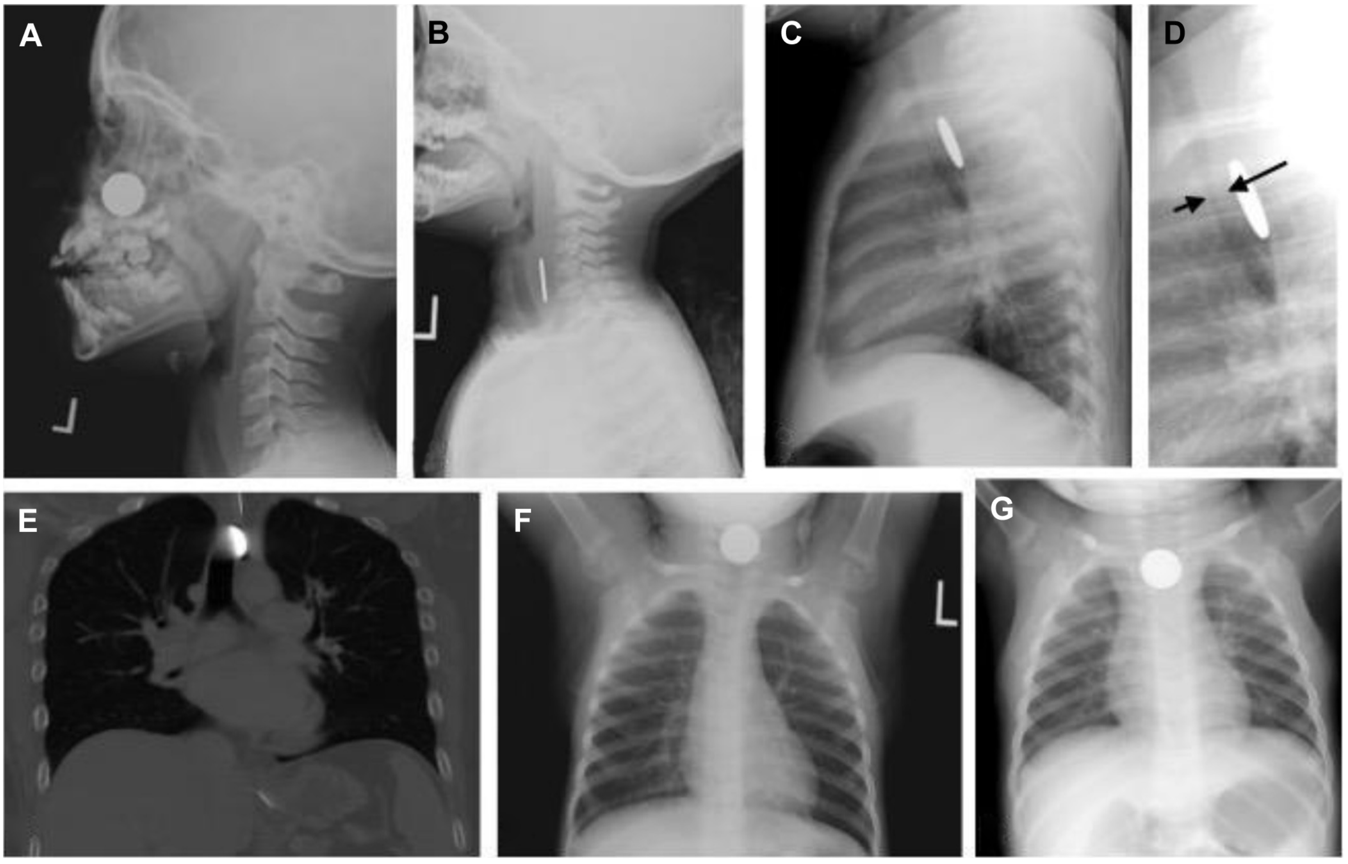

Figure E2. Ingested coins, with common sites of impaction. *A*, Coin in the nasal cavity of a 5-year-old boy who was thought to have swallowed a coin. *B*, Lateral radiograph with a coin in the cervical esophagus, at the level of the cricopharyngeus, the most common area for impaction. *C*, Lateral radiograph in a 16-month-old with 2 days of choking and gagging. The coin is seen in the esophagus at the level of the aortic arch. Magnified view in the same patient (*D*) shows anterior esophageal thickening in this region and effacement of the posterior aspect of the trachea (black solid arrows). This suggests local esophageal edema from irritation, compatible with 2-day history since ingestion. *E*, Coronal CT showing how an esophageal coin can perch and impact at the level of the aortic arch. *F*, PA view with inferior margin of the coin at the level of the cricopharyngeus. *G*, PA view with inferior margin of the coin at the level of the aortic arch.

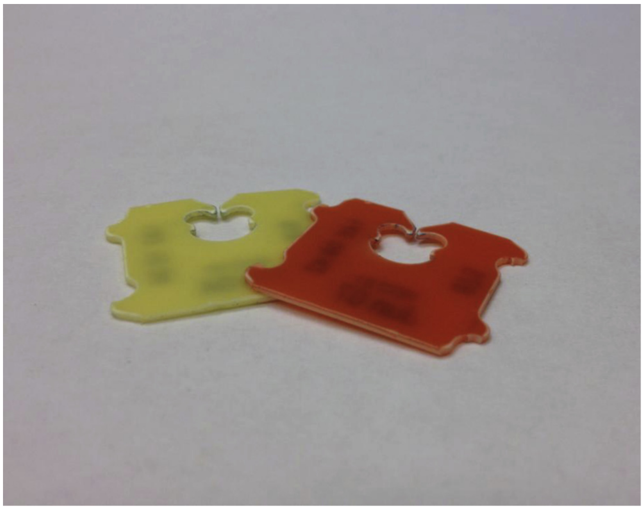

Figure E3. Plastic bread bag clips are radiolucent and pose great diagnostic challenges in the setting of ingestion. They have been shown to cause complications such as small bowel perforation, obstruction, and gastrointestinal hemorrhage.

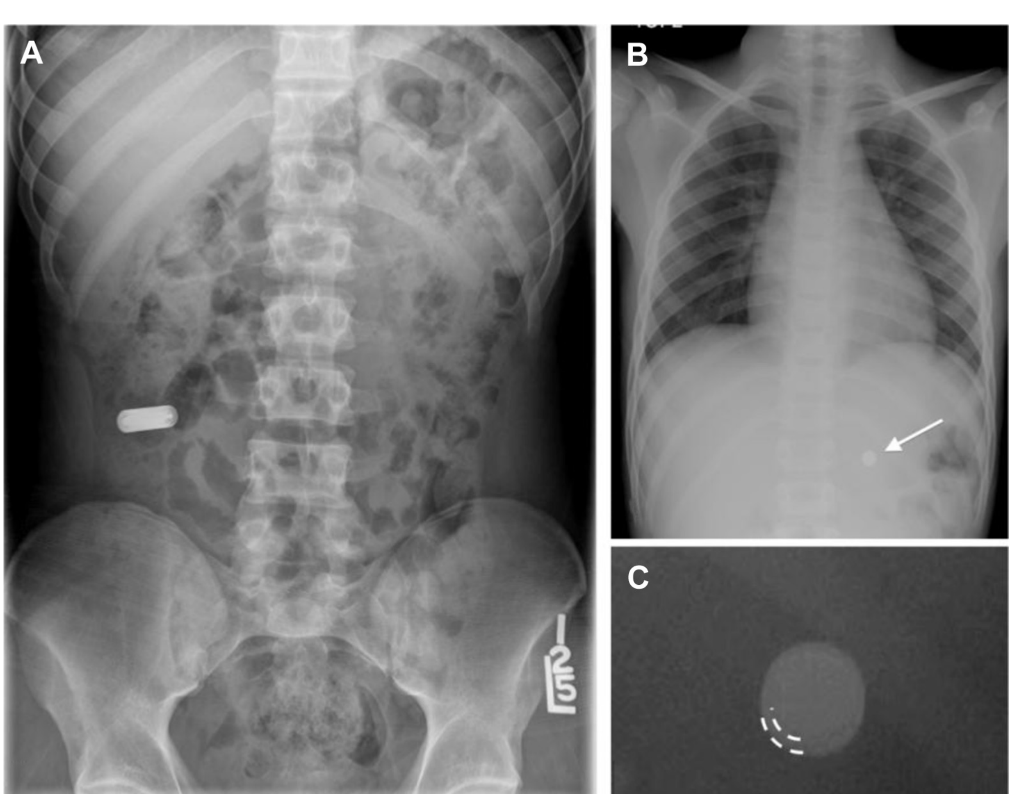

Figure E4. Battery ingestion. *A*, Typical appearance of a cylindrical battery. *B*, Four-year-old who ate a button battery (white solid arrow). *C*, Extreme magnification and close interrogation of the pattern reveal the step-off or halo sign (white dashed lines) characteristic of a button battery and confirm this is not a coin.

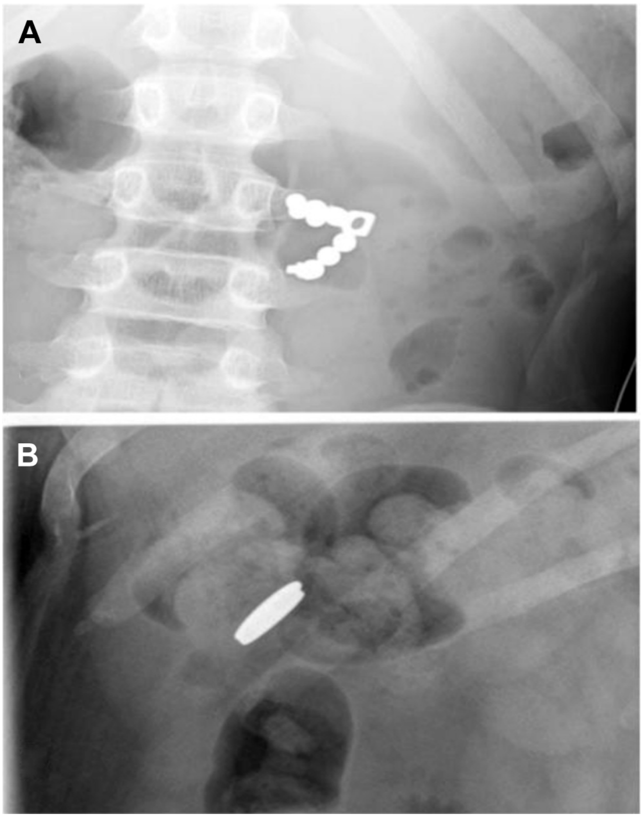

Figure E5. Magnets. *A*, Single supine view of the abdomen, with a string of connected radiopaque beads, compatible with magnets. A radiographic mimic would be an intact metallic beaded bracelet or necklace. *B*, Two adherent platelike magnets.

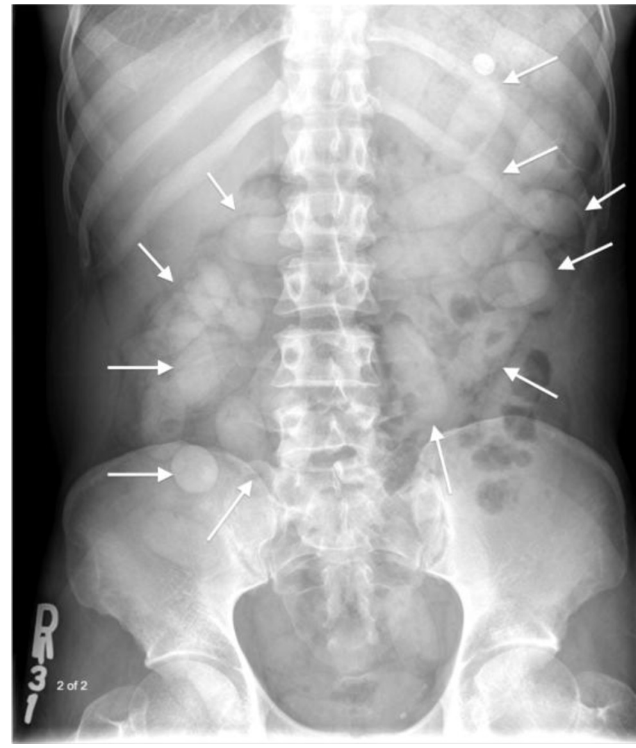

Figure E6. Drug packing. Numerous mildly radiopaque drug packages are seen throughout the gastrointestinal track (white solid arrows).

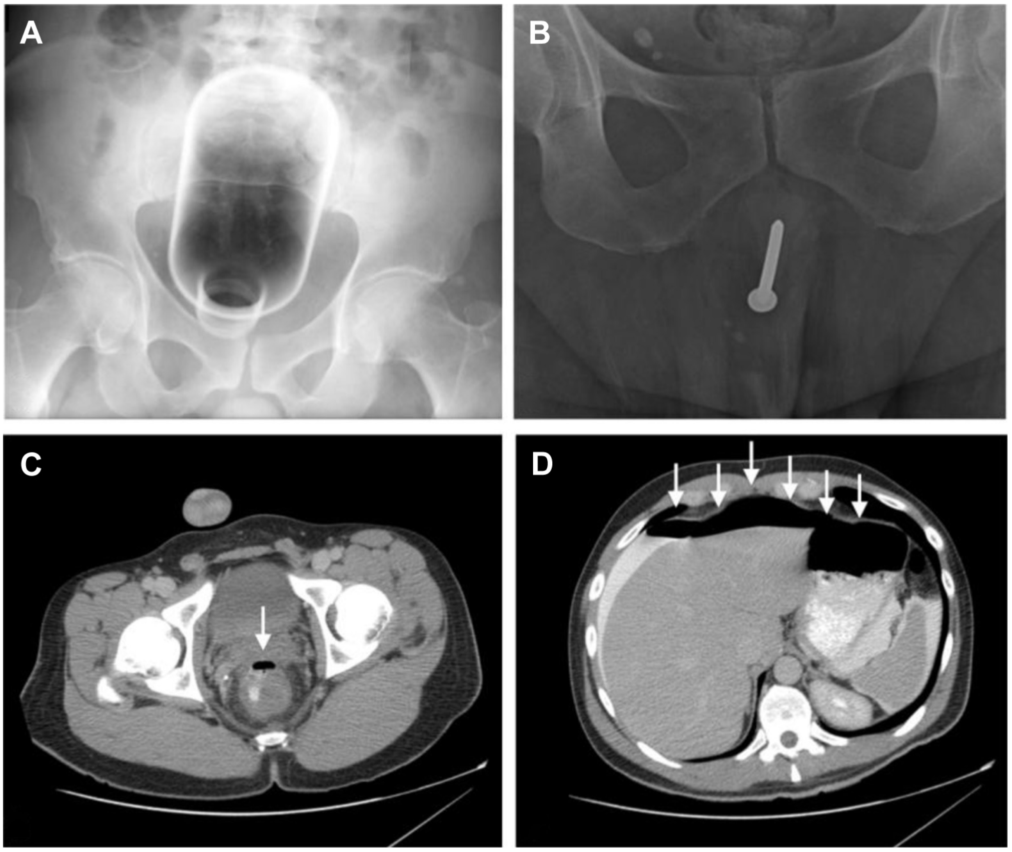

Figure E7. *A*, Rectally inserted glass bottle. *B*, A nail inserted into the urethra. *C*, Axial contrast-enhanced CT status after sharp rectal FB removal causing rectal perforation (white solid arrow). *D*, Large-volume pneumoperitoneum (white solid arrows), with additional leakage of oral contrast, which is layering in the peritoneal cavity and surrounding the spleen and liver.