Imaging Foreign Bodies

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After completing this article, the reader should be able to:

- List some challenges associated with detecting foreign bodies.
- Compare and contrast the capabilities of radiography, ultrasonography, computed tomography, and magnetic resonance imaging to visualize foreign bodies.
- Summarize research findings on the best methods for imaging glass, metal, wood, plastic, stone, and rubber foreign bodies.
- Describe the imaging appearance of a variety of special types of foreign bodies.
- Discuss how imaging is used intraoperatively to aid the removal of foreign bodies.

Foreign bodies are frequently encountered in medical imaging and can range from intentionally placed objects, such as medical devices and surgical hardware, to debris from accidents and injuries and a wide variety of swallowed items. Many foreign bodies are well visualized with radiography, ultrasonography, or another imaging modality and, once detected, are often easily treated or even resolve spontaneously. Occasionally, however, foreign bodies go undetected and can have serious consequences.

Untreated foreign bodies can cause a variety of complications, including obstruction and perforation, nerve injury, chronic pain, abscesses, draining sinususes, and life-threatening infection. Delayed diagnosis can result in cellulitis and deep-tissue infections such as myonecrosis and necrotizing fasciitis. In addition to being painful and a potential source of infection, foreign bodies also cause many lawsuits. An estimated 4% of liability claims against emergency department physicians involved foreign bodies in soft tissue, and foreign bodies were reported to be the second leading cause of lawsuits against emergency department physicians.

Consider, for example, the case report of a boy, aged 8 years, who fell from a tree and suffered a puncture wound on the back of his right thigh. During initial treatment in an emergency department, no imaging examinations were performed. The wound was closed and amoxicillin was prescribed. Two days later, the boy presented to a different health care facility with pain and redness in his thigh and a high fever. At surgery, a 2 × 4-cm piece of wood was removed from the midthigh area, along with necrotic tissue and 10 cc of pus. Cultures from the wound grew a variety of bacteria, including Escherichia, Streptococcus, and Enterococcus species.

Despite treatment with intravenous antibiotics and hyperbaric oxygen, the infection persisted and the boy’s condition worsened. A follow-up culture
grew Clostridium perfringens. One week after the injury, a second surgery revealed necrosis of the adductor and posterior thigh muscles. Hip disarticulation (ie, amputation) was performed. Subsequently, the boy had a systemic inflammatory response with reduced cardiac function, pleural effusion, and hemiparesis. A magnetic resonance (MR) scan of his head showed cortical laminar necrosis on both sides of his brain. He improved gradually during several weeks of hospitalization and underwent rehabilitation for 3 months. Nevertheless, his coordination, fine motor skills, and vision were permanently affected.8

Clearly, it is critical to detect foreign bodies at the earliest opportunity. Prompt diagnosis simplifies treatment, avoids complications, and improves outcomes.1 However, diagnosing foreign bodies can be difficult for many reasons. This is especially true for deeply embedded objects and those that are not apparent on radiographs.4 In addition, the onset of symptoms related to a retained foreign body can sometimes be delayed for months or even years so that the patient might not connect current symptoms with a prior injury (see Box 1).6 Also, many people delay treatment for foreign-body injuries. In one study, three-quarters of patients with a foreign body in soft tissue sought medical care within 48 hours; the other one-quarter did not seek care until sometime later.8 Pediatric patients present a special diagnostic challenge when they cannot accurately relate what happened or describe their symptoms, such as an infant or toddler who has swallowed or aspirated a foreign body. Some patients might not be aware of an injury involving a foreign body if, for instance, they have compromised sensation as in diabetic neuropathy.2 Finally, imaging modalities have widely differing capabilities to visualize different types of foreign bodies, and no single modality is ideal in all situations.

### Overview and Comparison of Modalities Used to Image Foreign Bodies

Many foreign bodies—78% according to one report—are discovered using only physical examination and surgical exploration, without imaging procedures.4 However, depending on the foreign body’s size and location, blind surgical exploration can be a slow and frustrating process, with no guarantee of success.9 Furthermore, surgery can be high risk, especially when the surgical site contains many nerves and blood vessels, such as the hands and feet, where foreign bodies often are located. In many cases, imaging foreign bodies before attempting removal can save physicians time and avoid additional injury and anxiety for patients.7 However, a foreign body that is visible using one modality might be easily overlooked using a different one.10 The foreign body’s size, location, and composition should all be taken into consideration when choosing an imaging approach.10

### Radiography and Fluoroscopy

Radiography frequently is used to detect foreign bodies and traditionally has been the first-choice
modality because it is inexpensive and available at most health care facilities. However, radiography’s ability to detect foreign bodies depends on the object’s size, location, orientation, and material. Radiography can detect most radiopaque foreign bodies (ie, objects that are relatively impermeable to x-rays and therefore appear white on radiographs). Table 1 displays the radiopacity of some foreign body materials in Hounsfield units, a measurement used in computed tomography (CT) scanning.

Two commonly encountered types of radiopaque foreign bodies are glass and metal. Radiography’s sensitivity for detecting glass foreign bodies ranges from

<table>
<thead>
<tr>
<th>Material</th>
<th>HU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal</td>
<td>3863-5363</td>
</tr>
<tr>
<td>Graphite</td>
<td>750-1036</td>
</tr>
<tr>
<td>Glass</td>
<td>540-1740</td>
</tr>
<tr>
<td>Acrylic</td>
<td>80-130</td>
</tr>
<tr>
<td>Wood</td>
<td>50-80</td>
</tr>
</tbody>
</table>

Figure 1. A. Axial computed tomography (CT) scan showing a fish bone (arrow) near the thyroid gland. B. 3-D CT scan showing the fish bone oriented obliquely downward (arrow). Reprinted from Watanabe K, Amano M, Nakanome A, Saito D, Hashimoto S, The prolonged presence of a fish bone in the neck, 227, 49-52, (2012), with permission from Tohoku University Medical Press.

Figure 2. Ultrasonographic image of the fish bone in the long axis. Reprinted from Watanabe K, Amano M, Nakanome A, Saito D, Hashimoto S, The prolonged presence of a fish bone in the neck, 227, 49-52, (2012), with permission from Tohoku University Medical Press.

Figure 3. Photograph of the excised fish bone. Reprinted from Watanabe K, Amano M, Nakanome A, Saito D, Hashimoto S, The prolonged presence of a fish bone in the neck, 227, 49-52, (2012), with permission from Tohoku University Medical Press.

Table 1

| Radiopacity of Some Foreign-Body Materials, Measured in Hounsfield Units (HU) |
|--------------------------|---------|
| Material                 | HU      |
| Metal                    | 3863-5363|
| Graphite                 | 750-1036 |
| Glass                    | 540-1740 |
| Acrylic                  | 80-130   |
| Wood                     | 50-80    |
83% to 99%.14 (Sensitivity is the proportion of true positives correctly identified by a test or procedure.) More specifically, 2-projection radiography (anteroposterior [AP] and lateral) can detect 99% of glass shards larger than 2 mm.12 However, for very small glass fragments (ie, those less than 2 mm), sensitivity falls to 61% to 83%, according to one estimate.13

Radiography also can be used to demonstrate some semiradiopaque foreign bodies, such as plastic objects.4 Radiography’s usefulness is limited, however, for imaging radiolucent foreign bodies (ie, those that are almost entirely transparent to radiation and therefore not as well visualized on radiographs). Foreign bodies made of cloth, rubber, wood, and other organic matter, including thorns and cactus spines, are radiolucent and can be difficult to discern in soft tissue.14-17 This is problematic because organic material is more likely to cause an inflammatory response and infection than inorganic foreign bodies.14

Cohen et al reported clinical success using a mobile fluoroscopic device to detect some foreign bodies, such as BB pellets and pieces of glass and metal, in an emergency department setting.4 Compared with plain-film radiography, spot imaging with a miniature C-arm offers portability, real-time imaging, and lower radiation dose. However, Cohen et al were curious to assess the device’s ability to detect a wider variety of foreign bodies in a blinded, randomized, controlled in vitro study.7

They inserted 5 types of foreign bodies (metal, gravel, glass, wood, and plastic) inside 2-cm incisions in chicken legs. Two observers examined the chicken legs using mobile fluoroscopic imaging. Each observer completed 50 examinations, including 25 shams (ie, no foreign body present) and 5 examinations with each type of foreign body present. In this study, fluoroscopy provided 100% accuracy for detecting metal, glass, and gravel foreign bodies but much less success with wood and plastic foreign bodies. For wood and plastic, the combined sensitivity was 0.4 and the combined specificity was 0.6.7 (Specificity is the proportion of true negatives accurately detected.)

Fluoroscopy also is sometimes used intraoperatively to help locate foreign bodies. However, continuous fluoroscopic imaging involves higher doses of radiation than conventional radiography.14 In addition, repositioning a C-arm during a surgical procedure can be cumbersome. Intraoperative ultrasonography may be preferable to fluoroscopy because of its lack of ionizing radiation and comparative ease of use.

**Ultrasonography**

After radiography, ultrasonography is the next most commonly used imaging technique for foreign bodies and can demonstrate all types of materials, including glass, metal, and plastic, as well as radiolucent items.15 Ultrasonography has been widely studied as a means of assessing foreign bodies and generally has been shown to have good sensitivity and specificity.14 Ultrasonography has many advantages: It does not involve ionizing radiation, is relatively inexpensive and widely available, provides real-time images, and can be performed intraoperatively and at the bedside.1,8,9,16 Ultrasonography also is useful for confirming that the entire foreign body has been successfully removed during or after surgery.14

Ultrasound imaging does have some limitations. It only is effective for detecting relatively superficial foreign bodies. However, the hands and feet are frequent sites of injuries involving foreign bodies,15 and many foreign bodies in these sites can be demonstrated using ultrasonography. Also, objects that are very superficially located might be difficult to detect with ultrasonography because sound waves do not reflect well very near the transducer.7 Another widely recognized limitation of ultrasonography is that it is somewhat dependent on the operator’s skill and experience.8,20 Finally, ultrasonography is not useful for visualizing foreign bodies surrounded by air, such as those located inside a nasal sinus.10

When imaging a suspected foreign body with ultrasound, it is important to scan the area in both the axial and sagittal planes.1 A transducer with a frequency between 7 and 13 MHz is ideal for imaging foreign bodies. Many ultrasound systems include a 7.5 MHz probe, but some researchers have suggested that a 10 to 12.5 MHz transducer enhances sensitivity for foreign body detection.7 Often, foreign bodies appear hyperechoic (ie, white or bright) on ultrasonography, as distinguished from the homogeneous echoes of soft tissues.16 Depending on the type of material being imaged and the angle of insonation, full or partial posterior acoustic
shadows might be visible (see Figure 4).\textsuperscript{19} When a foreign body causes an inflammatory reaction in the body, which typically occurs after it has been in place for at least 24 hours, the inflammation appears as a hypoechoic (ie, dark) rim around the foreign body on ultrasonography.\textsuperscript{14} The rim, or halo, is due to edema, abscess, granulation tissue, or a combination of these.\textsuperscript{21} The presence of the hypoechoic rim improves ultrasonography’s sensitivity and specificity for foreign bodies.\textsuperscript{14}

Using an ultrasound gel can enhance the visibility of foreign bodies and make the examination more comfortable for the patient.\textsuperscript{22} When a foreign body is very superficial, less than 1 cm deep, resolution can be improved by submerging the body part in water. The transducer also should be placed into the water 1 cm from the patient’s skin.\textsuperscript{9} A standoff pad also can be used to improve visualization of foreign bodies in soft tissues by raising the transducer slightly above the area of interest.\textsuperscript{19} An examination glove filled with ultrasound gel can be used as a standoff pad if a commercially manufactured one is not available.\textsuperscript{19} For comparison purposes, it is often useful to examine the contralateral body part.\textsuperscript{21} When the sonographer identifies a foreign body, he or she should measure both the object and its distance from the skin with computerized calipers.\textsuperscript{21} The sonographer also should survey the area near the foreign body for blood vessels.\textsuperscript{19}

Unfortunately, ultrasonography sometimes is ignored as a diagnostic modality for retained foreign bodies despite the fact that it is inexpensive and readily available. In some cases, clinicians opt instead for more costly modalities, such as MR, or high-radiation modalities, such as CT.\textsuperscript{14} However, in instances where a patient remembers being penetrated or possibly being penetrated by a foreign body, some have argued that ultrasonography should be the initial imaging technique of choice and in many cases the only necessary imaging examination.\textsuperscript{9,23} Ultrasonography also can be useful when radiography is negative but a foreign body still is suspected.\textsuperscript{21} For example, Mohammadi et al used high-frequency ultrasound to examine 47 patients whose radiographic findings were negative for possible foreign bodies in the soft tissues of the extremities.\textsuperscript{21} Ultrasound images detected foreign bodies in 45 of the patients, including wood and glass particles, thorns, and fish bones.\textsuperscript{21}

Ultrasonography and Foreign Body Imaging Research

To evaluate the role of ultrasonography in detecting foreign bodies, Saboo et al analyzed results for 123 patients with suspected soft-tissue foreign bodies who were referred for ultrasonography at a diagnostic facility.\textsuperscript{4} The study took place in a rural farming community in India, and most of the foreign bodies were either wood or wooden thorns (82.4%). The remainder comprised glass fragments, pins, and needles. Almost half of the injuries (49.5%) were to the feet. Hand, leg, and forearm injuries made up most of the rest.\textsuperscript{5} All of the patients were scanned by a highly experienced sonographer using a 7.5 MHz transducer. The sonographer noted the length and depth of the foreign bodies and provided a description of each. After the foreign bodies were surgically excised, the surgeon indicated whether the ultrasonographic assessment of the foreign bodies’ depth was accurate.\textsuperscript{5}

Overall, ultrasonography’s sensitivity for detecting foreign bodies in this study was 94.5%, and the specificity was 53.8%. False-negative findings were more likely when the foreign body was small, located deep within the body or adjacent to bone, or was obscured by subcutaneous gas. Conversely, false-positive findings tended to occur if calcified tissue, scar tissue, or

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4.png}
\end{figure}
a new hematoma was present. In 89% of cases, the surgeon indicated that the ultrasonographic assessment of the foreign body’s depth was accurate. The authors concluded that ultrasonography is highly sensitive for assessing foreign bodies in soft tissues and helpful in identifying the location and nature of the foreign body.

Crystal et al used cadavers to evaluate ultrasonography’s sensitivity and specificity for detecting wood, metal, plastic, and glass foreign bodies. In this study, the foreign bodies were small: 2.5 mm or less and not more than 5 mm long in any direction. They were inserted into the arms and legs of the cadavers up to a depth of 3 cm. A total of 900 examinations were recorded. The examiners in this study were emergency department physicians who had completed a 2-day course in ultrasound examination and had performed the minimum number of examinations required for proficiency by the American College of Emergency Physicians.

Crystal et al reported much lower sensitivity and specificity than Saboo et al. In Crystal’s study, overall sensitivity was 52.6%; the range for individual examiners varied from 40.8% to 72.3%. Overall specificity was 47.2%; the range for individual examiners varied from 30% to 66.7%. The authors noted several factors that might have contributed to the comparatively low sensitivity and specificity. First, the foreign bodies used in this study were very small, and some were placed more deeply in tissue than in other studies (eg, studies limited to foreign bodies in the hands, feet, or both). Also, the examiners in Crystal et al’s study lacked the level of training and experience in ultrasonography of the examiners in the Saboo et al study. Crystal et al concluded that ultrasonography was not sufficiently specific or sensitive for detecting small foreign bodies when used by relatively inexperienced physicians.

In 2012, Bradley reported the results of his study assessing the safety and viability of ultrasonographic guidance for percutaneous removal of foreign bodies in the emergency department. In this study, 350 patients were referred for ultrasonography because of penetrating wounds with suspected foreign bodies. Most of the foreign bodies were in the hands (n = 132) and feet (n = 110). Other injury sites were the calf, arm, face, chest wall, knee, and buttocks. Splinters, glass, and needles were the most common foreign bodies, and all of the objects were relatively small, ranging from 2 to 10 mm.

Among the patients referred for ultrasound imaging, 63 were negative for foreign bodies and 252 (88%) had foreign bodies successfully removed percutaneously with no complications. Of the remaining 35 patients in the study, 15 attempts at foreign body removal failed; 12 were referred for foreign body removal by a plastic surgeon; and 8 were not treated because of a lack of symptoms. The most common reasons for referring patients to a plastic surgeon in lieu of percutaneous image-guided removal were foreign bodies in the face, near an artery or nerve in the finger, or in a joint synovium, muscle, or nail bed.

Bradley noted that on ultrasonography, foreign bodies appear as hyperechoic foci with possible acoustic shadowing depending on the angle of insonation. Metal objects and some other types of foreign bodies can cause a “comet tail” artifact. Also, a hypoechoic halo might be evident if there is edema, abscess, or granulation tissue. To best visualize a foreign body, Bradley recommended orienting the probe as close to parallel to the foreign body as possible to obtain the greatest signal. Based on the results of his study, he concluded that ultrasound imaging is a safe and effective means of locating and guiding percutaneous removal of most foreign bodies, although clinicians should be aware of some potential pitfalls. For example, objects located under the nail bed can be difficult to visualize using ultrasound imaging.

Aras et al set out to compare ultrasonography’s effectiveness for foreign body detection with CT and radiography in different anatomic locations and tissue types. They used a sheep’s head with various foreign bodies inserted in the tongue, the maxillary sinus, and between the corpus mandible and muscle. For the radiopaque foreign bodies used in this study (metal, glass, and stone), all 3 imaging techniques were effective in all locations. For the less radiopaque items (wood, acrylic, and Bakelite), ultrasonography was more effective than CT or radiography for imaging objects in muscle (ie, the tongue) or between muscle and bone. However, ultrasonography was less useful for visualizing radiolucent foreign bodies in the maxillary sinus; for that task, CT was superior.
Finally, Soudack et al examined ultrasonography’s ability to detect foreign bodies in soft-tissue masses. This study focused on patients referred to one facility for imaging of masses during a 2-year period. All of the patients in the study had both color and power Doppler examinations using a 5 to 12 MHz linear transducer. Among the study group, 6 patients had ultrasonographic findings suggestive of foreign bodies, although none of them recalled a penetrating injury involving a foreign body. Table 2 summarizes the imaging results for these patients.

In some cases, the patients in Soudack’s study with ultrasonographically detected foreign bodies underwent additional imaging examinations, including MR, CT, bone scintigraphy, and labeled red blood cell scintigraphy. In most cases, however, the other imaging modalities either showed no evidence of a foreign body or were nonspecific. For example, in one instance, nonspecific findings on an MR scan might have indicated a foreign body, or they could have been associated with calcification or scar tissue.

Soudack et al stated that because of the comparatively high costs of the other imaging examinations and the fact that they did not contribute to decisions regarding treatment, those examinations should be avoided. This is especially true of CT and scintigraphy, both of which use ionizing radiation, and particularly for younger patients. Soudack et al also concluded that ultrasonography “should be the first-line imaging modality for any superficial soft tissue mass, regardless of the patient’s history.” Furthermore, “in the setting of a soft tissue mass, sonography can be useful in assessing for a foreign body even if it is not suspected clinically.”

### Computed Tomography and Magnetic Resonance Imaging

CT is considered by some to be the “gold standard” in foreign body imaging because it allows multiplanar images and can be used to determine a foreign body’s location more precisely than radiography. CT also provides more information about tissue reactions and abscesses that occur with foreign bodies.

### Table 2

**Ultrasonography Results for 6 Patients With Soft-Tissue Masses and Clinically Unsuspected Foreign Bodies**

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Age (y), Sex, Presence or Absence of Pain</th>
<th>Location and Size of Foreign Body (mm)</th>
<th>Duration of Mass</th>
<th>Sonographic Findings</th>
<th>Clinical Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>43, male, no pain</td>
<td>Dorsum of foot, 6 × 3</td>
<td>1 mo</td>
<td>Linear echogenic lesion with posterior reverberation and surrounding hypoechoic mass</td>
<td>Surgery</td>
</tr>
<tr>
<td>2</td>
<td>22, male, pain</td>
<td>Forearm, 20 × 2</td>
<td>4 y</td>
<td>Linear echogenic lesion with posterior reverberation and surrounding hypoechoic mass</td>
<td>Surgery</td>
</tr>
<tr>
<td>3</td>
<td>32, female, no pain</td>
<td>Calf, 7 × 2 and 5 × 2 (2 objects)</td>
<td>2 y</td>
<td>Linear echogenic lesion with surrounding hypoechoic mass</td>
<td>Refused surgery; had no clinical change 2.5 years later</td>
</tr>
<tr>
<td>4</td>
<td>19, male, pain</td>
<td>Forearm, 2 × 1</td>
<td>3 mo</td>
<td>Linear echogenic lesion with surrounding hypoechoic mass</td>
<td>Mass resolved spontaneously</td>
</tr>
<tr>
<td>5</td>
<td>21, male, pain</td>
<td>Dorsum of foot, 4 × 1</td>
<td>1 y</td>
<td>Curved echogenic lesion with surrounding hypoechoic vascular mass</td>
<td>Surgery</td>
</tr>
<tr>
<td>6</td>
<td>8, male, no pain</td>
<td>Lateral knee, 12 × 2 and 10 × 2 (2 objects)</td>
<td>1 mo</td>
<td>Linear echogenic lesion with posterior shadow and surrounding hypoechoic mass</td>
<td>Lost to follow-up</td>
</tr>
</tbody>
</table>

*Abbreviations: mm, millimeters; mo, month; y, year.

*At surgery, this patient was found to have infected granulation tissue, in addition to a foreign body.
than fluoroscopy or radiography. However, metal foreign bodies can cause imaging artifacts on CT scans. CT is also relatively expensive and delivers a significantly greater dose of radiation than radiography. Furthermore, although CT scans can be both sensitive and specific for foreign bodies, CT might miss extremely small foreign bodies (ie, those less than 0.5 mm). In such cases, MR might be a better imaging option. CT imaging might best be used in cases where radiography and ultrasonography are negative but a foreign body still is suspected.

MR offers better contrast in soft tissues and is preferable for imaging some types of foreign bodies. For example, in one small study, researchers concluded that MR was better than CT for detecting boluses of food within the larynx in cadavers whose death was due to asphyxiation. However, MR is contraindicated for imaging some metal foreign bodies because of the possibility that the MR magnet could cause the metal object to move and further damage tissue. In addition, metal can create strong interference artifacts on MR images. Furthermore, foreign bodies with low signal intensity can be hard to distinguish from low-density tissues and structures such as scar tissue, tendons, and calcifications. Finally, MR is more expensive than CT and less widely available. Nonetheless, MR imaging should be considered for cases involving a long-term wound or a focal infection with an unknown cause that might be due to a foreign body.

CT, MR, and Foreign Body Imaging Research

To compare the relative effectiveness of CT, MR, and radiography for imaging various types of foreign bodies, Pattamapaspong et al imaged 16 cadaver feet. Ten foreign bodies were inserted into the sole of each foot, distributed throughout to include the toes, forefoot, arch, and heel. Five different substances were implanted, including fresh wood, dry wood (ie, bamboo toothpicks), glass, porcelain, and plastic fragments (ie, tips of plastic toothpicks). All of the foreign bodies measured 2 × 5 mm. Also, 10 sites were prepared in each foot with no foreign body inserted.

Radiographs, MR scans, and CT scans were obtained for each foot. For the radiographs, 3 projections were used: dorsoplantar, pronate oblique, and lateral. MR imaging was performed using a foot and ankle coil, and both T1-weighted and T2-weighted images with fat suppression were obtained. Slices 3 mm thick were imaged in the axial, coronal, and sagittal planes. CT scanning was performed with 120 mA and 120 kVp, and multiplanar reconstructions in the axial, coronal, and sagittal projections were obtained.

Overall, the results of this study demonstrated that all 3 modalities had high specificity (98%-100%). However, sensitivity was poorer for all modalities (only 29% for radiography, 63% for CT, and 58% for MR). Variations in detection rates depended on the type of material and the location of the foreign body. For example, radiographs did not show any of the radiolucent foreign bodies (fresh wood, dry wood, or plastic). In addition, radiography was poorer at identifying foreign bodies in the forefoot than in the rest of the sole because efficacy decreases when a foreign body is close to bone. Radiography also failed to detect some of the radiopaque foreign bodies, especially glass (47% of glass foreign bodies in this study were missed).

Table 3 presents the percentage of foreign bodies detected by imaging modality and type of foreign-body material.

Although radiography cannot exclude the presence of a foreign body, it remains the first step used in evaluating the foot because it is widely available, easy to perform and inexpensive,” Pattamapaspong noted. Furthermore, radiographs can be useful when foreign bodies have been retained in the body long enough to cause certain changes in the bone, such as erosion, osteoblastic lesions, and periosteal reaction.

<table>
<thead>
<tr>
<th>Type of Material</th>
<th>Radiography</th>
<th>Computed Tomography</th>
<th>Magnetic Resonance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh wood</td>
<td>0</td>
<td>66</td>
<td>28</td>
</tr>
<tr>
<td>Dry wood</td>
<td>0</td>
<td>47</td>
<td>63</td>
</tr>
<tr>
<td>Glass</td>
<td>53</td>
<td>100</td>
<td>41</td>
</tr>
<tr>
<td>Porcelain</td>
<td>91</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Plastic</td>
<td>0</td>
<td>3</td>
<td>56</td>
</tr>
</tbody>
</table>
In this study, the sensitivity and specificity for CT and MR were not significantly different, nor was there a difference in the efficacy of these modalities to detect foreign bodies in the forefoot vs the rest of the sole. However, CT better detected glass and fresh wood than did MR. Nevertheless, foreign bodies can sometimes be difficult to detect with CT because of the foot’s complex anatomy and the varying densities of the different tissues in the foot (eg, fat, muscle, tendon, and bone). Also, some patients have soft-tissue calcification, which can make it difficult to distinguish a foreign body on CT scans. Calcified soft tissue tends to be associated with conditions such as arteriosclerosis, neuropathy, and traumatic injury.

Foreign bodies typically appear hypointense in MR images. MR also shows inflammatory responses in tissues around a foreign body. However, MR images of a retained foreign body might be misinterpreted as a tendon, scar tissue, or calcification. Several kinds of foreign bodies are associated with artifacts on MR, especially porcelain, metal, gas-containing wood, and stone. Pattamapaspong et al noted that foreign body detection on MR can be improved by selecting pulse sequences that enhance the susceptibility artifact, such as frequency-specific fat suppression and long echo time pulse sequences. Unfortunately, it can be difficult to detect wood foreign bodies on MR imaging, especially when there is no collection of fluid or abscess associated with the wood and the foreign body is small.

CT is better than MR for imaging water-rich wood. This is because the wood absorbs fluid from surrounding tissues and appears hyperdense on CT. On MR, water-rich wood can appear either isointense or hypointense compared with surrounding muscle. Wood is an especially troublesome foreign body because it can fracture and be difficult to remove, and bacteria tend to grow on it, leading to infection. In addition to its superiority for imaging water-rich wood, CT is also less expensive, quicker to perform, and more readily available than MR. Lastly, CT is also the superior modality for imaging foreign bodies surrounded by air, such as those inserted in a sinus.

A study by Russell et al in the 1990s showed that CT and MR were both highly effective for detecting many different types of foreign bodies in cadaveric hands; however, in Russell’s study the foreign bodies were larger than those used in the study by Pattamapaspong. In particular, Russell reported that CT and MR were useful for identifying wood foreign bodies, whereas wood was not well visualized on radiographs. MR was somewhat limited in distinguishing plastic foreign bodies, and MR images of gravel foreign bodies showed streak artifacts because the gravel was ferromagnetic.

3-D Computed Tomography

It is more difficult to pinpoint the exact location of a foreign body than it is to merely confirm its presence. Plain-film radiography, CT, and ultrasonography are all useful for detecting foreign bodies, but determining their exact position can be challenging with 2-D imaging methods. The true size and orientation of a foreign body might not be clear with 2-D techniques; therefore, the surgical approach for removing foreign bodies is often exploratory and somewhat blind. Radiographs taken at right angles are often used but might not be helpful for very small foreign bodies. Three-dimensional CT is used to trace the path of bullets through the body and guide their surgical removal, and it is helpful in locating other small foreign bodies to aid in surgical removal.

Tao et al described a simple and reliable imaging technique for locating and surgically removing small metal foreign bodies using 3-D CT. The objects in this study ranged from 2 to 6 mm long and 0.5 to 5 mm wide. They included a fish hook, nails, and the tip of a syringe needle used to self-administer insulin. Under local anesthesia, at least 3 needles oriented at 90° relative to each other were inserted near the foreign body’s point of entry. CT scanning with multiplanar reconstruction was performed, allowing clinicians to see the implanted needles and the foreign body and determine the most direct surgical approach based on the length, depth, and orientation of the foreign body.

In the Tao study, 8 foreign bodies were successfully removed using this approach, and the mean operative time was only 20 minutes. No complications occurred, and all of the patients were pleased with the surgical results.

A Multimodality Imaging Algorithm for Foreign Bodies

Ipaktchi et al recently proposed an imaging algorithm that uses several modalities to detect radiolucent
foreign bodies in the hands. Their aim was to limit diagnostic costs and exposure to ionizing radiation while maximizing the detection of foreign bodies. They discussed the new algorithm in the context of detecting retained wood splinters in the palm, but the approach could be useful for other types of superficially located radiolucent objects as well. According to the proposed algorithm, suspected foreign bodies should first be imaged with multiple projection radiography. If necessary, ultrasonography and MR or CT might follow, depending on the radiographic results, clinical examination findings, and the type of foreign body suspected (see Figure 5).

Photoacoustic Imaging

A new imaging technique, not yet in use clinically, could someday prove helpful for detecting foreign bodies in soft tissues. Photoacoustic tomography, also known as optoacoustic tomography, uses pulsed light from lasers directed into the body. The light increases the temperature of tissue a minuscule and harmless amount, causing the cells to expand and contract. The expanding and contracting cells emit ultrasonic waves that computers can convert into 2-D and 3-D images. Photoacoustic imaging might one day be performed inexpensively with handheld devices similar to ultrasound units; in fact, ultrasonographic and photoacoustic images might be obtained using the same device and then coregistered. One possible application is imaging radiolucent foreign bodies, including wood and plastic.

To test the ability of photoacoustic imaging to detect foreign bodies in soft tissue, Cai et al embedded a variety of items in chicken breasts, including pieces of plastic, wood, cloth, glass, and a metal blade. The objects were embedded at depths of 3 to 10 mm. The researchers determined that photoacoustic imaging was excellent for precisely locating even very small objects. In addition, photoacoustic imaging and ultrasonography have complementary contrasts, and coregistering the 2 types of images could increase sensitivity and specificity for foreign body detection, Cai et al concluded.

Foreign Body Imaging by Type of Material

Glass

Radiographs generally are effective for identifying glass and other radiopaque foreign bodies, and radiography is routinely performed when glass foreign bodies are suspected. However, some researchers have questioned whether all of these examinations are necessary. Orlinsky and Bright performed a prospective study to determine whether a subset of patients with glass-caused injuries might derive no benefit from radiography and thus imaging could be skipped.

In this study, 2-projection radiographs of glass-caused wounds were obtained for all patients who presented to an urban emergency department during a 2-year period. Without examining the radiographs,

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clinicians anesthetized the wounds, examined and probed them, and removed any foreign bodies. The clinicians noted the extent of the injury and whether they were able to completely visualize and explore the wound. Only then were the radiographs examined, and further examination of the wound was performed, if necessary. This study included 167 patients with 264 glass-caused wounds. The most common injury sites were the hands and arms; the most common mechanism of injury was putting a hand through glass, such as a window or glass door.\(^1\)

Approximately half of the wounds in the Orlinsky study were superficial and the other half were classified as deep (ie, deeper than the subcutaneous fat). Among the superficial wounds, only 1.5% were found to be “x-ray beneficial,” meaning the radiographs revealed more foreign bodies than were found during clinical examination. In contrast, 7.7% of the deep wounds were determined to be “x-ray beneficial.”

As expected, Orlinsky and Bright concluded that radiography is more beneficial with deeper glass-caused wounds than for superficial wounds. Furthermore, routine radiographs are not necessary for superficial glass-caused wounds that can be adequately explored visually. In these cases, Orlinsky and Bright argued, “routine x-rays obtained for purposes of ruling out retained glass foreign bodies are an unnecessary cost to the health care system, expose the patient to unnecessary radiation, tax the resources of time and space in a busy [emergency department], and provide little or no clinically useful information.”\(^1\)

Nevertheless, in their review of the research on glass-caused wounds and the need for radiographic examination, Weinberger et al cautioned that certain situations merit extra care because they are more likely to be associated with retained glass foreign bodies. These situations include injuries in which the patient has a sensation that a foreign body is present, injuries involving the head or foot, and injuries caused by a motor vehicle collision or puncture.\(^2\)

Glass foreign bodies also are highly detectable on ultrasonography.\(^9\) Because glass is solid and contains no fluid, it echoes most ultrasonic energy. Glass also tends to create shadow artifacts on ultrasound images. Shadow artifacts appear as black streaks and indicate that no sound has penetrated the glass to reach the tissues underneath.\(^9\)

**Metal**

Both radiography and ultrasonography can be effective for identifying metal foreign bodies. On ultrasonography, metal foreign bodies appear white and often show a shadow artifact. With larger metal objects, such as bullets or bullet fragments, bright arcs might appear deep to the foreign body. Smaller metal objects, such as needles, are more likely to show the comet tail artifact on sonograms.\(^9,19\)

To help determine which modality is superior for detecting metal foreign bodies, Manson et al studied the ability of emergency medicine resident physicians to remove metal pins inserted into pigs’ feet using either radiographs or dynamic ultrasound.\(^1\) Fourteen residents participated in this blinded, randomized, in vitro study. The researchers embedded 1.5-cm metal pins 1 cm below the surface, at a 30° angle to the surface, and in random orientations. Each resident removed the pins from 2 pigs’ feet: In one case the residents used 2 radiographs (AP and lateral projections) and in the second they used dynamic ultrasound imaging performed with a portable ultrasound machine (SonoSite Titan, SonoSite, Inc).\(^1\)

Manson et al measured the time required to remove the pins, the cosmetic outcome for each surgical procedure, and the length of the incision. They found no significant differences in the time required for removal, overall cosmetic outcome, or length of incision for radiography vs ultrasonography. However, the time for ultrasound-guided removal was slightly, although not significantly, shorter than for radiography. In this study, radiologic technologists obtained the radiographs; the resident physicians performed the ultrasound imaging.\(^1\)

“Because many previous authors have theorized that dynamic, ultrasound-guided soft-tissue foreign-body removal might be superior, the authors of this study were surprised that this small study did not show a dramatic benefit,” Manson and coauthors observed. However, the results might have been different had the emergency medicine residents had more experience with ultrasound and surgical removal of foreign bodies, they added.\(^1\)
In gunshot wound cases, CT scans have proven useful for detecting bullets and bullet fragments retained in the body, as well as the bullet’s pathway through the body and associated injuries, such as shattered bone and free air.\(^29\) For assessing soft-tissue injuries caused by a gunshot wound, MR might be a better imaging modality, with caveats. MR imaging is safe for ammunition made of lead with a jacket of copper or an alloy, which includes many types of bullets. However, ammunition made of steel, such as shotgun pellets, can move if subjected to a strong magnetic field. This could be especially risky when a steel object is located near a critical structure.\(^30\) Also, steel creates significant artifacts on MR images, which might impede diagnosis.\(^30\)

**Wood**

Wood foreign bodies are detectable on ultrasonography because wood has a different acoustic impedance (or resistance) than soft tissues.\(^14\) On sonograms, wooden objects are highly echogenic and thus appear white.\(^14\) They might or might not show posterior acoustic shadowing.\(^9\) On the other hand, because of its radiolucency, wood can be overlooked on radiographs. According to one author, only in about 15% of cases are wood foreign bodies visible on radiographs.\(^14\)

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To gain a clearer understanding of various imaging modalities’ ability to detect wood foreign bodies, a group of Portuguese researchers compared images of chicken thighs implanted with wood splinters.\(^31\) This study used 11 chickens; all of the chickens received a puncture wound in both thighs. A splinter was inserted and left in place in one thigh, while a similar splinter was inserted and then removed from the opposite thigh. (These were the experimental controls.) The chickens were killed and their thighs imaged using radiography, ultrasonography, MR imaging, and CT. As expected, the researchers concluded that ultrasonography and CT were the best options for detecting wooden foreign bodies, while radiography was a poor diagnostic tool for this purpose (see Table 4).\(^31\)

However, for wood foreign bodies in the intraorbital area, MR imaging might be a better option than CT, according to one report.\(^32\) Lakshmanan described a case in which a 3-cm-long wood foreign body in a boy’s orbit went undetected on a CT scan. A hypodense area on the scan was misidentified as a gas shadow by the interpreting radiologist, who thought it represented an area of pus. Fortunately, the splinter in the boy’s eye spontaneously extruded through the draining wound 2 days later and he recovered well.\(^32\) Lakshmanan pointed out that wood’s density is similar to both air and fat on radiographs and CT scans, which can be misleading.\(^32\)

**Plastic**

Plastic objects can be difficult to detect with radiography. An example is plastic Lego toys, which sometimes get stuck in children’s tracheas or esophagi.\(^33\) Applegate and colleagues at the Cleveland Clinic studied low-dose spiral CT to determine the optimal technique for imaging Legos.\(^33\) They used both a neck phantom and a cadaver. Three radiologists read the examinations. These researchers found that Legos in the trachea were well visualized on CT scans, using both lung windowing and soft-tissue windowing (sensitivity 89%, specificity 89%). However, Legos in the esophagus were less visible (sensitivity 31%, specificity 100%). The best technique for demonstrating Legos with CT was 120 kV, 90 mA, 3 mm collimation, and 0.75 seconds per revolution, which allowed imaging of the entire tracheobronchial tree in about 18 seconds.\(^33\)

<table>
<thead>
<tr>
<th>Imaging Modality</th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
<th>PPV</th>
<th>NPV</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiography</td>
<td>13.6</td>
<td>100</td>
<td>100</td>
<td>53.7</td>
<td>56.8</td>
</tr>
<tr>
<td>Ultrasonography</td>
<td>63.6</td>
<td>100</td>
<td>100</td>
<td>73.7</td>
<td>81.8</td>
</tr>
<tr>
<td>Magnetic resonance</td>
<td>59.1</td>
<td>95.5</td>
<td>93.8</td>
<td>70.1</td>
<td>77.3</td>
</tr>
<tr>
<td>Computed tomography</td>
<td>72.7</td>
<td>95.5</td>
<td>95</td>
<td>78.3</td>
<td>84.1</td>
</tr>
</tbody>
</table>

Abbreviations: NPV, negative predictive value; PPV, positive predictive value.
Stone
Stone foreign bodies are rarely encountered, being less common than wood splinters, glass shards, or metal fragments. Nevertheless, stone penetration can occur with falls, explosions, and military activities. On both radiographs and CT scans, stones appear opaque and have variable density. Stones can mimic both calcified tissue and bone fragments.

Maizlin et al studied the CT and radiographic appearance of a variety of common rocks and minerals and found that the density of rocks ranged from 296 to 2830 HU (see Table 5), while the density of minerals ranged from 1580 to 7776 HU. Of the materials studied, pumice had the lowest density and thus might be most easily mistaken for a bone fragment or soft-tissue calcification on CT images. For comparison, the density of cortical-spongy bone is 400 to 600 HU.

Stone also is detectable on ultrasonography because it produces a strong echo and appears bright white with black shadows beneath. If inflammation is present, it appears as a dark rim around the stone on ultrasound images. Some stones are ferromagnetic and can cause streaking artifacts on MR images.

Rubber
Wood is the most common type of radiolucent foreign body, but rubber also is fairly common. Rubber foreign bodies can occur, for example, when someone steps on a nail or other sharp object that completely penetrates a rubber-soled shoe and drives a piece of rubber into the puncture wound. This type of injury is especially likely to become infected with Pseudomonas aeruginosa, which makes detecting and removing rubber foreign bodies critical. Turkcuer et al studied the ability of plain radiography, soft-tissue radiography (ie, reduced kilovoltage imaging), and ultrasonography to detect both rubber and wood foreign bodies in chicken thighs. They concluded that ultrasonography was the superior modality and also determined that a higher frequency transducer, specifically 12.5 MHz, is superior to 7.5 MHz transducers for this application. An important limitation, however, is that higher frequency transducers can only detect foreign bodies 2 to 20 mm deep and thus would miss more deeply embedded objects.

Special Categories of Foreign Bodies
Swallowed Objects
It was recently estimated that more than 100,000 foreign bodies are swallowed each year in the United States. Fortunately, fewer than 1% require surgical intervention. Approximately 80% of the time, swallowed foreign bodies pass naturally through the body and are excreted in the stool. Endoscopic removal is required in most of the remaining 20% of cases. If they are long, hard, or sharp, swallowed foreign bodies can cause perforation of the gastrointestinal tract. Possible complications related to swallowed foreign bodies include sepsis, peritonitis, abscesses, ulcerative esophagitis, fistulas, recurrent pneumonitis, and hemorrhage. In the United States, about 1500 deaths each year are due to swallowed foreign bodies.

Swallowed foreign bodies are most common in children aged 6 months to 6 years. Objects commonly swallowed by children include coins, safety pins, toy parts, and small batteries. In adults, swallowed foreign bodies usually are ingested along with food. The most commonly swallowed foreign bodies in adults are bones (particularly fish and chicken bones), dentures and parts of dentures, and toothpicks. Dental appliances might also be inadvertently swallowed while a patient is under general anesthesia. Other types of swallowed foreign bodies are keys, jewelry, nails, razor blades, screws, clips, pins, and needles (see Figure 6). Swallowed foreign bodies are more common among people who are elderly, people who have an intellectual disability or psychological disorder, and among alcohol abusers (see Box 2). Symptoms of a swallowed foreign body can include coughing, especially immediately after the object is swallowed. Vomiting, hypersalivation, and pain...

Table 5
CT Density of Selected Types of Rock

<table>
<thead>
<tr>
<th>Type of Rock</th>
<th>Density (HU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumice</td>
<td>296</td>
</tr>
<tr>
<td>Obsidian</td>
<td>1590</td>
</tr>
<tr>
<td>Sandstone</td>
<td>1630</td>
</tr>
<tr>
<td>Schist</td>
<td>2640</td>
</tr>
<tr>
<td>Limestone</td>
<td>2830</td>
</tr>
</tbody>
</table>

Abbreviations: CT, computed tomography; HU, Hounsfield units.
Radiographs taken at 90° angles to each other usually are recommended initially, although in one study radiographs revealed only 144 of 414 ingested foreign bodies. Radiographs can, however, demonstrate perforations with resultant pneumomediastinum or pneumoperitoneum. Small foreign bodies might be hidden by fluids or soft tissues on radiographs. Contrast media are not recommended because they can mask swallowed foreign bodies. CT is more effective for demonstrating smaller swallowed foreign bodies, with 100% sensitivity and 91% specificity, according to one report. Ultrasonography is rarely used for swallowed foreign bodies. Imaging should be performed immediately before treatment, if possible, because swallowed foreign bodies tend to shift position. Some patients might indicate where a swallowed foreign body seems to be located, but these impressions are not necessarily reliable.

Toys and other small objects that contain magnets are a particular concern because they can cause a variety of problems if swallowed, including bowel obstruction, perforation, volvulus (intestinal twisting), necrosis, and sepsis (see Figure 8). Serious complications are possible when tissue is trapped between 2 or more magnets that are attracting each other. The small, round batteries found in watches, calculators, and hearing aids, known as “button batteries,” are a special concern when swallowed because they can be toxic when stuck in the esophagus. These batteries might contain an alkaline solution that causes liquefaction necrosis in which cells die and are transformed to liquid. Tissue necrosis can occur 4 to 6 hours after a button battery becomes lodged in the esophagus. However, when a button battery is observed in the stomach, it usually passes harmlessly. On CT scans, button batteries are round and highly attenuating.

**Figure 6.** CT scan showing an accidentally swallowed sewing needle (arrow) in the small bowel lumen, with no evidence of bowel perforation. Reprinted with permission from Gayer G, Petrovich I, Jeffrey RB. Foreign objects encountered in the abdominal cavity at CT. Radiographics. 2011;31(2):409–428.

**Box 2**

**Case Study: Swallowed Silverware**

A man, aged 62 years, presented at an emergency department. He was apparently drunk and reported that he had swallowed a fork. He explained that he had been attempting to cure his hiccups by pressing the fork’s handle against the roof of his mouth when he accidentally swallowed the fork. He complained of dysphagia, dyspnea, and hypersalivation.

The 22-cm-long fork was clearly visible in the patient’s esophagus on anteroposterior and lateral radiographs (see Figure 7). An endoscopic examination revealed that the fork’s tines projected through the upper esophageal sphincter. The fork was removed under direct visualization, and the patient was released 2 days later.

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Figure 7. Anteroposterior (A) and lateral (B) radiographs of the thorax showing a table fork occupying the entire thoracic esophagus. Reprinted from Mevio E, Mevio N. Unusual foreign body: a table fork. Case Reports in Otolaryngology. doi:10.1155/2013/987504.
Bezoars are a separate category of swallowed foreign body. They are concretions of swallowed material, often hair or undigestible plant products, found in the stomach or small intestine. Bezoars composed of hair are known as trichobezoars; bezoars made up of plant material and cellulose are called phytobezoars. Sometimes bezoars cause small bowel obstruction and must be removed surgically. On CT scans, bezoars have a mottled appearance and contain gas bubbles.

**Aspirated Foreign Bodies**

Small foreign bodies can be aspirated and become lodged in the trachea, bronchi, or lungs. Often, these objects are bits of food, such as peanuts, corn kernels or other small pieces of vegetables, or popcorn. Teeth also are aspirated occasionally, for example during traumatic injury or intubation. Young children are most commonly affected. Signs and symptoms can include coughing and wheezing, a choking sensation, and dyspnea. Removal of the foreign body with bronchoscopy is the usual treatment, although surgery occasionally is necessary. If the patient’s breathing is severely compromised, emergency procedures such as the Heimlich maneuver might be necessary.

AP and lateral radiographs of the chest and neck are recommended initially. AP projections should be obtained both on inspiration and expiration. For patients who cannot comply with a radiographer’s instructions, such as infants and toddlers, a lateral decubitus projection or fluoroscopic images can be obtained instead.

Although some aspirated foreign bodies are radiopaque, many are radiolucent, so clinicians often use secondary radiographic signs to make a diagnosis. These signs include a shift of the mediastinum, obstructive emphysema, and atelectasis. CT also can be a helpful option for imaging aspirated foreign bodies; the use of narrow windows is recommended to increase the likelihood of detection. Some authors have reported successful MR imaging of aspirated peanuts because the nuts have a high fat content compared with lung tissue.

**Orthopedic Hardware**

Radiologic technologists often are called on to image hardware used in orthopedic surgeries, such as screws, plates, wires, pins, intramedullary rods and...
nails, spinal fixation devices, and artificial joints. The goal of imaging in these cases might be to assess how a fracture is healing, check the alignment of the hardware and whether it has loosened, evaluate bone fusion, or determine whether infection is present.

Hardware used in orthopedic surgery is composed of various metals, including cobalt-chrome, iron, stainless steel, and titanium. Denser metals appear white on radiographs and CT scans; less dense metals, such as titanium, appear gray. When imaging orthopedic hardware, technologists should keep these guidelines in mind:

- Take at least 2 orthogonal projections of the body part.
- Include the entire orthopedic device in the image, ideally with several centimeters of normal bone on each end.
- Slightly overexposing the image might aid in visualizing metallic devices.

CT can be a helpful adjunct to radiography for imaging orthopedic hardware but is prone to artifacts, especially with stainless steel. Some tips for minimizing metallic artifacts on CT scans are to reduce the collimation and detector pitch, increase kilovolt peak and milliampere seconds, and select thin sections. Also, images should be obtained with the beam traversing the hardware at its narrowest cross section. To reduce metal artifacts on MR imaging, a fast spin-echo pulse sequence is the best option. Lower magnetic field strength also is preferred, and the metal object should be aligned parallel to the main magnetic field as much as possible.

**Intrauterine Devices**

Intrauterine devices (IUDs) are an effective and widely used method of contraception. In the United States, 2 types of IUDs are available: one containing copper wire and another that releases levonorgestrel. Both have a T-shaped frame made of polyethylene and an attached monofilament string (see Figure 9). Copper IUDs have a copper “collar” encircling the stem; the other type has a levonorgestrel-containing collar. IUDs with copper are hyperechoic on sonography; they also are radiopaque and visible on radiographs. IUDs that release levonorgestrel contain barium sulfate and are visible on radiographs.

Figure 9. Pelvic radiograph showing normal positioning of an intrauterine device (IUD). The IUD is upright in the midline pelvis inferior to the pelvic brim, in the expected location of the uterus. Reprinted with permission from Boortz HE, Margolis DJA, Ragavendra N, Patel MK, Kadell BM. Migration of intrauterine devices: radiologic findings and implications for patient care. Radiographics. 2012;32(2):335-352.

Perforation of the uterus and migration of the IUD occurs in about 1 in 1000 cases. Most often, perforation occurs when the IUD is placed. Migrated IUDs can cause a variety of complications, such as perforation of the bowel or bladder. However, in most cases (85%) other organs are not affected. Migrated IUDs also can become embedded in the uterus. Occasionally, pregnancy occurs in women with IUDs. An IUD in place during a pregnancy can cause spontaneous abortion, premature birth, and low birth weight. When possible, IUDs typically are removed early in the pregnancy. Imaging is performed in these cases to guide removal.

Ultrasonography is usually the first modality used to evaluate IUD location because of its advantages: wide availability, relative low cost, and lack of ionizing radiation and magnetic fields. When an IUD is located outside the uterus, radiography might be used to confirm its location. AP and lateral projections usually are performed, and the radiation dose is minimal. CT also might be used in some cases to locate an IUD, but more commonly IUDs appear on CT scans as incidental findings. MR imaging is not
used to locate IUDs, but it is safe to use for other indications in women who have IUDs.\(^{48}\) On MR scans, IUDs appear as a signal void.\(^{49}\)

Other types of foreign bodies from prior medical procedures also might be visible on imaging examinations. Examples include stents, which can be made of metal or plastic, feeding tubes, and endoscopic capsules. Stents and tubes can migrate from their expected positions, leading to bowel obstruction or perforation.\(^{38}\)

**Candy and Gum in the Mouth**

CT scans of the head and neck sometimes reveal intraoral foreign bodies, such as chewing gum, candies, and chewing tobacco, even though patients are instructed to remove these items before imaging examinations. As a result, it is important to distinguish food and tobacco from pathology.\(^{50}\) To study the imaging appearance of common edible foreign bodies in the mouth, McDermott et al assigned patients undergoing CT scans of the head and neck various types of candy or gum to hold in their mouth during scanning. The foreign bodies in this study included jawbreakers, Lemonheads, Werther’s Original candies, Life Savers, Tic Tacs, Starbursts, Tootsie Rolls, Bubble Yum bubble gum, and Eclipse chewing gum (see Table 6).\(^{50}\)

![Figure 10. Coronal reformatted CT image demonstrating a malpositioned IUD (white arrow) in the endometrial cavity (black arrow) with its arms perforating the myometrium. Reprinted with permission from Boortz HE, Margolis D JA, Ragavendra N, Patel MK, Kadell BM. Migration of intrauterine devices: radiologic findings and implications for patient care. Radiographics. 2012;32(2):335-352.](image)

<table>
<thead>
<tr>
<th>Table 6 Edible Intraoral Foreign Bodies: Appearance on CT Scans(^{50})</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type of Foreign Body</strong></td>
</tr>
<tr>
<td>Jawbreakers</td>
</tr>
<tr>
<td>Lemonheads</td>
</tr>
<tr>
<td>Werther’s Original</td>
</tr>
<tr>
<td>Life Savers</td>
</tr>
<tr>
<td>Tic Tacs</td>
</tr>
<tr>
<td>Starbursts</td>
</tr>
<tr>
<td>Tootsie Rolls</td>
</tr>
<tr>
<td>Bubble Yum</td>
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<tr>
<td>Eclipse gum</td>
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Abbreviations: CT, computed tomography; HU, Hounsfield units.
The researchers found that large candies (e.g., jawbreakers) were less likely than smaller items to be confused with pathology but might be mistaken for an osteoma or other bony excrescence. Small candies were more prone to motion artifact, which increased the possibility of misdiagnosis. Tic Tacs, in particular, can be problematic because they mimic small calcified tumors (see Figure 11). Soft foreign bodies, such as gum, were difficult to identify on scans because they usually had a lower radiodensity than hard candies and had an amorphous shape. Also, soft foreign bodies tended to mold to the mucosal surfaces of the mouth and could be mistaken for mucosal lesions.

Retained Surgical Sponges

Surgical sponges retained in the abdomen, thoracic cavity, or elsewhere in the body are relatively rare, thanks to surgical protocols that require multiple counts of these items before and during surgery. Unfortunately, however, sponges and other items used during surgery are sometimes unintentionally retained in the body. They can go undetected, occasionally for long periods of time, and might have serious complications. The term for this phenomenon is gossypiboma, from the Latin word gossypium, meaning cotton, and the Swahili word boma, a hiding place.

Symptoms of a retained surgical sponge in the chest, for example, might include chronic cough, expectoration, hemoptysis, chest pain, fever, and weight loss. Radiography, usually the first imaging technique used to evaluate gossypiboma, might show an unusual opacity, atypical mass, or a “whirl-like gas collection.” Radiopaque markers in surgical sponges might or might not be visible on images. On CT scans, surgical sponges can appear as walled masses with a spongiform interior pattern with gas bubbles (see Figure 12). Sponges also are described as having a “whorled texture or a spongiform pattern containing gas bubbles.” These can be confused with an abscess, hematoma, or the gel foam particles used to control intraoperative bleeding.

Bioabsorbable sponges also are used during surgery and are intentionally left in place to help control bleeding. These sponges typically are absorbed by the body 1 to 2 weeks after surgery. On imaging, they can appear as gas-filled masses that might also be confused with abscesses.

Body Packing

Concealing illegal drugs within the body as a means of transporting them across borders, also known as body packing, was first described in the medical literature in the 1970s. It has become more common since September 11, 2001, because of the increased border security that resulted from the terrorist attacks on the United States. Drugs such as heroin, cocaine, amphetamines, ecstasy, and hashish are sometimes wrapped in condoms, balloons, the fingers of latex gloves, aluminum foil, or plastic food wrap. The packets might be sealed with tape or wax. Often, drug packets are swallowed, but they also are inserted in the rectum or vagina. Typically, each packet contains 5 g to 10 g of drugs.

Most body packers have no symptoms; slightly less than 10% of cases require surgery. Endoscopic removal of drug packets is not recommended because of the possibility that the packets might rupture during the procedure. When packets leak or rupture, drug carriers might present with symptoms of drug toxicity. Obstruction of the gastrointestinal tract is another risk associated with body packing.

Abdominal radiographs are useful for identifying body packers, with reported sensitivity between 74% and 100%. CT scans also appear to be both sensitive and specific. Packets of drugs appear as ovoid or round radiodense foreign bodies (see Figure 13) and can be located anywhere in the gastrointestinal tract. Hashish typically appears more dense than stool, whereas cocaine is similar in density. Heroin has a gaseous, transparent appearance. However, the attenuation of drug packets depends on the purity of the drug and what has been mixed with it. A crescent of air might be visible between layers of latex used to wrap the drugs; this is known as the “double condom” sign.

While ultrasonography is not typically used to image swallowed foreign bodies, it can be a cost-effective means of detecting packets of illegal drugs, according to a study of suspected body packers in a prison hospital setting in the Netherlands. In this study, 50 individuals charged with body packing underwent abdominal scanning using a portable

![Figure 12. Sponge left unintentionally in the abdomen. A. Coronal contrast-enhanced CT scan demonstrates a sponge (blue arrows) with a radiopaque marker at its center (white arrow). B. Topogram shows the classic appearance of the radiopaque marker (arrow). Reprinted with permission from Gayer G, Petrovitch I, Jeffrey RB. Foreign objects encountered in the abdominal cavity at CT. Radiographics. 2011;31(2):409-428.]

![Figure 13. Abdominal radiograph revealing multiple oval radiopaque packets throughout the abdomen. The packets, later evacuated by the patient, proved to be illicit drugs tightly wrapped in aluminum foil. Reprinted from Shahnazi M, Sanei Taheri M, Pourghorban R. Body packing and its radiologic manifestations. Iran J Radiol. 2011;8(4):205-210.]
ultrasound unit with a 2 to 4 MHz curved array transducer. The suspects remained in custody after the imaging examinations and their stools were examined for evidence. In 47 of 50 individuals (94%), abdominal ultrasonography correctly determined whether drug packets were present or not. More specifically, 40 of the 42 suspects with drug packets were correctly identified with ultrasound imaging. Seven of 8 individuals without drug packets were identified correctly.55

**Self-Embedded Foreign Bodies**

Deliberate self-injury without suicidal intent is fairly common among adolescents, with 13% to 23% of adolescents in the United States reporting this activity.56 In fact, the phenomenon may be under-reported because of its social unacceptability and feelings of guilt or shame, according to one report. However, self-embedding with foreign bodies has only recently begun to be studied.56

Young et al retrospectively identified 11 patients with self-embedded foreign bodies from a large database of patients.56 All of the patients in this study group were aged 14 to 18 years; 9 of them were girls. Diagnosis was performed using radiography or ultrasonography and the foreign bodies were removed with imaging guidance (ultrasonography, fluoroscopy, or both). A total of 68 self-embedded objects were removed from the patients, including staples, pencil lead, unfolded paper clips, fingernail polish applicator stems, comb teeth, a crayon, and a metal pin (see Figure 14). Seven of the patients in this study were treated more than once for self-embedded objects. The most common body site for self-embedding was the arm (n = 69), followed by the neck (n = 4), with 1 item each in the foot, ankle, and hand. No infections, injuries to nerves, blood vessels, or tendons, or other types of complications occurred as a result of image-guided percutaneous foreign body removal in this study.56

Ten of the 11 patients also had a diagnosed psychological or behavioral disorder or disorders. These included bipolar disorder, depression, obsessive-compulsive disorder, and post-traumatic stress disorder. In some cases, the self-embedding behavior was considered to be “an attempt by the patient to intentionally effect tissue destruction with the purpose of converting intense emotional pain to more acceptable physical pain…” the authors explained.56 By raising awareness among radiologists and other health care professionals about self-embedding behavior, Young et al hoped to mobilize early, effective, multidisciplinary care for self-embedding adolescents.56

**Rectal Foreign Bodies**

Foreign bodies in the rectum are sometimes encountered in emergency department settings and their incidence might in fact be increasing.57,58 Many of these objects are inserted via the anus, although some are swallowed and become trapped in the rectum during passage through the gastrointestinal tract. Most commonly, objects are inserted voluntarily into the rectum for sexual stimulation; however, objects also are inserted rectally during sexual assault. In addition, foreign bodies occasionally are inserted rectally in an attempt...
to break up impacted fecal matter.\textsuperscript{59} Radiographs of the pelvis and abdomen usually are adequate to identify rectal foreign bodies.\textsuperscript{42}

Two reported difficulties in treating patients with rectal foreign bodies are delayed presentation, often because of embarrassment, and patients’ reluctance to disclose the situation to health care professionals, which can lead to diagnostic delays and extensive work-ups. In some cases, patients attempt to remove the object themselves before seeking medical care, and these attempts can cause additional injury. Complications of rectal foreign bodies include perforation of the rectum and colon, sepsis, lacerations, rectal bleeding, and injury to the anal sphincter.\textsuperscript{57} Mortality is rare but can result from perforation and infection with long-delayed presentation.\textsuperscript{59}

Coskun and colleagues recently reviewed medical records at a hospital in Turkey to identify 15 patients with rectal foreign bodies.\textsuperscript{57} The patients’ mean age was 48 years and all were men. On average, these patients waited almost 24 hours before presenting for medical care (range, 6 to 72 hours). All were examined with abdominal radiography; CT scanning was not deemed necessary in any case. The following foreign bodies were detected in the patients’ rectums: aerosol spray cans (see Figure 15), bottles, dildos, an eggplant, a brush, a drinking glass, a ball-point pen, and a wishbone. The last item was ingested orally.\textsuperscript{57}

In 12 cases, the objects were removed through the anus while the patient was under general anesthesia to allow anal dilatation. In the remaining 3 cases, laparotomy was required to remove the foreign body. Various tools are used to remove rectal foreign bodies anally, including obstetrical forceps and vacuum extractors and surgical clamps.\textsuperscript{57} One patient in this study had a perforation in the recto-sigmoidal area, which was repaired surgically and required a colostomy. Postprocedural rectosigmoidoscopies revealed rectal lacerations in 4 patients. The authors also recommended follow-up radiography to check for injury or perforation that might have occurred during removal of the foreign body.\textsuperscript{57}

\textbf{Intraoperative Imaging of Foreign Bodies}

Ultrasonography can be crucial during surgical removal of embedded foreign bodies. For example, Ng and colleagues reported the case of a man, aged 28 years, whose neck was badly injured in an industrial accident.\textsuperscript{60} The patient had been using an angle grinder made of carborundum (silicon carbide) to cut an overhead beam composed of wood and metal. He lost his grip on the grinder and it fell, cutting him across his neck. Radiographs showed many fragments that were presumed to be pieces of the grinder. Exploratory surgery was planned, and a radiologist and a high-resolution ultrasound machine were present in the operating room. With ultrasound guidance, more than 100 foreign bodies were removed from the patient’s neck, including particles of carborundum, wood splinters from the beam, and cloth fibers from the grinder’s backing material. The wood and cloth were radiolucent and not visible on initial radiographs. Therefore, ultrasonography was crucial to locating all of the objects while avoiding damage to blood vessels in the neck.\textsuperscript{60}

Ng et al wrote “in our case, having the ultrasound machine in theatre whilst operating was invaluable. When used in real time, the continuous imaging capability of ultrasound imaging is far more useful to the surgeon than static single shots, as represented by the other imaging modalities.”\textsuperscript{60} Fluoroscopy, which also can be used intraoperatively, involves ionizing radiation and does not show blood vessels and soft tissues without

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{image15.png}
\end{figure}
the use of iodinated contrast. However, as Cohen et al noted, fluoroscopy can be useful intraoperatively for detecting metal, gravel, and glass foreign bodies, even though wood and plastic cannot be reliably visualized using fluoroscopy.

**Conclusion**

Imaging foreign bodies can be challenging, but radiologic technologists must be prepared because undetected and unre moved foreign bodies can lead to infection, tissue damage, and other potentially serious complications. No single imaging modality is ideally suited to all types of foreign body materials. Radiography is a mainstay for imaging radiopaque foreign bodies such as glass and metal but is less effective for imaging radiolucent objects. Ultrasonography can be used to visualize many types of foreign bodies, including wood, but is limited in its ability to image some objects if they lie deeper in the body’s tissues. CT and MR imaging, too, have advantages and drawbacks in terms of detecting foreign bodies, and photoacoustic imaging might one day offer a valuable adjunct to currently available clinical imaging technologies.

Radiologic technologists are likely to encounter a variety of foreign bodies while imaging their patients, whether the objects are sought for or unexpected. Technologists should be familiar with the usual imaging appearance of these items and the best ways to image them so they can provide optimal care to their patients.

**References**


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1. Which of the following complications might result from an untreated foreign body and a delayed diagnosis?
   a. obstruction and perforation
   b. nerve injury and chronic pain
   c. cellulitis and deep-tissue infection
   d. 1 and 2

2. According to one study, 25% of patients with a foreign body in soft tissue:
   a. sought immediate medical care.
   b. did not seek care within the first 48 hours.
   c. were unaware of their injury because of compromised sensation.
   d. could not describe their symptoms or explain what had happened.

3. Commonly encountered radiopaque foreign bodies include:
   a. wood and other organic matter.
   b. plastic and rubber.
   c. glass and metal.
   d. thorns and gravel.

4. Organic foreign bodies are more likely to cause an inflammatory response and infection than inorganic foreign bodies.
   a. true
   b. false
5. Which of the following limit ultrasonography’s usefulness for detecting foreign bodies?
   1. It is somewhat dependent on the operator’s skill and experience.
   2. It is only effective for detecting relatively superficial foreign bodies.
   3. It might not detect foreign bodies that are very superficially located.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

6. When a foreign body causes an inflammatory reaction, the inflammation appears on ultrasonography as:
   a. a hyperechoic rim.
   b. a hypoechoic rim.
   c. a comet tail.
   d. a bright arc deep to the foreign body.

7. According to a study by Saboo et al, false-positive findings of a foreign body on ultrasonography tended to occur in cases with:
   1. subcutaneous gas.
   2. calcified tissue.
   3. new hematoma.
   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 1, 2, and 3

8. How should the probe be oriented to obtain the best signal and visualize a foreign body sonographically, according to Bradley?
   a. perpendicular to the foreign body
   b. as close to parallel as possible to the foreign body
   c. at a 30° angle to the foreign body
   d. It depends on the type of material to be visualized.

9. According to the Directed Reading, when might computed tomography (CT) scanning be the best choice for foreign body imaging?
   a. for metal foreign bodies
   b. for foreign bodies less than 0.5 mm
   c. for detecting boluses of food within the larynx
   d. when radiography and ultrasonography are negative, but a foreign body still is suspected

10. According to the Directed Reading, when might magnetic resonance (MR) imaging be the best choice for foreign body imaging?
    a. for metal foreign bodies
    b. for foreign bodies with low signal intensity
    c. for initial investigation of a suspected foreign body
    d. for cases involving a long-term wound or a focal infection that might be due to a foreign body

11. MR is better than CT for imaging glass and fresh wood foreign bodies, according to the study by Pattamapaspong et al.
    a. true
    b. false

12. Why are wood foreign bodies especially problematic?
    1. They can fracture and be difficult to remove.
    2. Bacteria tend to grow on them, leading to infection.
    3. They are often not well visualized on radiographs.
    a. 1 and 2
    b. 1 and 3
    c. 2 and 3
    d. 1, 2, and 3

continued on next page
13. According to the imaging algorithm proposed by Ipaktchi et al, which modality should be used first for a suspected foreign body?
   a. ultrasonography  
   b. fluoroscopy  
   c. multiple projection radiography  
   d. CT scout imaging

14. Which type of images might be coregistered with photoacoustic images to enhance sensitivity and specificity for foreign bodies?
   a. ultrasonography  
   b. radiography  
   c. MR  
   d. nuclear medicine

15. According to Orlinsky and Bright, routine radiographs are necessary for all glass-caused wounds.
   a. true  
   b. false

16. Which of the following situations call for extra care because they are more likely to be associated with retained glass foreign bodies?
   1. injuries caused by a motor vehicle accident  
   2. injuries to the hand or arm  
   3. patients who report having the sensation that a foreign body is present
   a. 1 and 2  
   b. 1 and 3  
   c. 2 and 3  
   d. 1, 2, and 3

17. Small metal foreign bodies such as needles can cause which type of artifacts on ultrasonography?
   a. black streaks  
   b. hypoechoic rims  
   c. bright arcs  
   d. comet tails

18. Which type of stone is most likely to be mistaken for a bone fragment on a CT scan because of its density?
   a. sandstone  
   b. limestone  
   c. pumice  
   d. schist

19. In their study comparing imaging modalities for detecting wood and rubber foreign bodies, Turkcuer et al found ultrasonography to be the best modality and specifically recommended using a _____ MHz transducer for this application.
   a. 7.5  
   b. 9.5  
   c. 10.5  
   d. 12.5

20. Which of the following was not mentioned as being among the most commonly swallowed foreign bodies in adults?
   a. fish and chicken bones  
   b. dentures and parts of dentures  
   c. crowns and fillings  
   d. toothpicks

21. Which imaging technique usually is recommended initially in cases of a swallowed foreign body?
   a. CT scanning with oral contrast  
   b. ultrasonography with a high-frequency transducer  
   c. MR imaging of the head, neck, and thorax  
   d. radiographs taken at 90° angles to each other

22. When are the small, round batteries found in watches and calculators especially concerning?
   a. when found in the stomach  
   b. when lodged in the esophagus  
   c. as they pass through the colon  
   d. never; they are harmless and of no concern
Directed Reading Quiz

23. Which type of metal used in orthopedic hardware is less dense and thus likely to appear gray, rather than white, on radiographs?
   a. titanium
   b. stainless steel
   c. cobalt-chrome alloy
   d. iron

24. Which of the following will not help to reduce artifacts on CT scans caused by metallic orthopedic hardware?
   a. reducing the pitch
   b. reducing the collimation
   c. decreasing kilovolt peak
   d. increasing milliampere seconds

25. An intrauterine device with a copper collar appears _______ on ultrasonography and _______ on radiography.
   a. hyperechoic, radiopaque
   b. hyperechoic, radiolucent
   c. hypoechoic, radiopaque
   d. hypoechoic, radiolucent

26. Which type of edible intraoral foreign body is likely to be mistaken for a small calcified tumor on a CT scan?
   a. Bubble Yum bubble gum
   b. Werther's Original candies
   c. Tic Tacs
   d. Starbursts

27. What is another term for a retained surgical sponge?
   a. trichobezoar
   b. phytobezoar
   c. gossypiboma
   d. osteoma

28. A crescent of air visible between layers of latex used to wrap concealed drugs within the body is known as the _______ sign.
   a. “rising moon”
   b. “double condom”
   c. “2 gloves”
   d. “Saran Wrap”

29. In the study by Young et al, what was the most common site for self-embedded foreign bodies among a group of adolescent patients?
   a. face
   b. thigh
   c. abdomen
   d. arm

30. Fluoroscopy can be used intraoperatively to visualize all of the following except:
   a. gravel.
   b. glass.
   c. wood.
   d. metal.