Capturing Elusive Foreign Bodies With Ultrasound

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Embedded objects that are invisible on x-rays can waste physicians' precious time and upset patients. The authors describe the evidence favoring sonography as a superior technology for this purpose and a skill that urgent care physicians can quickly learn.

A 13-year-old girl presents to urgent care with a lacerated right arm. Her mother states that the injury occurred when the child's arm struck a glass pane in a French door. She thinks there may be retained glass in the wound. In examining the child, you note a 2-cm linear laceration with no obvious foreign body, but radiography shows what appears to be a residual piece of glass at or near the site of the laceration (see example in Figure 1). You anesthetize the area and begin dissection in an attempt to locate the glass fragment, which goes on for 20 minutes without success. The child and her mother are becoming anxious. You call for the portable ultrasound system, and using its high-frequency transducer, quickly locate the foreign body (see example in Figure 2). After additional anesthesia is applied, the splinter is easily removed under ultrasound guidance and the patient is discharged.

A 2-year-old boy complains of pain in his foot after stepping on a toothpick. His father suspects that part of the toothpick remains in the foot. Examination of the child's foot reveals a plantar puncture wound but no sign of a foreign body. Radiography is also negative for a foreign body and shows no deformity. Ultrasound examination with a high-frequency transducer, however, finds the offending toothpick segment located slightly deep to the site of the puncture wound (as illustrated in Figures 3a and 3b). With local anesthesia and ultrasound guidance, the splinter is easily removed and the patient is discharged.

Patients commonly report foreign bodies, real or perceived, to both acute and primary care physicians. Identification and localization of these foreign bodies remains a challenge for many practitioners. Overlooking a retained foreign body is associated with repeat physician visits and increased morbidity due to infection and pain. Even when the object has been identified, removal can be frustrating and time-consuming.

Radiography, the traditional method of confirming foreign bodies, can make precise localization difficult because it yields limited information on the depth and orientation of the object. If a foreign body is composed of radiolucent material such as wood, rubber, or plastic, it may not be evident in plain radiographs at all.

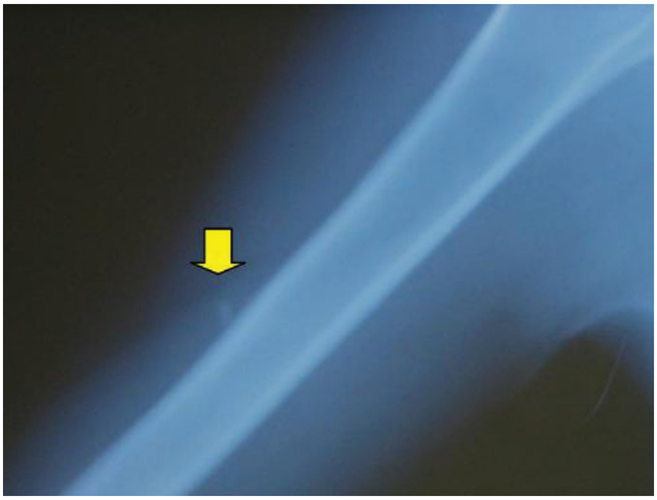

FIGURE 1. Glass foreign body on x-ray. X-ray of the arm of a patient with multiple lacerations as a result of a motor vehicle collision. A foreign body, suspected to be glass, is noted on the lateral film.

Both CT and MRI have demonstrated high sensitivity to foreign bodies but are expensive, time-consuming, and not always readily available. Blind exploration of the wound is another option but can be a painful, frustrating, slow process. It also poses a considerable risk when the site of the suspected foreign body is a hand or foot—as is frequently the case—since the high neurovascular density of those sites makes them particularly vulnerable to injury during dissection.

In many cases, the best choice for evaluating the possibility of a foreign body is ultrasound. It is a portable, rapid, bedside assessment that does not require exposing the patient to ionizing radiation. Unlike plain radiographs, ultrasound detects radiolucent foreign bodies, pinpointing their location and relationship to surrounding structures. It can also guide and confirm removal of the object, minimizing risk of iatrogenic injury incurred with attempted blind removal.

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EVIDENCE OF EFFICACY

Several studies have demonstrated the utility of ultrasound in localizing the presence of a foreign

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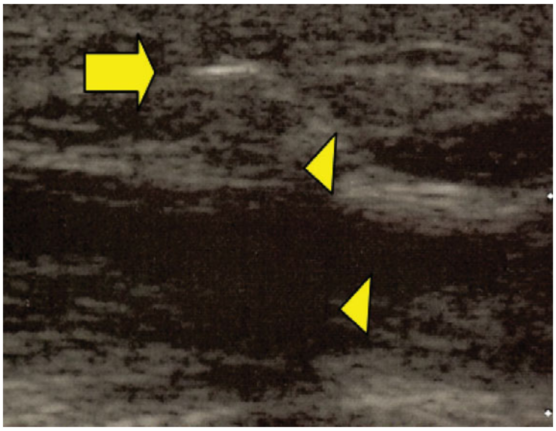

FIGURE 2. Ultrasound localization of glass foreign body. A fragment of glass is hyperechoic (white) and clearly visible (arrow) in the soft tissue. Due to its dense structure, it creates a reverberation artifact (arrowheads), which is visible below the foreign body. The presence of reverberation artifact aids in confirming that the object visualized is, in fact, a foreign body and not a part of normal anatomy. The other bright white object, seen at the bottom of the image, is the cortex of a bone.

body. A 1997 study by Hill and colleagues examined the sensitivity of ultrasound in detecting wooden and plastic foreign bodies placed in recently amputated human legs.[1] The sensitivity was 93% for wooden foreign bodies and 73% for plastic objects. The overall sensitivity was reported as 83%. This was noted as a key finding, as neither of these objects would be visible on plain radiographs.

Ultrasound was again shown to have high sensitivity in finding wooden foreign bodies in a study by Jacobson and colleagues in 1998.[2] Ultrasound detected wood embedded in cadaveric tissue with a sensitivity of 90% and a specificity of 96.7%. An important side note in this study was that the size of the foreign body was found to be an important factor. As the size of the object increased from 2.5 to 5 mm, the sensitivity also increased from 86% to 93%.

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Toothpicks are common in foreign body cases and unlikely to be seen on x-ray.

Toothpicks are common in foreign body cases and unlikely to be seen on x-ray. Orlinsky and colleagues embedded toothpicks in chicken thighs (occasionally used as a substitute for human tissue in evaluating diagnostic imaging methods) and easily localized them using ultrasound.[3] Sensitivity was 79% and specificity, 86%.

Radiopaque foreign bodies have been studied as well, with one study by Bray and colleagues showing a sensitivity of 94% and specificity of 99% for glass and metal objects embedded in a cadaveric hand.[4]

An outlier to these studies was one performed in 1996 by Manthey and colleagues to measure ultrasound detection of several types of foreign body, including gravel, metal, glass, cactus spine, wood, and plastic embedded in chicken thighs.[5] None of the participants achieved greater than 50% sensitivity in locating any of the foreign bodies. The highest sensitivity was found in the examination of the radiopaque objects (metal, gravel, glass) and the lowest in the radiolucent objects (wood and plastic). Cactus spines were never identified by ultrasound in this study but were found with plain radiography. It should be noted that the chicken thighs in this study were opened with hemostats to insert the foreign bodies. The damage to underlying tissue may have produced enough air artifact to obscure the ultrasound image.

Ultrasound has been compared head-to-head with other imaging modalities as well. A 2006 study by Turkcuer and colleagues compared the efficacy of radiography, using standard and soft-tissue techniques, and ultrasound in localizing wooden and rubber foreign bodies placed in chicken thighs.[6] This study found ultrasound to be clearly superior to the other modalities. The sensitivity for localizing these objects with ultrasound was reported as 90% versus 5% for both types of x-ray.

The studies discussed above utilized cadavers or chicken thighs to simulate living human tissue. Two other studies measured actual ultrasound detection of foreign bodies in patients.[7,8] The sensitivity achieved in these studies was impressive, ranging from 95% to 100%.

URGENT CARE IMPLEMENTATION

In most of the studies discussed in this article, radiologists or trained sonographers performed and interpreted the ultrasound examinations. This is not practical in urgent care settings. To maintain the convenient and expeditious nature of bedside ultrasound, physicians must have the technology and results readily available. This raises the question of how much training a physician needs in order to use ultrasound effectively.

Orlinsky and colleagues gave a group of emergency department residents with no prior ultrasound experience a 2-day basic ultrasound course.[3] These physicians then attended a 1-hour course on the use of ultrasound to detect foreign bodies, which was also attended by radiologists and trained sonographers. Afterward, all were asked to identify foreign bodies by ultrasound. The emergency physicians achieved 80% accuracy—statistically equivalent to the accuracy of the radiologists (83%) and the sonographers (85%).

Hill and colleagues compared the accuracy of an experienced emergency department physician with an inexperienced emergency department resident.[1] Both were given a 2-hour course specific to foreign body ultrasound and asked to identify wooden and plastic foreign bodies in amputated human limbs. Once again, accuracy was statistically similar (77% vs 70%). These studies confirm that nonradiologist physicians need only limited, focused training to learn and competently perform ultrasound for the detection of foreign bodies.

TECHNICAL FUNDAMENTALS AND TIPS

The basic principle of ultrasound is the use of a transducer to penetrate tissue with ultrasonic waves at various frequencies. When the waves strike a denser component of tissue, they bounce back (echo) to the transducer. The ultrasound machine can then interpret the speed and intensity of the sound waves to determine the location and composition of the object.

Structures are plotted on the screen based on their depth and location relative

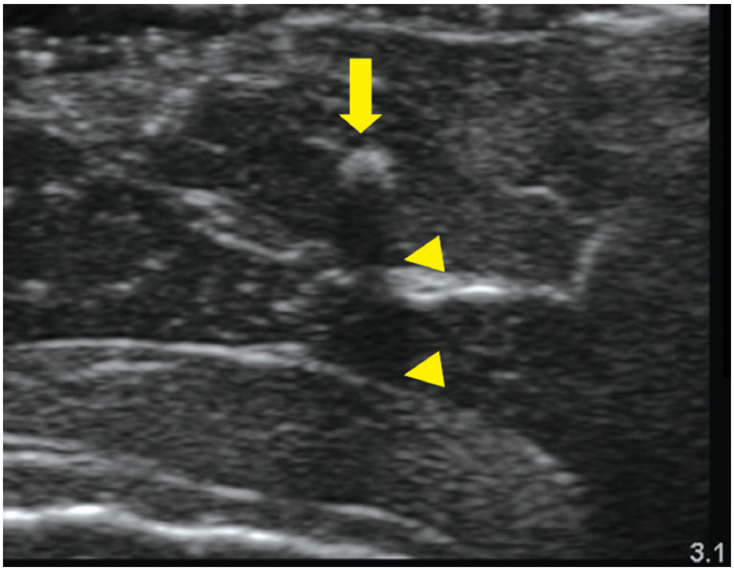

FIGURE 3a. Short-axis view of toothpick. Although the toothpick does not create a reverberation effect, a shadow artifact (arrowheads) can clearly be seen extending from it, helping to confirm that the object is a foreign body.

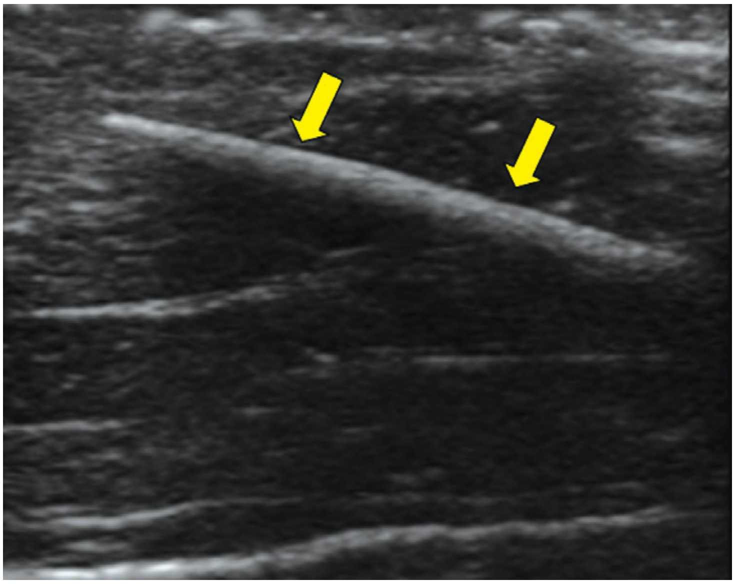

FIGURE 3b. Long-axis view of toothpick. The toothpick is identified as a hyperechoic structure (arrows) lying at an oblique angle in the tissue. As the toothpick is made of organic material, it does not create a reverberation artifact; however, the toothpick can be easily differentiated from the surrounding striations by its end points. Normal striations do not have finite ends and can be followed from the affected area. Shadowing can also be seen underneath the toothpick.

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to the transducer. The machine plots superficial structures at the top and deeper structures toward the bottom of the screen. Structures that are closer to the skin bounce waves back more quickly than do deeper structures. They are plotted closest to the top of the screen. Deeper objects appear lower on the screen.

The appearance of foreign bodies on the screen varies with the shape and density of the material. In general, metal, mineral, glass, wood, and rubber foreign bodies reflect sound, appearing white on the screen. The larger the surface area of the object that is facing the transducer, the more sound it will reflect. As Figures 3a and 3b demonstrate, if the tip of a toothpick is facing the transducer, only a small, easily overlooked point will appear on the screen, but if the same toothpick is aligned lengthwise, it will be seen as a larger and more visible area of white.

Dense objects, which reflect all sound, cause a black streak to appear behind them, an artifact called shadowing. The shadow demonstrates that no sound has penetrated through the object to reach the deeper structures. Shadowing is an important artifact. An object can be too small to see but big enough to produce a shadow that signals its presence.

The clarity of the image and the tissue depth it represents are determined primarily by the frequency of the transducer selected. A high-frequency (7 to 13 MHz) transducer is optimal for visualizing superficial foreign bodies, although its depth of penetration is limited. Most common ultrasound machines offer a high-frequency probe of 7.5 MHz.[1,9] This was used in many of the studies discussed here, but several authors noted that a greater sensitivity might be possible with use of a higher-frequency transducer (10 to 12.5 MHz).

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Extremely superficial structures test the imaging capacity of ultrasound. For example, the hands and feet have a relatively thin layer of overlying skin and soft tissue that makes differentiation of the most superficial structures difficult. Using a water bath improves resolution in very superficial (less than 1 cm deep) imaging. Submerge the affected body part in a basin of water and place the transducer into the water at a distance of 1 cm from the patient's skin. If the affected area cannot be submerged in a basin, a step-off pad or a gel- or water-filled cushion (such as a glove) positioned between the skin and the transducer will produce an equivalent improvement in the image.

Knowledge of normal anatomy and its typical appearance on ultrasound is essential, as some structures, such as bone or muscle striation, can be mistaken for a foreign body. Comparison with the unaffected side helps to distinguish normal from abnormal.

Identifying the various types of foreign bodies requires an understanding not only of the properties of ultrasound but also of the properties of the object itself.

Glass. Glass foreign bodies are among the easiest objects to identify via ultrasound. Being solid and without fluid content, glass foreign bodies echo almost all of the ultrasonic energy to the machine. Glass may also create a shadow artifact (Figure 2).

Wood. Wooden foreign bodies, such as toothpicks or splinters, are also seen as hyperechoic (white) objects owing to the relatively strong echo they produce. They may or may not produce a posterior shadow artifact, depending on their density. Other findings that might further confirm the presence of a wooden object are discussed below. The toothpick in Figures 3a and 3b shows the typical appearance of a wooden foreign body.

Metal. Metal objects are also readily apparent by ultrasound. They appear white and will frequently show shadowing artifact deep to the object. Another finding that may confirm localization of a metallic foreign body is called reverberation artifact, which appears when the ultrasound beam strikes a strongly echogenic structure. Larger metallic objects, such as needles or bullet fragments, may cause recurrent bright arcs to appear deep to a strongly echogenic structure, while smaller ones, such as a metal pellet, are likelier to generate the similar—but smaller and more focal—artifact known as a comet tail. Figures 4a and 4b illustrate a metal foreign body.

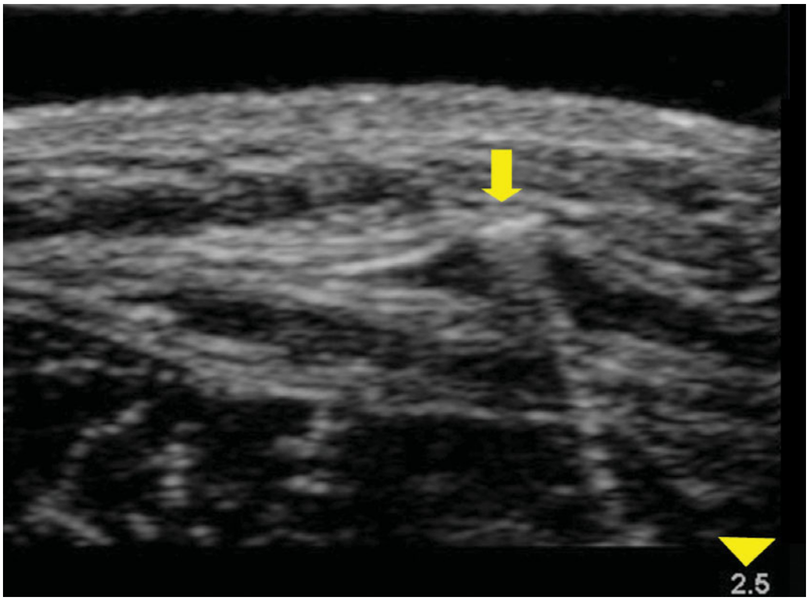

FIGURE 4a. Visible nail head. The thick head of a nail (arrow) embedded in a patient's calf is seen as a bright hyperechoic line perpendicular to the body of the nail. Noting its position may facilitate removal of the object, as the head of the nail may be easier to identify within the tissue on visual inspection. Note that in this image the overall depth has been decreased to clarify the superficial area and to aid in visualization of the foreign body (see the depth marker on the bottom right of the screen) (arrowhead).

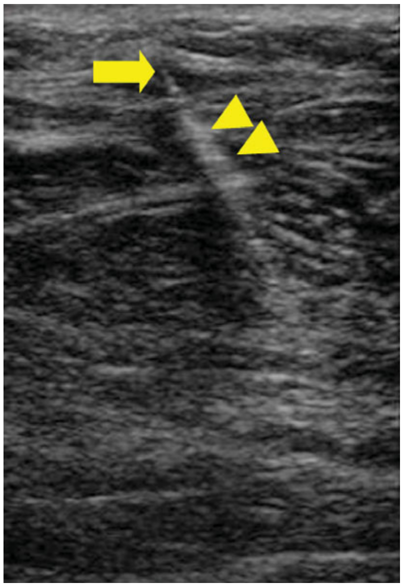

FIGURE 4b. Long-axis view of the nail. Imaged along its long axis, the embedded nail is easily identified as a hyperechoic (white) object (arrow). The nail may at first glance resemble striations in normal muscle, but closer inspection reveals that it is at an almost perpendicular angle to the other striations. Also, some reverberation artifact can be seen around the object (arrowheads).

Gravel. Gravel or stone objects are easily identified by ultrasound because their anterior surface produces a strong echo, resulting in a bright white structure seen on the screen. These objects also produce a strong black shadow behind them.

The longer an object has been present in the tissue, the greater the host inflammatory response. The inflammation will be seen with ultrasound as a black rim of fluid around the foreign body. This finding is especially helpful when looking for wooden objects, as these usually do not produce a strong shadow and can thus be more difficult to differentiate from normal tissue. There may be no evidence of inflammation, however, in acute cases in which the foreign body has only been present for a short time.

FOREIGN BODY REMOVAL

Ultrasound facilitates the removal of foreign bodies using either of two techniques performed on anesthetized tissue.

The first technique involves visualizing the object in its long axis by ultrasound. A sterile needle is then introduced under real-time ultrasound guidance until its tip touches that of the foreign body. The needle will often appear hyperechoic with reverberation effect. Movement of the skin and surrounding tissue can be seen as the needle is advanced. The physician feels the needle strike the foreign body, incises around the needle, and dissects toward the needle tip, where the foreign object will be found.

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Inflammation will be seen with ultrasound as a black rim of fluid around the foreign body.

In the second technique, two needles are used. Once again, the object is visualized in its long axis. One needle is inserted as above, followed by the insertion of a second sterile needle under ultrasound guidance at a 90° angle to the first. The retrieval then proceeds as above, with incision over the intersection of the two needles to locate the foreign bodies. One study compared these two methods and found that using two needles resulted in a more rapid retrieval of the object and less need to extend the initial incision.[10]

The identification, localization, and retrieval of a foreign body remains challenging. Although plain radiographs have been used in the past with some success, ultrasound localizes a broader spectrum of objects. It has been demonstrated that the technique of ultrasound-guided localization of foreign bodies can be quickly learned by novice physicians. Ultrasound improves not only identification but also retrieval of embedded objects, making it an excellent aid for managing patients in whom a foreign body is suspected. □

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