Detection of Soft Tissue Foreign Bodies in the Presence of Soft Tissue Gas

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**Objective.** To determine the effect of soft tissue gas on the accuracy of foreign body detection by real-time sonography. **Methods.** This was a prospective randomized study using glass, metal, and bone inserted into turkey breasts to simulate human soft tissue foreign bodies. Air was subsequently injected around a random selection of the foreign bodies to simulate soft tissue gas that can accompany a blast or high-force injury. Using a linear transducer, physicians credentialed in the use of sonography were each asked to scan the breasts, identify the location of any foreign body, and describe whether the object located was bone, metal, or glass. They were also asked to describe the characteristics of the foreign body, including surface echogenicity, visibility, and artifacts, if any. **Results.** The sensitivity for localization of each foreign body by each sonographer was 100% (48 of 48) and was unaffected by the presence of soft tissue gas. The accuracy of classifying the foreign body was poor except with bone. Glass and metal were often confused with each other. With the addition of soft tissue gas over the foreign bodies, the sensitivity of classifying the foreign body was decreased further from a combined 58% to 28%. The presence of soft tissue gas decreased the amount of reflection of the foreign body and obscured the subtle differences in the brightness of each foreign body, leading to a decrease in the accuracy of identification but not localization of the foreign body. **Conclusions.** In an experimental model, soft tissue gas does not affect the localization of soft tissue foreign bodies. However, correct identification of the type of foreign body is limited by soft tissue gas because of loss of the typical sonographic characteristics. **Key words:** crepitus; emergency sonography; foreign body; soft tissue gas; sonography.

Sonography is currently used extensively in many medical centers across the country for the evaluation and treatment of a wide variety of patient conditions. The use of sonography at bedside in the evaluation of acutely ill patients is increasing due to improvement in sonographic technology, increased availability of equipment, and the increasing mobility of individual units. In patients in an emergency department, sonography is used to evaluate a variety of pathologic conditions, including torso trauma, obstetric and gynecologic emergencies, abdominal pain, acute scrotum, and extremity thrombosis, among others.¹⁻³
Many superficial applications for sonographic examination have been explored. Among these is a frequently encountered problem in the emergency department: the detection of soft tissue foreign bodies. Foreign bodies come in many different shapes and sizes and typically consist of wood, glass, and metallic splinters. Finding a foreign body can be quite challenging because most superficial foreign bodies are removed by the patient, leaving the physician to deal with deeper and larger foreign bodies. If unrecognized, a retained foreign body may lead to complications such as inflammation, infection, toxic reactions, and foreign body granulomas. A variety of diagnostic modalities are available for the detection of foreign bodies, including plain radiography, sonography, computed tomography, fluoroscopy, and magnetic resonance imaging. Plain radiography remains the most commonly used imaging study for the evaluation of foreign bodies despite the fact that it will miss radiolucent objects such as wood splinters and some types of glass. Computed tomography can detect radiolucent foreign bodies but has many limitations, such as cost, the use of ionizing radiation, and poor sensitivity for small foreign bodies, all of which limit its role. Magnetic resonance imaging is also used in the evaluation of both radiolucent and radiopaque foreign bodies. However, an increased relative cost, limited availability, concern regarding magnetic foreign bodies, and limited accessibility for some patient populations are disadvantages of the use of magnetic resonance imaging.

Sonography has been shown to be accurate in the detection of both radiopaque and radiolucent foreign bodies and offers several advantages over other imaging techniques. Orlinsky et al compared the performance of sonography at the bedside for detecting a wooden foreign body in chicken thighs and showed good correlation between sonologists of different training backgrounds. Recent studies have shown the potential use of sonography in unique situations such as extremity gunshot wound evaluation, in which locating a bullet under the skin can help elucidate the extent of soft tissue injury and even suggest the likelihood of pneumothorax if the wound is near the chest.

Evaluation of traumatic wounds such as those resulting from a gunshot are far different from previous laboratory evaluations of the ability of physicians to simply locate the foreign body using sonography. More commonly occurring in practice is the potential for the presence of several foreign bodies simultaneously. For example, a wound resulting from a gunshot can have fragments of bone, metal (actual bullet), pieces of clothing, and gas present. Previous studies have evaluated the accuracy of sonography in the detection of soft tissue foreign bodies, but, to our knowledge, none have evaluated this ability in the presence of soft tissue gas. We sought to determine the effect of air (soft tissue gas) on the accuracy of foreign body detection by real-time sonography. Three different types of foreign bodies were placed in turkey breasts to simulate foreign material in human tissue. Metal, bone, and glass fragments were used because they are among the most common soft tissue foreign bodies encountered.

Materials and Methods

This was a prospective randomized study to determine the effects of tissue gas on the detection of soft tissue foreign bodies. Thawed turkey breasts were chosen to simulate human soft tissue. The breasts ranged from 15 to 20 mm in thickness. Foreign body materials used were clear glass, metal, and chicken bone. Glass fragments were approximately 5 mm in length and approximately square, with the larger sides being flat and parallel. The metal pieces were obtained by cutting flat 1-mm-thick washers into approximately 5-mm lengths. Bone was obtained from the leg of a chicken and was cut to approximately 5-mm rectangles consisting of cortex only and about 1 mm thick.

Four fragments were randomly embedded into each of 4 thawed turkey breasts. The loading of fragments was performed in a water bath to prevent unintended introduction of air into the tissue. Fragments were placed at depths ranging from 5 mm to 1.0 cm with emphasis on placing the largest surface area of the fragment parallel to the surface of the turkey breast. Ten milliliters of air was introduced through a 25-gauge needle anterior (between the surface used for sonography and the foreign body) into the soft tissue randomly in half of the foreign bodies. Bone was obtained from the leg of a chicken and was cut to approximately 5-mm rectangles consisting of cortex only and about 1 mm thick.

Each breast was laid flat on a sheet of absorbent material, which was in turn placed on an aluminum push cart. Each breast was num-
bered 1 through 4 from top to bottom. An HDI 4000 system (Phillips Medical Systems, Bothell, WA) and a broadband linear array transducer with a frequency range of 5 to 12 MHz on the small parts setting was used by all sonologists.

Three physicians with hospital credentialing in the performance and interpretation of sonography were each asked to scan the breasts, identify the location of the foreign body, and describe whether the object they were looking at was bone, metal, or glass. They were also asked to describe the characteristics of the foreign body, including surface echogenicity, visibility, and acoustic shadowing. All 3 physicians had experience with bedside sonographic evaluation of patients with trauma and vascular and superficial injuries. Each sonologist entered the room, placed the ultrasonic transducer on the breast, made their observations, and then left the room without having contact with any other sonologist. All interpretations were made by subjects directly from the monitor on the HDI 4000 system. Subjects were blinded to the foreign body location and type and the presence of gas. All interpretations were recorded sequentially, and the identification of the foreign bodies was not revealed to the subject until completion of the experiment. There was no time limit placed on the sonologist in the completion of the examination, and the sonologists were allowed to manipulate the sonographic settings as desired to find and interrogate the foreign body.

Results

The sensitivity for the localization of each of the foreign bodies by each sonologist was 100% (48 of 48) and was unaffected by the presence of soft tissue gas. The sensitivity in the classification of the foreign bodies is described in Table 1, and accuracy differences were present for all sonologists with no significant differences among them. The accuracy of classifying the foreign body was poor except with bone as the foreign body. Most frequently, the glass and metal were mistaken for each other, with both being described as strong reflectors with shadowing (Figures 1A and 2A). Both the metal and glass foreign bodies were described as having similar sonographic characteristics (ie, reverberation, a ring-down artifact, and dense shadowing). Bone was correctly identified every time and was described as a bright reflection with a deep, dense shadow and no artifact (Figure 3A).

### Table 1. Accuracy, Sensitivity, and Specificity in the Classification of Foreign Bodies

<table>
<thead>
<tr>
<th>Foreign Body</th>
<th>Accuracy, %</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>64</td>
<td>41</td>
<td>75</td>
</tr>
<tr>
<td>Glass</td>
<td>69</td>
<td>33</td>
<td>81</td>
</tr>
<tr>
<td>Bone</td>
<td>94</td>
<td>100</td>
<td>93</td>
</tr>
<tr>
<td>With air</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>78</td>
<td>0</td>
<td>93</td>
</tr>
<tr>
<td>Glass</td>
<td>64</td>
<td>17</td>
<td>73</td>
</tr>
<tr>
<td>Bone</td>
<td>81</td>
<td>67</td>
<td>85</td>
</tr>
</tbody>
</table>

Figure 1. A, Glass without the interference of soft tissue gas (arrows). B, Glass with soft tissue gas over it (arrows). The artifact produced (arrowheads) and the foreign body itself are much less clearly shown.

Figure 2. A, Metal without the interference of soft tissue gas (arrows). B, Metal with soft tissue gas over it (arrows). The artifact produced (arrowheads) and the foreign body itself are much less clearly shown.

Figure 3. A, Bone without the interference of soft tissue gas (arrows). B, Bone with soft tissue gas over it (arrows).
With the addition of soft tissue gas, the sensitivity of classifying the foreign body was decreased from a combined 58% to 28%. The presence of soft tissue gas decreased the amount of reflection of the foreign body and obscured the subtle differences in the brightness of each of the foreign bodies (Figures 1B, 2B, and 3B). The presence of soft tissue gas also decreased the amount and occasionally the presence of reverberation and a ring-down artifact with the glass and metal foreign bodies, and thus they were more frequently confused with bone.

Discussion

Plain radiography is the most commonly used method of detecting soft tissue foreign bodies in patients undergoing emergency evaluation. However, sonographic evaluation for soft tissue foreign bodies has several advantages over plain radiography. Unlike plain radiography, sonography has a high sensitivity in detecting both radiopaque and radiolucent foreign bodies. Sonographic examination is accurate in predicting the size, exact location, depth, and 3-dimensional structure of the foreign bodies.14 In addition, and more importantly, sonography can show the relationship of the foreign body to adjacent soft tissue structures such as tendons, vessels, and muscle.14 Unlike plain radiography, sonography can also be used in real time to evaluate the location of a foreign body while attempting removal.

Previous studies have shown that metal, glass, and wood foreign bodies produce distinct sonographic images in experimental models.15 Typically, metal produces a distinct and dramatic linear trail of echoes known as a comet tail artifact.15 Glass typically produces a linear series of bright echoes along the path of the foreign body. In contrast, wooden soft tissue foreign bodies produce a discrete acoustic shadow without an artifact.15 In actual patients with trauma such as a gunshot wound, the sonographic picture may be quite a bit more complicated because more than 1 foreign body type may be introduced at once, such as glass, bone, metal, and air. Crawford and Matheson14 showed that soft tissue conditions such as cellulitis with edema or pus can decrease the accuracy in predicting the size of the foreign body as well as decrease the sensitivity of detecting a foreign body. Although not studied directly, it has been postulated that soft tissue air could pose a potential source of error when searching for foreign bodies, as can occur with penetrating projectiles. Air typically produces a sonographic pattern of bright echoes and complex shadowing that can be confused with a foreign body.16 In addition, the “dirty” shadowing produced by soft tissue air can obscure the actual foreign body itself.16 The obstructing dirty shadowing from gas is due to the refracting properties of small gas bubbles and the high impedance of a gas. This leads to an attenuation of the signal deep to the gas, limiting the amount of sound signal available for reflection from the foreign body. If the attenuation is great enough, the distal foreign body may be completely obscured by shadowing resulting from the gas bubbles.

As shown in our study, the effects of soft tissue gas can be minimized by experienced sonologists by altering the gain, probe angle, and other sonographic techniques. The sensitivity in detecting the foreign bodies was not degraded by the soft tissue gas. However, the soft tissue gas did affect the typical echo pattern of each of the foreign bodies, which led to confusion in the identification but not in the presence of the foreign body. Thus, searches for traumatic foreign bodies such as in gunshot wounds are not without utility, even when air may have been introduced.

The turkey breast model has been used in many prior studies and has been proven to be a good in vitro model for studying foreign body fragments with sonography.15,16 The tissue echo texture is similar to that of the human extremity muscle tissue, which was one of the objectives of simulation in this study.16 There are several limitations to this study. The use of 10 mL of air as the source of the soft tissue gas was arbitrarily chosen; however, this amount was thought to be appropriate to the size of the foreign body. As evidence of this, the soft tissue gas was apparent during the sonographic study independent of the foreign body. It could be argued that more or less air could be introduced into the tissues depending on the mechanism of soft tissue injury. Another limitation of this model is that because skin was not present on the turkey breast, subcutaneous air could not be simulated. However, if subcutaneous emphysema were present in vivo, it would be easily detected by physical examination. The effect from this subcutaneous air has not been studied, but this may not cause any more interference than the intramuscular air used in this study.
In conclusion, in this experimental model, soft tissue gas did not affect the localization of soft tissue foreign bodies. However, the identification of the type of foreign body is obscured by soft tissue gas because of loss of the typical sonographic characteristics seen with various foreign bodies.

References