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Original Contribution

Ultrasound for the evaluation of soft tissue foreign bodies before and after the addition of fluid to the surrounding interstitial space in a cadaveric model☆,☆☆

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ABSTRACT

Background: Point-of-care ultrasound may be used to facilitate foreign body (FB) localization and removal. We hypothesized that injection of normal saline adjacent to an FB may make it easier to detect.
Methods: The study was performed on one embalmed human cadaver. Potential FB sites were created of wood (24), metal (24), and null (24). Two sonographers evaluated each of the 72 sites both before and after a 25-gauge needle was inserted into each incision and 3 cc of normal saline was injected. Accuracy, sensitivity, and specificity were calculated both before and after injection of normal saline. Binomial tests were used to determine the statistical significance of FB detection before and after injection. A 2-tailed Student's *t* test was used to determine if there was a statistically significant difference between the 2 methods.
Results: Preinjection, 116 (81%) of the 144 interpretations ($P \le .001$) were correct in their assessment of whether or not an FB was present, with a sensitivity of 81% (95% confidence interval [CI], 72%-88%) and a specificity of 79% (95% CI, 65%-90%). Postinjection, 119 (83%) of these 144 interpretations ($P \le .001$) were correct in their assessment of whether or not an FB was present, with a sensitivity of 85% (95% CI, 77%-92%) and a specificity of 77% (95% CI, 63%-88%). This difference was not significant ($P = .08$; 95% CI, −0.04 to 0.01).
Discussion: Ultrasound was reasonably accurate, sensitive, and specific in identifying 1-cm metal and wood FBs. Although accuracy and sensitivity did improve after normal saline injection, this difference was not significant.

1. Introduction

Subcutaneous foreign bodies (FBs) are a common chief complaint in the emergency department. Some FBs are not easily visualized during physical examination, and if left undetected, an FB can cause delayed wound healing and infection. When occult FB is suspected, the area may require evaluation with diagnostic imaging, which can include plain radiograph, computed tomography (CT), magnetic resonance, or ultrasound. Organic material such as wood, however, is not radio-opaque and may not be detected on plain radiographs or CT [1,2]. Point-of-care ultrasound has several potential advantages over these other imaging modalities: it does not use ionizing radiation, it is capable of visualizing FBs of varying densities [3–4], it has a lower cost than CT or magnetic resonance, and it may be used in real time at the bedside to directly facilitate FB localization and removal.

Various foreign materials differ in how easily they are visualized sonographically. For example, metal FBs are associated with acoustic shadowing and a characteristic "ring down" artifact caused by the blockage and reverberation of the ultrasound waves. Organic matter such as wood, however, has a similar sonographic appearance to soft tissue and can thus be more difficult to detect. Therefore, we sought to identify a way to enhance the sonographic appearance of organic FBs that would allow for more accurate sonographic detection.

We hypothesized that fluid in the soft tissue might have this effect. Fluid is an excellent medium for the transmission of ultrasound waves. In the soft tissue, interstitial fluid can outline or create anechoic or hypoechoic halos around structures. In addition, fluid can cause the tissue to swell, increasing the space between the surface of the probe and structures of interest deep to the skin surface. This can move the area of interest further out of the dead zone (distance between transducer and the first identifiable echo) and closer to the

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focal zone (the most focused area of the ultrasound beam resulting in the highest image resolution).

Objectives

The objectives of this study were to determine the test characteristics of sonographic detection of FBs and to determine if injecting fluid into the soft tissue in the area of a suspected FB changed these test characteristics. Because organic material does not have as many artifactual clues as metal, we hypothesized that this difference, if present, would be more pronounced with wood FBs than with metal FBs.

2. Methods

This was a prospective observational study performed in a gross anatomy laboratory on the lower extremities of a single embalmed human cadaver. This study was exempt from institutional review board approval. The FBs were created from toothpicks (wood) and 21-gauge needles (metal). Each FB was approximately 1 cm in length and 1 to 3 mm in width. A pilot experiment of FB detection in a similar setting (FB inserted into porcine tissue, data not presented) showed an overall accuracy of FB detection of 73.9%. A power calculation based on this result determined that 48 FB test sites and 24 null sites were required in order to achieve a 95% confidence interval (CI) for sensitivity and specificity. Because it is not known whether metal and wood would be equally detectable, we included 24 pieces of each of the 2 materials.

The cadaveric specimen was positioned supine and the FB test sites were marked on the lower extremities by outlining 72 sectors with a skin-marking pen. Seventy-two incisions, each 2 cm in length, were made in the skin, and the FBs were inserted with a needle driver to a depth of approximately 1 cm. Each was inserted at an angle of approximately 45° with the intent to replicate how the FB might enter the skin in a real-world scenario (Fig. 1). For each of the null sites, a needle was inserted into the incision 1 cm into the deeper tissues, manipulated in a manner similar to those in which the FBs were inserted, and then removed.

The pattern of FB placement was determined using a computerized random sequence generator (www.random.org). Half of the FBs were placed by the primary investigator (T.S.), an emergency ultrasound fellowship–trained attending physician, and half were placed by an emergency ultrasound fellow (A.B.D.).

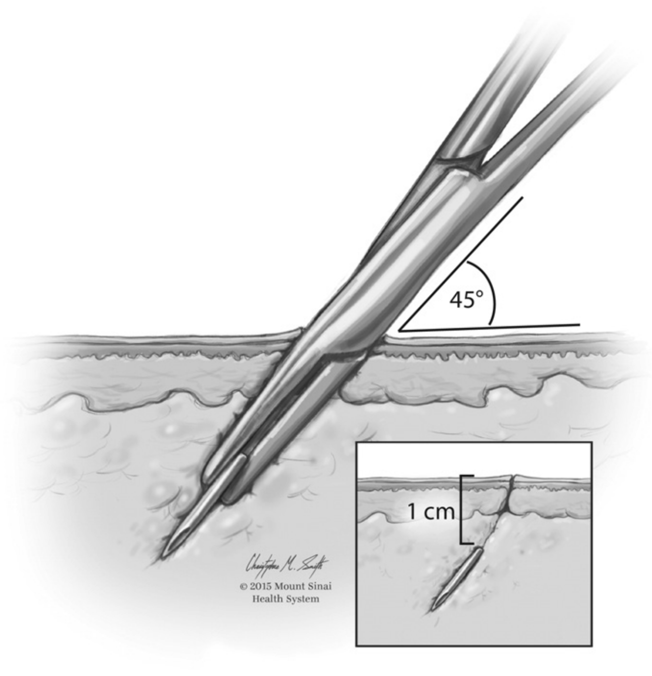

Fig. 1. Foreign body insertion at a 45° angle using a needle driver.

2.1. Measures

Two emergency ultrasound fellowship–trained physician sonographers (G.R., S.D.S.) performed the scan protocol. Sonographers had each previously performed a minimum number of 175 ultrasound studies, meeting the recommendations of the American College of Emergency Physicians 2008 policy statement [5]. This included at least 10 scans in soft tissue/musculoskeletal ultrasound but did not include any specific requirements for the identification of FBs. Two Sonosite Edge (Bothell, WA) ultrasound machines were used with L38 10-5 MHz linear transducers. The machines were set to the MSK setting and the multifrequency probes were set to resolution. The sonographers were permitted to adjust the depth and gain to their preference and to use as much conducting gel as desired. The sonographers were blinded to specimen preparation as well as to the frequency of FBs, the frequency of type of FBs, and the pattern of the FBs. Sonographers documented the presence or absence of an FB on a data sheet. Each sonographer worked independently and was blinded to the other sonographer's data sheet.

After the 2 sonographers completed the evaluation of each of the 72 FB sites, T.S. and A.B.D. inserted a small 25-gauge needle to a depth of 1 cm into each incision in the same direction as the FB had been inserted, and injected 3 cc of normal saline into the tissue. The sonographers then evaluated all 72 sites again and recorded their findings on the data sheet.

2.2. Data analysis

Accuracy, sensitivity, and specificity were calculated for the FBs both before and after injection of normal saline. These test characteristics were also calculated after stratifying by FB type. Diagnostic test evaluation was performed using MedCalc online statistical software (MedCalc Software bvba, Ostend, Belgium). Binomial tests were used to determine the statistical significance of FB identification both before and after injection. A 2-tailed student's t test was used to determine if there was a significant difference between the 2 methods.

3. Results

Preinjection, the 72 sites were evaluated by the 2 sonographers, for a total of 144 interpretations. Of the 144 (81%) interpretations ($P \leq .001$), 116 were correct in their assessment of whether or not an FB was present, with a sensitivity of 81% (95% CI, 72%-88%) and a specificity of 79% (95% CI, 65%-90%; Figs. 2 and 3). After the injection of 3 cc of normal saline into each site, the 2 sonographers evaluated the 72 sites a second time. One hundred nineteen (83%) of these 144 interpretations ($P \leq .001$) were correct in their assessment of whether or not an FB was present, with a sensitivity of 85% (95% CI, 77%-92%) and a specificity of 77% (95% CI, 63%-88%; Figs. 4 and 5). Accuracies, sensitivities, and specificities for each FB type both before and after injection can be found in the Table.

There was no statistically significant difference found between the preinjection and postinjection sonographic evaluations ($P = .08$; 95% CI, -0.04 to 0.01).

4. Discussion

Previous studies of point-of-care sonographic detection of FBs have been in deceased animal tissue (e.g., chicken legs) [6] or human cadaveric tissue [7,8] with varying results. Orlinsky et al [6] implanted wooden toothpicks in 104 chicken thighs. Three emergency medicine physicians, 2 ultrasound technologists, and 1 radiologist performed