

The Comparative Accuracy of Radiolucent Foreign Body Detection Using Ultrasonography

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The purpose of this prospective study was to determine the accuracy of ultrasonography in detecting radiolucent foreign bodies and to compare the performance of three newly trained emergency physicians with two experienced ultrasound technologists and one radiologist. One hundred-four chicken thighs were penetrated with a needle-driver, half of them embedded with a 1.5 cm toothpick. An 8.0 MHz linear array ultrasound probe was used to detect the presence or absence of the foreign body. The overall accuracy (95% confidence interval [CI]) was 82% (79, 85); sensitivity 79% (74, 83), specificity 86% (82, 90), positive predictive value (PPV) 85% (81, 89), and negative predictive value (NPV) 80% (76, 84). The accuracy (95% CI) of the radiologist was 83% (75, 90); of the ultrasound technologists was 85% (80, 90); and of the emergency physicians was 0% (76, 85). The difference in accuracy among the three types of personnel was not statistically significant. Ultrasonography is an accurate modality in detecting radiolucent foreign bodies. Emergency physicians can be trained to provide a degree of accuracy comparable with more experienced ultrasonographers. (*Am J Emerg Med* 2000;18:401-403. Copyright © 2000 by W.B. Saunders Company)

Detection of retained foreign bodies in the soft tissues remains a significant problem in the emergency department. Foreign bodies may go undetected¹ causing inflammatory, allergic, and infectious complications.² Undetected foreign bodies are a leading cause of malpractice suits.³ Of the available imaging options, plain radiography is the most widely available but detects only radiopaque foreign bodies.^{4,5} Xeroradiography provides better edge enhancement, but it requires special equipment and is inadequate in detecting radiolucent foreign bodies.^{1,4,6,7} Computed tomography (CT) can detect radiolucent foreign bodies, but it has limitations because of cost, radiation, and sensitivity.^{4,6,8,9} Magnetic resonance imaging (MRI) can also detect radiolucent foreign bodies, but it is too inaccessible and expensive.⁶ On the other hand, ultrasound causes no radiation exposure, provides real time imaging, and can be done at the bedside. Ultrasound has shown promising results, particularly in

detecting radiolucent foreign bodies.^{8,10-19} However, these studies lack one or more of the following: appropriate models, statistical power, blinding and controls, adequate transducer frequencies, multiple readers, or different types of sonographers.

We conducted this experiment to evaluate the diagnostic accuracy of ultrasonography in detecting radiolucent foreign bodies and compare the performance of newly trained emergency physicians with experienced ultrasound technologists and a radiologist.

METHODS

Three senior emergency medicine residents, two credentialed ultrasound technologists, and one board-certified radiologist whose practice is limited solely to ultrasonography participated in the experiment. The three emergency physicians had no prior experience in ultrasonography. Each attended a standardized 2-day ultrasound course consisting of 16 hours of instruction, equally divided into didactic and practical hands-on sessions. The course content was based on the Society of Academic Emergency Medicine (SAEM) guidelines for emergency ultrasound. All participants, including the ultrasound technologists and radiologist, attended a 1-hour foreign body detection training session. The course and training session were under the direction of one of the authors (D.M.), whose credentials include exceeding the SAEM guidelines for emergency ultrasound training and leading similar workshops both nationally and internationally for the past 5 years.

Preparation of Experimental Subjects

Intact, fresh, unfrozen chicken thighs with skin and bone were used as experimental subjects. This model has been shown to simulate the different fascial planes of human subcutaneous tissue and the muscles, tendons, and bone which lie underneath.²⁰ All experimental subjects were prepared by one of the investigators. An incision of approximately 1 cm was made into the skin of each chicken thigh using a scalpel. A needle-driver was used to penetrate the chicken thigh approximately 1 to 1.5 cm deep. For the group with foreign bodies, a rounded, tapered toothpick segment measuring 1.5 cm in length and 2 mm to 5 mm in diameter was placed during this process. For the control subjects, no toothpick segment was placed. To more closely simulate the different ways in which foreign bodies can penetrate the soft-tissue, the study included three orientations of the placement of the toothpick with respect to the skin surface: parallel, oblique, or perpendicular. The preparation of all experimental samples was completed in the morning of the study.

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Presented in abstract form at CAL/ACEP, Monterey, CA June 1998; the ACEP Research Forum San Diego, CA, October 1998.

Manuscript received August 20, 1999, returned September 13, 1999, revision received November 11, 1999, accepted November 22, 1999.

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Key Words: Ultrasound, ultrasonography, foreign body, radiolucent.

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0735-6757/00/1804-0009\$10.00/0
doi:10.1053/ajem.2000.7315

Study Procedure

A total of 104 chicken thighs were used in the study. A randomized scheme was generated to balance the three types of orientation and the number of experimental and control samples. The prepared samples were randomized and were divided into two sets of 52, one set for each ultrasound machine. The order in which the participants would scan and at which machine they would scan first was also randomized.

Each ultrasound machine had an 8.0 MHZ linear array ultrasound transducer. Each participant used real-time ultrasonography to detect the presence of the foreign body. They were allowed to manipulate the transducer and adjust the depth and gain to make the most accurate decision and to manipulate the chicken to achieve the best view. The presence or absence of the foreign body in each chicken thigh was recorded by each participant onto a predesigned data sheet. Indeterminate choice was allowed. Each participant performed the scan independently and in privacy.

This study was granted exemption status by our Institutional Review Board.

Statistical Analysis

The overall percent of accurate detection (accuracy), percent of correct detection when the foreign body was present (sensitivity), percent of correct detection when the foreign body was absent (specificity), percent of correctly detected presence of the foreign body (positive predictive value, PPV), and percent of correctly detected absence of the foreign body (negative predictive value, NPV) were derived for each of the six participants and for each type of personnel. Ninety-five percent CIs were derived using the normal distribution. The accuracy of each participant and of each type of personnel was tested using the test of proportions. The difference between sensitivity and specificity for each participant or each type of personnel was tested for significance using McNemar's test of symmetry. Procedure BMDP04F of the BMDP statistical package was used for the analysis. The statistical program used to calculate kappa values was the MAGREE macro of SAS (Statistical Analysis System, Cary, NC).

RESULTS

Table 1 presents the accuracy, sensitivity, specificity, PPV, and NPV of detection of radiolucent foreign bodies by

ultrasonography. The overall accuracy was 82%; varying from 80% for the emergency physicians, to 83% for the radiologist, and to 85% for the ultrasound technologists. The difference in accuracy among the three types of personnel was not statistically significant ($P = .42$). There was moderate interobserver agreement between the two ultrasound technologists, with accuracies of 84% and 86% ($\text{kappa} = 0.52$; 95% CI: 0.38, 0.66). There was also moderate interobserver agreement among the three emergency physicians, with accuracies of 77%, 80%, and 84% ($\text{kappa} = 0.42$; 95% CI: 0.31, 0.53).

Comparing sensitivity and specificity, the radiologist and the two ultrasound technologists performed at similar levels whether the foreign body was present or absent. However, all three emergency physicians were more likely to detect absence of foreign body than presence of the foreign body (McNemar's test of symmetry P value $< .01$).

DISCUSSION

An accuracy rate of 82% to detect a radiolucent foreign body is comparatively better than findings in other studies. Manthey et al²⁰ in their study using 120 chicken thighs with 10 containing wood, showed only a 50% sensitivity in detecting wood foreign bodies. Our finding that ultrasonography is a promising modality for detecting retained soft-tissue foreign bodies is consistent with findings of previous studies,^{8,10-19} using chicken models, beef cubes, cadaver hands, or amputated legs. This study also showed that emergency physicians could be trained to perform the task. Given the accuracy achieved by the radiologist (83%) and the ultrasound technologists (85%) to represent the degree of accuracy achieved by the experienced reader, the emergency physicians' 80% accuracy was very close to their more experienced colleagues.

The use of ultrasonography in the emergency department to detect and eventually remove foreign bodies by emergency physicians is an important issue because there is not always an ultrasound technologist or radiologist available 24 hours a day. It is likely more efficient, practical, and medically beneficial to treat the patients while they are in the emergency department rather than having them return hours or even days later to deal with the problem when another

TABLE 1. Accuracy of Detection of Radiolucent Foreign Bodies by Ultrasonography

Personnel	Accuracy (95% CI)	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Radiologist	83 (75, 90)	83 (72, 93)	83 (72, 93)	83 (72, 93)	83 (72, 93)
US technician 1	86 (78, 97)	88 (78, 97)	85 (74, 95)	86 (76, 96)	87 (77, 97)
US technician 2	84 (77, 91)	82 (71, 93)	86 (76, 96)	85 (75, 95)	82 (72, 93)
Emergency MD1	80 (72, 88)	70 (57, 83)	90 (82, 98)	88 (77, 98)	75 (65, 86)
Emergency MD2	77 (69, 85)	69 (57, 82)	84 (74, 94)	82 (70, 93)	73 (62, 84)
Emergency MD3	84 (77, 91)	82 (72, 93)	87 (77, 96)	86 (76, 96)	83 (73, 93)
Radiologist	83 (75, 90)	83 (72, 93)	83 (72, 93)	83 (72, 93)	83 (72, 93)
US technicians	85 (80, 90)	85 (78, 92)	85 (78, 92)	86 (79, 93)	84 (77, 92)
Emergency MD\$	80 (76, 85)	74 (67, 81)	87 (82, 92)	85 (79, 91)	77 (71, 83)
Overall	82 (79, 85)	79 (74, 83)	86 (82, 90)	85 (81, 89)	80 (76, 84)

staff would be available to perform the ultrasound. Cost-effectiveness studies are highly encouraged.

Several aspects of our experimental procedure are worth discussing in light of possible improvements when designing future studies or comparing our results with other studies. Chicken thighs are not exactly the same as human tissues. The level of accuracy in our study may not be comparable with studies using other experimental models, although our findings comparing the relative performances of the three types of personnel would not be affected. Of interest, the use of amputated human limbs has been shown to cause potential problems (false-positive results) because of vascular calcifications.¹³ Additionally, our study used only one radiologist. Future comparative studies could be improved by having an equal number (more than one) of each type of participant.

Our study was completed in 1 day. Toward the end of the day, participants showed signs of fatigue and the skin of chicken thighs began to dry out. Furthermore, each piece of chicken thigh was handled six different times and therefore, it is possible that the toothpick segment might have been disrupted. It is our recommendations that the experiment be performed in several days of shorter duration and that fresh chicken thighs be used daily.

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