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# Rapid Detection of Traumatic Effusion Using Surgeon-Performed Ultrasonography

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### Abstract

Background: In the injured patient, rapid assessment of the thorax can yield critical information for patient management and triage.

Objectives: The objectives of this prospective study were (1) to determine if experienced surgeon sonographers could successfully use a focused thoracic ultrasonographic examination to detect traumatic effusion, and (2) to compare the accuracy and efficiency of ultrasonography with supine portable chest radiography.

Methods: Surgeon-sonographers performed thoracic ultrasonographic examinations on patients with blunt and penetrating torso injuries during the Advanced Trauma Life Support secondary survey. All patients also underwent portable chest radiography. Performance times for ultrasonography and chest radiography were recorded. Comparisons were made of the performance times and accuracy of both tests in detecting traumatic effusion.

Results: In 360 patients, there were 40 effusions, 39 of which were detected by ultrasonography and 37 of which were detected by chest radiography. The 97.5% sensitivity and 99.7% specificity observed for thoracic ultrasonography were similar to the 92.5% sensitivity and 99.7% specificity for portable chest radiography. Performance time for ultrasonography was significantly faster than that for chest radiography (1.30 +/- 0.08 vs. 14.18 +/- 0.91 minutes, p < 0.0001).

Conclusion: Surgeons can accurately perform and interpret a focused thoracic ultrasonographic examination to detect traumatic effusion. Surgeon-performed thoracic ultrasonography is as accurate but is significantly faster than supine portable chest radiography for the detection of traumatic effusion.

Key Words: Ultrasonography, Traumatic effusion, Chest radiograph, Surgeon-sonographer.

A rapid assessment of the thorax for the detection of occult or potentially lethal injuries is an essential part of the evaluation of the injured patient. Because an optimal patient outcome is time-dependent, efforts should be directed at expediting evaluation so that the diagnosis can be made rapidly and treatment can be initiated early.

There is increasing appreciation for the focused assessment of the sonographic examination of the trauma patient (FAST), a surgeon-performed, bedside test that rapidly detects blood in dependent abdominal and pericardial regions. [1-7] Using a slight modification of this examination and applying basic ultrasonographic physics principles, [8,9] a focused thoracic ultrasonographic examination was developed that can be used for the detection of traumatic or nontraumatic pleural effusion. [1,10]

The objectives of this study were (1) to determine if surgeons could accurately perform and interpret a focused thoracic ultrasonographic examination to detect traumatic effusion, and (2) to compare the accuracy and efficiency of surgeon-performed ultrasonography and portable chest radiography in the detection of traumatic effusion.

We hypothesized that surgeons could reliably perform and interpret a focused thoracic ultrasonographic examination in injured patients and that ultrasonography would more rapidly detect traumatic effusion than supine portable chest radiography.

## METHODS

During a 12-month period, a focused thoracic ultrasonographic examination was evaluated at a Level I trauma center. Patients with suspected blunt or penetrating torso injury who required, in addition to physical examination, a chest radiograph for a complete evaluation, were included in the study. Patients presenting with thoracic injury and clinical signs or symptoms dictating immediate tube thoracostomy were excluded from the study.

Ultrasonographic examinations were conducted by experienced surgeon-sonographers who successfully completed a training program consisting of didactic, practical, and written test sessions. An essential part of the training was the performance of ultrasonographic examinations on patients with known pathologic conditions, including pleural effusions.

### Technique

The ultrasonographic tests were performed with the B&K Panther 2002 Ultrasound Scanner (B&K Medical Systems, Bellerica, Mass) using a 3.5-MHz transducer. All sonograms were made with the patient in the supine position during the Advanced Trauma Life Support secondary survey and within 10 minutes of the patient's arrival in the resuscitation center. Using the annotation keys, the patient's medical record number was entered so that each image was appropriately labeled.

Ultrasonographic evaluation of the thoracic cavity was accomplished by adding right and left supradiaphragmatic views to the FAST as previously described [1,2] (Figure 1). The resultant six-view examination was conducted in sequence: (1) pericardial area, (2) right upper abdominal quadrant, (3) right supradiaphragmatic space, (4) left upper abdominal quadrant, (5) left supradiaphragmatic space, and (6) pouch of Douglas (Figure 2). Whatever the type of injury, the pericardial view was always made first so that appropriate adjustments of the "gain" setting could be made using the density of blood as a standard. [1,8]

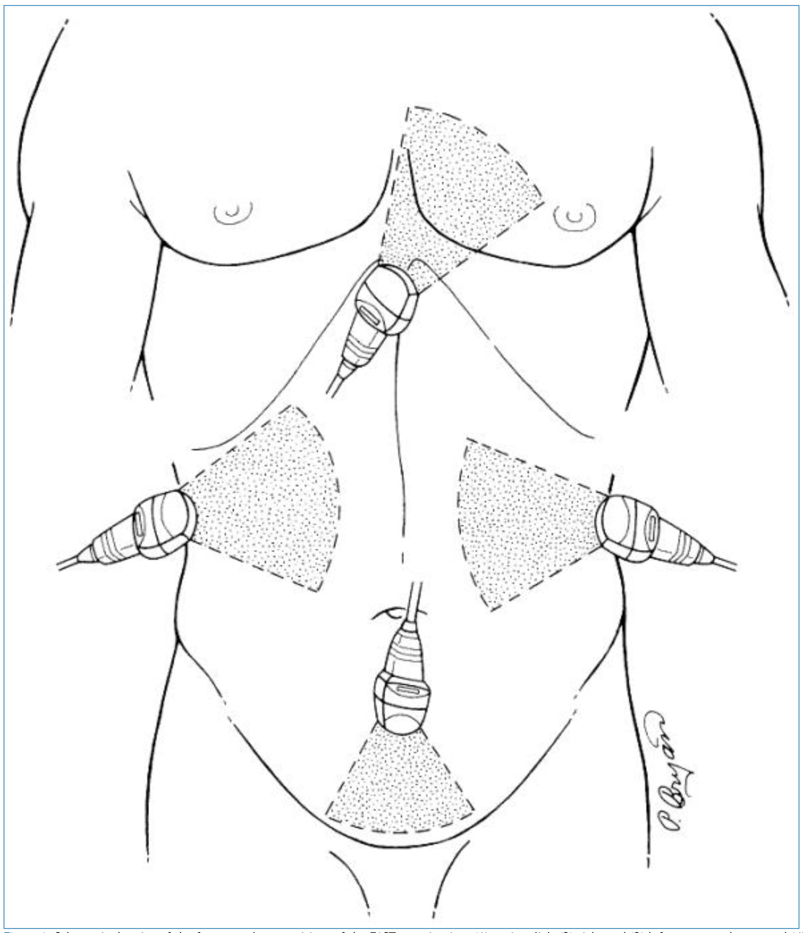
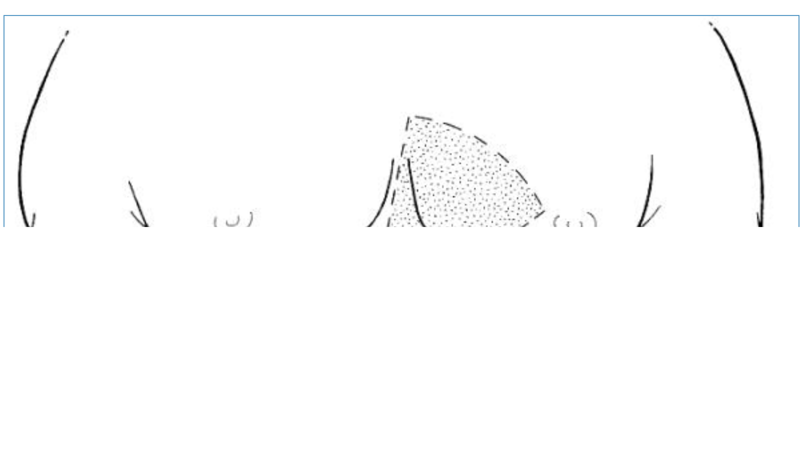


Figure 1. Schematic drawing of the four transducer positions of the FAST examination: (1) pericardial; (2) right and (3) left upper quadrants; and (4) pouch of Douglas.



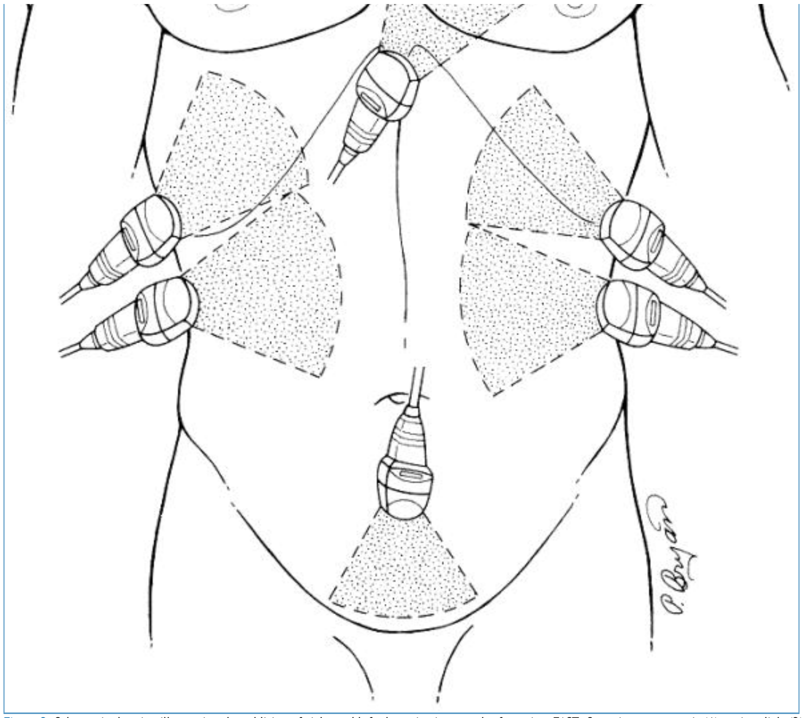


Figure 2. Schematic drawing illustrating the addition of right and left thoracic views to the four-view FAST. Scanning sequence is (1) pericardial, (2) right upper abdominal quadrant, (3) right supradiaphragmatic area, (4) left upper abdominal quadrant, (5) left supradiaphragmatic area, and (6) pouch of Douglas

Warmed hypoallergenic ultrasonographic transmission gel was applied to the thoracoabdominal area, and the surgeon oriented the transducer for sagittal sections. Visualization of the right thoracic space was accomplished by placing the transducer in the right midaxillary line between the 10th and 11th ribs to identify the liver, kidney, and diaphragm. The transducer was slowly advanced cephalad until the right supradiaphragmatic space was visualized (Figure 3). A normal ultrasonographic image of the lung appears as a hazy, gray area because the ultrasound waves do not traverse through aerated tissue well. When a traumatic effusion is present, however, the fluid appears hypoechoic or "dark" and functions as an acoustic window, enabling visualization of the lung (Figure 4). The left thoracic space was inspected by positioning the transducer at the left posterior axillary line between the 9th and 10th ribs. After identification of the left kidney and spleen, the transducer was advanced cephalad until the left hemidiaphragm and left supradiaphragmatic space were identified.

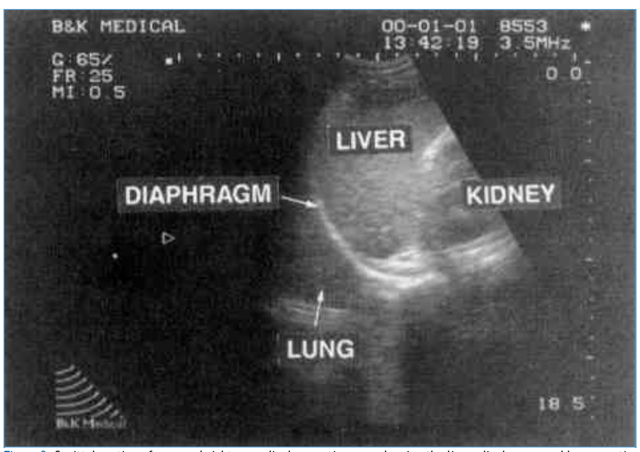



Figure 3. Sagittal section of a normal right supradiaphragmatic space showing the liver, diaphragm, and lower portion of the right lung.

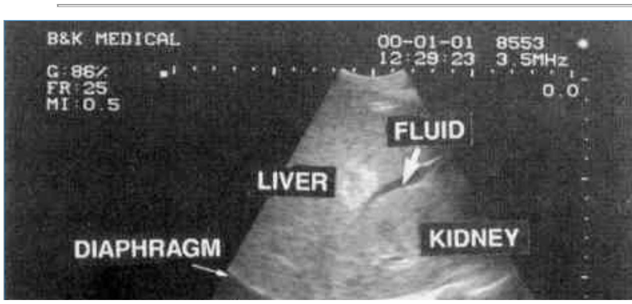


Figure 4. Sagittal section of the right supradiaphragmatic space. The right hemithorax contains fluid (blood), which appears hypoechoic.

After each good-quality view was obtained, the timed and dated images were photographed, attached to a data form, and retained for later review. Patients also had a supine portable chest radiograph made. Performance times of both tests were recorded for those patients with potential thoracic injuries who required only a chest radiograph and no other radiographic films. Performance time for thoracic ultrasonography was defined as the interval from the time printed on the previous image to the time each supradiaphragmatic view was photographed. Performance time for portable supine chest radiography was defined as the interval from the time the film was taken to the time development was completed.

Thoracic ultrasonography results were not used to decide patient management, and therefore, tube thoracostomy was not performed until the chest radiograph was available. Results of chest radiography were determined by radiologists who were blinded to the data. When the chest tube was inserted, the volume of effluent was recorded. An experienced surgeon-sonographer reviewed all ultrasonographic images for technique and the presence or absence of a pleural effusion. Patients were followed through discharge, and repeat chest radiographs were obtained per clinical management protocols.

A true-positive focused thoracic ultrasonographic examination result was defined as the presence of fluid on the ultrasonographic image and the presence of a pleural effusion on the chest radiograph. A true-negative result was defined as the absence of fluid on the ultrasonographic image and the absence of a pleural effusion on the chest radiograph. A false-positive result was defined as the presence of fluid on the ultrasonographic image and the absence of a pleural effusion on the chest radiograph. A false-negative result was defined as the absence of fluid on the ultrasonographic image and the presence of a pleural effusion on the chest radiograph.

The performance times for the focused thoracic ultrasonography and chest radiography were compared using Student's t test. This study was approved by the Emory University School of Medicine Human Investigations Committee; however, informed consent by the patient was not required.

## RESULTS

Three hundred sixty patients underwent the focused thoracic ultrasonographic examination. The mean age was 31 years (range, 1-81 years), and most of the patients (75.6%) were male. Of the total, 268 patients (74.4%) suffered blunt injuries, and the other 92 (25.6%) had penetrating wounds. The mean Injury Severity Score was 9.5, and the mean hospital length of stay was 6.4 days.

Among the 360 patients, there were 40 traumatic pleural effusions, 39 of which were detected by ultrasonography and 37 of which were detected by supine portable chest radiography. The mean volume of effluent obtained on tube thoracostomy placement was 380 mL (range, 60-1, 100 mL). Ultrasonography results were characterized as 319 truenegatives, 39 true-positives, 1 false-negative, and 1 false-positive, yielding a 97.5% sensitivity and a 99.7% specificity, with a positive predictive value of 97.5% and a negative predictive value of 99.7%. Portable supine chest radiography results were characterized as 319 true-negatives, 37 true-positives, 3 false-negatives, and 1 false-positive, yielding a 92.5% sensitivity and a 99.7% specificity, with positive and negative predictive values of 97.4 and 99.1%, respectively (Table 1).

| | Ultrasonography | Chest Radiography |
|---|---|---|
| Sensitivity | 97.5 (39 of 40) | 92.5 (37 of 40) |
| Specificity | 99.7 (319 of 320) | 99.7 (319 of 320) |
| PPV | 97.5 (39 of 40) | 97.4 (37 of 38) |
| NPV | 99.7 (319 of 320) | 99.1 (319 of 322) |

Values shown are percentages followed by actual numbers in parentheses. PPV, positive predictive value; NPV, negative predictive value.

Table 1. Comparison of thoracic ultrasonography and portable supine chest radiography results in 360 patients

The three patients with false-negative chest radiographs had effusions detected by other clinically indicated diagnostic tests, such as upright chest radiography or computed tomography. All three effusions were successfully detected by ultrasonography. There was one false-negative ultrasonography result in which a 250-mL effusion was detected by supine portable chest radiography.

One patient had false-positive ultrasonography and chest radiography results. No fluid returned when the chest tube was placed, but a pulmonary contusion was evident on the upper sections of an abdominal computed tomographic (CT) scan.

There were 115 patients with potential thoracic injuries who required only a chest radiograph and no other radiographic films. The mean performance time of the chest radiography for those 115 patients was 14.18 +/- 0.91 minutes compared with a much faster ($p < 0.001$) mean performance time of 1.30 +/- 0.08 minutes for the thoracic ultrasonography. Analysis of the data showed that the sensitivities, specificities, and positive and negative predictive values by mechanism of injury were not significantly different (Table 2).

| | Blunt (n = 268) | Penetrating (n = 92) |
|---|---|---|
| Sensitivity | 100 (7 of 7) | 96.97 (32 of 33) |
| Specificity | 100 (261 of 261) | 98.31 (58 of 59) |
| PPV | 100 (7 of 7) | 96.97 (32 of 33) |
| NPV | 100 (261 of 261) | 98.31 (58 of 59) |

Values shown are percentages followed by actual numbers in parentheses. PPV, positive predictive value; NPV, negative predictive value.

Table 2. Thoracic ultrasonography results by mechanism of injury (no significant differences were noted)

## DISCUSSION

As a noninvasive and sensitive diagnostic modality, ultrasonography is becoming an integral part of the surgeon's practice, especially in the emergent setting. Considering the many occult and potentially lethal injuries associated with thoracic trauma, ultrasonographic imaging is particularly useful because it allows a noninvasive bedside diagnosis to be made rapidly with the additional advantage of being easily repeatable. In this project, the types of reflective echoes were not evaluated to assess the character of the effusions; however, as expected, all traumatic effusions were hemothoraces and were confirmed by the bloody effluent after tube thoracostomy was performed. A test that promptly detects a traumatic effusion is worthwhile because it dramatically shortens the interval from diagnosis to tube thoracostomy insertion, which facilitates patient management.

### True-Negative Results

As expected, most of the patients in the study had truenegative results, and the negative predictive value of thoracic ultrasonography was 99.7%. Ultrasonography, therefore, is valued not only for its sensitivity but also as a safe, practical, and time-saving screening tool in patients with potential thoracic injury.

### True-Positive Results

In the 40 patients with traumatic effusions, ultrasonography was sensitive enough to detect 39 of them, with effluent amounts ranging from 60 to 1,100 mL. This underscores the ability of ultrasonography to detect even a small traumatic effusion, because although these patients are initially asymptomatic, avoidance of physiologic deterioration by early diagnosis and treatment can lessen their morbidity. [3] In this study, the focused thoracic ultrasonographic examinations were completed by surgeon-sonographers in a mean time of only 1.30 minutes. The use of a rapid and accurate modality by the surgeon who controls the resuscitation is an important way to decrease the time spent in the emergency department when operative intervention is indicated. Real-time ultrasonographic imaging allows the surgeon to view the results of the examination instantaneously so that patient-management decisions can be made sooner. An early diagnosis of traumatic effusion is even more important for the hypotensive patient with multiple potential sources of blood loss. In this case, ultrasonography can rapidly document the source and shorten the interval to definitive treatment when every second counts.

In this study, each patient who had a documented effusion underwent a tube thoracostomy. The question arises, however, whether all patients with blunt injury, especially those with a small effusion, required this intervention. Our use of tube thoracostomy to treat these patients with acute effusion was consistent with that emphasized by Richardson and Miller and was not influenced by the ultrasonography results. [11]

### False-Positive Results

There was one false-positive ultrasonography and supine portable chest radiography result in which there appeared to be a right effusion, but tube thoracostomy yielded no effluent. Subsequently, a CT scan revealed a right lower lobe contusion, although no free fluid was identified. Lipscomb and colleagues reported a similar finding in their study when a pleural effusion was misread as pleural thickening or tumor. [12] Comparison of their result with those presented here is difficult, however, because their ultrasonography tests were conducted with A-mode scanning. Since then, ultrasonography technology has advanced and resolution improved so that such pathologic conditions are much easier to distinguish. Further studies should be conducted to examine the ultrasonographic qualities of pulmonary contusions in the acute setting.

### False-Negative Results

The false-negative ultrasonography result was reassessed to identify any correctable factors that influenced the result. Although the examination was performed correctly and the image was judged to be of good quality by an experienced surgeon-sonographer, the timing of the performance of the examination and the patient's position may have contributed to the false-negative result. Because all ultrasonographic examinations were performed within 10 minutes of the patient's arrival, a repeat test performed 30 minutes later may have detected the effusion. Additionally, placement of the patient in the lateral decubitus or upright position may have enhanced the sensitivity of ultrasonography in detecting the effusion, but neither strategy was consistent with the objectives of this investigation. Apart from the constraints of this study, repeat ultrasonographic examinations and repositioning of the patient may be indicated in select patients to enhance the detection of pleural fluid. [12-16]

The three patients with false-negative chest radiography results had their effusions (from 60 to 350 mL) detected by ultrasonography and upright chest radiography or computed tomography, indicated as part of the diagnostic assessment of the patient (Table 3). These false-negative results may be understandable in view of data reported by Gryminski and colleagues, who compared chest ultrasonography and radiography for the detection of pleural fluid. [15] In that study, no false-negative results for thoracic ultrasonography were noted when the pleural fluid exceeded 100 mL, but at least 500 mL was required to eliminate the false-negative results using plain radiography.

| Patient | Portable Chest Radiograph | Ultrasound | Other Tests | Effluent |
|---|---|---|---|---|
| 1 | Negative | Positive | Posteroanterior/lateral chest radiograph positive (rib fracture) | 60mL |
| 2 | Negative | Positive | CT scan of abdomen (fluid in lower chest) | 350mL |
| 3 | Negative | Positive | Posteroanterior/lateral chest radiograph positive (pulmonary contusion/rib fracture) | 200mL |

Table 3. False-negative supine portable chest radiographs (n = 3)

Unlike in other studies of the surgeon's use of ultrasonography in the trauma setting, [1,2] in this study the learning curve did not have as great an impact on the sensitivity and specificity of the results because most of the tests were performed by surgeons and surgical residents who were well trained and experienced in the performance of the FAST. This underscores the importance of adequate training and supervision with a defined curriculum to ensure that basic ultrasonography principles are learned. [17] Similar to the development of surgical skills, each technique learned reinforces the surgeon's knowledge of ultrasonography principles, encourages rapid learning of new ultrasonographic techniques, and extends the surgeon's diagnostic armamentarium. Also, the investigators received instruction that visualization of the echogenic diaphragm was an essential component of the examination. Furthermore, the technique was initially observed by the radiologist consultant.

A weakness of the study was the lack of a consecutive patient enrollment, because not all of our residents and attending physicians were proficient in ultrasonographic techniques. Consequently, the data may be biased, but, overall, they are typical of our trauma patient population.

In this study, the performance time for portable supine chest radiography was a lengthy 14.18 +/- 0.91 minutes, despite the restriction of calculating performance times for those patients who underwent only chest radiography. The authors recognize that this prolonged time is not typical and that with improved resources, such as an on-site radiograph developer, shorter performance times for chest radiographs would be anticipated. Nonetheless, the performance time for the focused thoracic ultrasonography was 1.30 minutes, with an upper 95% confidence interval of 1.46 minutes. From a practical standpoint, even if a more streamlined process could be implemented in our institution, consistently obtaining a chest radiograph within this time would be difficult.

An additional advantage of the focused thoracic ultrasonographic examination is that it can be performed as part of the Advanced Trauma Life Support secondary survey without interrupting the clinical assessment to move the patient for placement or removal of the radiographic cassettes. Furthermore, the FAST and thoracic ultrasonography tests are performed with the same transducer, therefore allowing a sequential survey of the thoracoabdominal region as an extension of the physical examination.

In our practice, as documented in our previous studies, the use of FAST by surgeons has led to a decrease in the performance of diagnostic peritoneal lavage procedures and computed tomography. [1] Similarly, if a traumatic effusion can be identified with ultrasonography and treated before obtaining a chest radiograph, then only one chest radiograph would be needed. Therefore, the focused thoracic ultrasonographic examination does not replace the chest radiograph, but it can expedite the treatment process and decrease the number of chest radiographs obtained. Also, from the perspective of possible cost savings, an early diagnosis is advantageous for patients with both positive and negative examination results, because the patient can be moved from the resuscitation center sooner and improve resource allocation.

We conclude that experienced surgeon-sonographers can accurately perform and interpret the results of a focused thoracic ultrasonographic examination to detect a traumatic effusion. Based on our data, surgeon-performed thoracic ultrasonography is as accurate for the detection of a traumatic effusion as supine portable chest radiography, but it is statistically much faster. We encourage the routine inclusion of this focused thoracic ultrasonographic examination as part of the thoracic evaluation in select injured patients.

**Acknowledgments**

We acknowledge the valuable assistance of William C. Small, MD, PhD, as radiologist consultant in this research project and the assistance of Craig Hall in the preparation of the manuscript.

**DISCUSSION**

Dr. Michael C. Chang (Winston-Salem, North Carolina): Dr. Ochsner, Dr. Rotondo, members and guests: I would like to thank Dr. Sisley and the other authors for getting this paper to me well in advance of the meeting and giving me plenty of time to review it. I would also like to commend them on a beautiful presentation.

The authors have, with this paper, added to their continuing body of research regarding the role of surgeon-performed ultrasound during trauma evaluation. In this case, they have moved up the torso to the thorax and evaluated the pleural spaces with the ultrasound probe.

They have shown prospectively that ultrasound is an effective way to detect pleural fluid during trauma evaluation and that in selected situations the use of ultrasound is quicker than chest x-ray in detecting traumatic hemothorax.

Appropriately, they do not suggest that ultrasound replace the chest x-ray during trauma evaluation since there is so much more information obtained from the chest film that the ultrasound does not provide, such as nasogastric and endotracheal tube placement, mediastinal dimensions, pneumothorax, etc. This means then that the clinical advantage of using ultrasound to evaluate the pleural spaces is functionally limited to knowing that tube thoracostomy is indicated roughly 13 minutes earlier than if chest x-ray is used.

Given the fact that chest x-rays will usually be needed anyway, perhaps a useful comparison would have been between ultrasound and physical examination in a finding of decreased breath sounds, currently the standard indication for chest tube placement during the primary survey.

Perhaps the more important issue with regard to this paper is whether the advantages of earlier chest tube placement are clinically significant in this group of patients. This is certainly the case for the patient in extremis from either tension pneumothorax or massive hemothorax. But wouldn't these patients have their hemothorax detected by physical examination anyway?

Given all this then, I would ask the authors three questions. Number one, did they compare ultrasound with conventional physical examination-in other words, chest auscultation or percussion? Number two, is there a role for ultrasound in detecting traumatic diaphragmatic injuries? And finally, and perhaps most important, what do they believe the clinical impact of this technique will be on patient management and outcome?

I would like to thank Dr. Cunningham and the Association for the honor and opportunity to discuss this paper.

Dr. Philip S. Barie (New York, New York): I enjoyed the paper very much.

Patients are more likely to develop pneumothorax and perhaps more likely to get in trouble from pneumothorax than from many of the small volume hemothoraces that we see, and certainly, by extension, this technology could, if accurate, be very helpful in a critical care setting. Not only could we place lines using ultrasound guidance, but we could rapidly determine whether or not a pneumothorax had occurred, as it often does, 5% in most series.

Were you able to detect pneumothoraces? Do you know if you will be able to detect pneumothoraces with this technology? Thank you.

Dr. Frank E. Davis III (Savannah, Georgia): I would like to commend Dr. Sisley on a very nice presentation.

One quick question. Do you have any data for trying to quantitate the amount of fluid? Is it small, moderate, or large? And do you think that will have an impact on how you will treat these patients?

Dr. M. Gage Ochsner (Savannah, Georgia): I have several questions for the authors. Again I would like to commend you, Amy, on an absolutely magnificent presentation.

The first question that comes to my mind, however, is why did you get a radiologist involved? You have got some of the finest surgeon sonographers in the country at your institution, so why did you drag them into it?

Secondly, what is a significant hemothorax? I mean, is 200 mL significant? Do we need to put a chest tube in everybody that has 200 mL of fluid, presumably blood, in the chest?

And I will repeat the comments before, how do we really use this clinically? Because you are going to get a chest x-ray on these patients anyway. How do you decrease the use of chest x-ray as you alluded to earlier?

Dr. Amy C. Sisley (closing): Thank you very much for your comments.

Dr. Chang, we do not have the data comparing ultrasound with physical examination. However, particularly in the trauma bay, we find that physical examination is fairly unreliable and difficult, because of the noise level that is there.

The ultrasound is part of a secondary survey, and is actually an extension of the physical examination. Although we don't have data to show, it would probably be substantially more accurate because it doesn't depend on being able to hear.

Is ultrasound relevant for evaluation of diaphragmatic injuries? There is one case review in the literature that I am aware of that indicates they saw diaphragmatic injury on the ultrasound. You can see more commonly fluid above and below the diaphragm, and that is an indication of diaphragmatic injury.

Although it is possible if the injury occurs in the portion of the diaphragm that you are seeing with your ultrasound probe that you would actually see the injury, I think it more likely that you would get a clue just because there is fluid above and below. And we have had that occur on several instances at our institution.

There was a question about whether or not the ultrasound could be used to detect a pneumothorax. We haven't had a whole lot of success at that. Ultrasound, you know, is a technology in which sound waves do not transit well through air. And for that reason alone it is difficult to visualize unless it happens to have fluid in it. A paper on the use of this for pneumothorax has been published, and they were looking at the pleural surfaces. We have not tried to do that at our institution, although it has been reported.

In terms of quantitating the amount of fluid that is in the chest based on the ultrasound, no, we are not able to do that. Our practice has been to find fluid in the chest and then to place tube thoracostomy.

Why did we get a radiologist involved in this study? The radiologist was involved from the very beginning, helped train our residents, and helped us do some quality assurance with our machine and with the images. I think it is important, and we were very fortunate at our institution not to run into a lot of resistance from the radiology department; I think it is important to gain their cooperation whenever possible.

And the final question that was asked by both Dr. Ochsner and Dr. Chang is, what is the clinical impact of doing this and does it really help you to know 12 minutes sooner that a patient has blood in their chest? I think it does, particularly in a patient with multiple injuries who is hypotensive, if you can either rule in or rule out the chest as the source of the bleeding. That is very useful and the sooner you can do it, the better it is.

We have also used it in instances of penetrating injuries to the chest to determine if there isn't fluid in the lung. We had a patient who had a stab wound to the chest and pericardial effusion, and instead of wasting time putting in chest tubes for nothing, we just looked at the ultrasound, saw there was nothing there, and proceeded to the operating room.

In addition, it can reduce the number of chest x-rays in the following scenario. Normally you get a chest x-ray, you see that there is blood in the chest, you put in a chest tube and then you get another chest x-ray to see the tube placement and to make sure you have evacuated the hemothorax. In our scenario you get an ultrasound, you see that there is blood in the chest, you put in a chest tube, and then you get one chest x-ray to check the tube placement and to make sure that the hemothorax has been adequately evacuated.

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## IMAGE GALLERY

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Figure 3

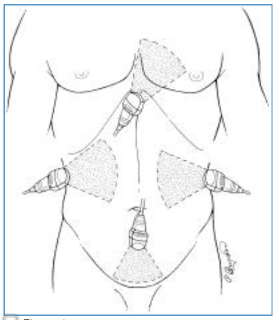

Figure 1

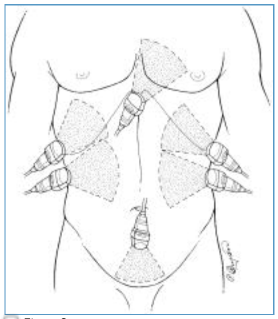

Figure 2


Figure 4

| | Ultrasonography | Chest Radiography |
|---|---|---|
| Sensitivity | 97.5 (39 of 40) | 92.5 (37 of 40) |
| Specificity | 99.7 (319 of 320) | 99.7 (319 of 320) |
| PPV | 97.5 (39 of 40) | 97.4 (37 of 38) |
| NPV | 99.7 (319 of 320) | 99.1 (319 of 322) |

Values shown are percentages followed by actual numbers in parentheses. PPV, positive predictive value; NPV, negative predictive value.

Table 1

| | Blunt (n = 268) | Penetrating (n = 92) |
|---|---|---|
| Sensitivity | 100 (7 of 7) | 96.97 (32 of 33) |
| Specificity | 100 (261 of 261) | 98.31 (58 of 59) |
| PPV | 100 (7 of 7) | 96.97 (32 of 33) |
| NPV | 100 (261 of 261) | 98.31 (58 of 59) |

Values shown are percentages followed by actual numbers in parentheses. PPV, positive predictive value; NPV, negative predictive value.

Table 2

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |

Table 3

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