Trauma Ultrasound Examination Versus Chest Radiography in the Detection of Hemothorax

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Study objective: To compare the sensitivity, specificity, and accuracy of ultrasonography with those of the initial plain chest radiograph for detection of hemothorax in trauma patients.

Methods: Data from a prior prospective study of trauma ultrasonography at a Level I trauma center were retrospectively analyzed. The medical records of a convenience sample of adult patients who presented with major blunt or penetrating torso trauma during a 17-month period were reviewed. Emergency physicians performed a trauma ultrasound examination, which included evaluation for pleural fluid. Ultrasound interpretations were recorded before other diagnostic tests were obtained and were not used in patient management decisions. Records of the study patients were reviewed for confirmation of the presence or absence of hemothorax by other diagnostic and therapeutic interventions. The chest radiograph and computed tomography (CT) scan interpretations were performed by attending radiologists who were not blinded to patient outcome.

Results: Five of the 245 patients enrolled in the study were excluded because tube thoracostomy was performed before the ultrasound examination was done. Altogether, 26 of the 240 study patients had hemothorax, as confirmed by tube thoracostomy or CT. Both ultrasound examination and the initial chest radiograph resulted in 0 false-positive, 1 false-negative, 25 true-positive, and 214 true-negative findings. Overall, both modailties were 96.2% sensitive, 100% specific, and 99.6% accurate.

Conclusion: Ultrasonography is comparable to the initial chest radiograph for accuracy in detection of hemothorax and may expedite the diagnosis and treatment of this condition for patients with major trauma.

[Ma OJ, Mateer JR: Trauma ultrasound examination versus chest radiography in the detection of hemothorax. *Ann Emerg Med* March 1997;29:312-316.]

INTRODUCTION

During the last 15 years, the use of ultrasonography by emergency physicians and surgeons for accurate identification of free intraperitoneal fluid and pericardial fluid in trauma patients has been well documented.[1-9] Although the accuracy of ultrasonography in the identification of hemoperitoneum is established, few studies have examined its accuracy for identification of hemothorax.[3,5] Because patients who have sustained major trauma routinely present to the emergency department immobilized on a long spine board, clinicians occasionally have difficulty identifying bilateral hemothoraces or a small unilateral hemothorax on the initial supine chest radiograph. The trauma ultrasound examination may assist in detection of hemothorax when the chest radiograph is equivocal. No previous study has directly compared the trauma ultrasound examination with the initial plain chest radiograph for the diagnosis of hemothorax in trauma patients.

The objective of this study was to compare the sensitivity, specificity, and accuracy of ultrasonography, as performed by emergency physicians, with those of the initial plain chest radiograph for detection of hemothorax in trauma patients.

MATERIALS AND METHODS

This retrospective study used data gathered from a prospective study[3] of ED patients who had sustained major blunt or penetrating torso trauma. The prospective study was approved by the Medical College of Wisconsin's investigational review board and was conducted between July 1, 1992, and November 30, 1993. Investigational review board exemption was obtained for this retrospective study.

The study was conducted in an ED with an annual volume of 60,000 patients that serves as a Level I trauma center. Adult patients (18 years of age or older) who presented with major blunt or penetrating trauma to the torso were enrolled into the study if an emergency physician in the investigator group was immediately available. Exclusion criteria included younger patients and those for whom an ultrasound examination might have delayed emergent procedures or transport of the patient to the operating room.

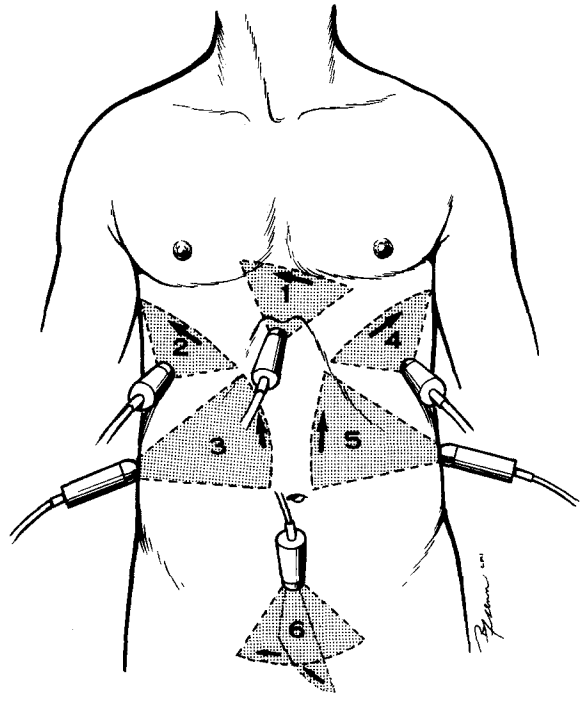
Emergency physicians performed and interpreted all the trauma ultrasound examinations for this study. The investigators used an AU530 (Esaote Biomedica, Genoa, Italy) or a Genesis 3000 CFM (Biosound) ultrasound machine and a 2.5- to 3.5-MHz probe. All of the ultrasound examinations were performed immediately after the primary clinical survey in the ED and with the patient supine. Trauma team members continued with routine trauma evaluation and procedures and were instructed not to allow the ultrasound examinations to interfere with patient management.

During the prospective study, six anatomic areas were evaluated with the rapid trauma ultrasound examination for free intrathoracic and intraperitoneal fluid (Figure). Two of these areas were used in this study to identify free pleural fluid: the right intercostal oblique view (area 2) for the right hemithorax and the left intercostal oblique view (area 4) for the left hemithorax. Findings of free intraperitoneal, retroperitoneal, or pericardial fluid were not considered positive results in this study, which focused on free pleural fluid only.

In the trauma ultrasound examination, fluid in the pleural cavity is viewed as an anechoic space distal to the hyperechoic line that represents the diaphragm. The liver and spleen are easily visualized acoustic windows proximally, and the lower lung margins may be discernible.

Ultrasound examination interpretations were recorded before other diagnostic tests were obtained; by design, they were not used in patient management decisions. Medical records of the study patients were later reviewed for confir-

Figure.
Rapid trauma ultrasound examination. Areas 2 and 4 were used to identify free fluid in the pleural cavities.



mation of the presence or absence of hemothorax by other diagnostic and therapeutic interventions.

Positive findings of hemothorax by tube thoracostomy or computed tomography (CT) of the chest, or both, were used as the criterion standard for pathology. The chest radiograph and CT scan interpretations were performed by attending radiologists who were not blinded to patient outcome.

For the ultrasound examination, a true-negative result occurred when the examination revealed the absence of free fluid and that finding was subsequently confirmed by negative results on serial chest radiography, tube thoracostomy, or CT. A true-positive result was an examination that revealed the presence of free fluid confirmed by positive findings on tube thoracostomy or CT. A false-negative result was an examination that demonstrated no free fluid in a patient with documented positive findings on subsequent tube thoracostomy or CT. A false-positive result was an examination that suggested free fluid but was followed by negative findings on serial chest radiography, tube thoracostomy, or CT.

For the initial chest radiograph, negative and positive results were categorized as true or false in the same manner, using tube thoracostomy, serial chest radiography, or CT as the confirming standard in each case.

The sensitivities, specificities, accuracies, positive predictive values (PPVs), and negative predictive values (NPVs) of the ultrasound examination and the initial chest radiograph were determined along with their 95% confidence intervals (CIs).[10,11]

RESULTS

Five of the 245 patients enrolled in the study were excluded because tube thoracostomy was performed before the ultrasound examination was done. Of the remaining 240 patients, 160 (66.7%) had sustained blunt trauma and 80 (33.3%) had penetrating trauma. Altogether, 26 (10.8%) of the 240 study patients had hemothorax confirmed by tube thoracostomy or CT scan, or both. Of these, 8 (30.8%) were patients with blunt trauma, and 18 (69.2%) were patients with penetrating trauma.

When the results of the trauma ultrasound examination for detection of free pleural fluid were compared with those of the criterion standard definitions, there were 0 false-positive, 1 false-negative, 25 true-positive, and 214 true-negative findings. Overall, ultrasonography had a sensitivity of 96.2% (95% CI, 81.1% to 99.3%), a specificity of 100% (95% CI, 98.2% to 100%), and an accuracy of 99.6% (95% CI, 97.7% to 99.9%). The PPV was 100% (95% CI, 86.7% to 100%), and the NPV was 99.5% (95% CI, 97.4% to 99.9%).

The initial chest radiograph, in comparison with the criterion standard definitions, produced exactly the same number of findings in each category and therefore generated the same statistical results.

The single false-negative finding for both studies involved a patient who presented after a motor vehicle crash. The trauma ultrasound examination correctly detected free intraperitoneal fluid (confirmed by CT scan of the abdomen) but did not identify a hemothorax. The initial chest radiograph in the ED was interpreted by both the trauma physicians and the attending radiologist as being normal. The CT scan of the chest, performed 2 hours after admission, revealed a small hemothorax that was confirmed by tube thoracostomy.

DISCUSSION

This study demonstrates that the trauma ultrasound examination can serve as a sensitive, specific, and accurate diagnostic tool for detection of hemothorax in patients with major trauma. The data show that ultrasonography is comparable to chest radiography for identification of hemothorax.

Trauma patients may benefit from the speed and accuracy of ultrasonography. The mean time for rapid trauma ultrasound examination of the thoracic and abdominal cavities has been reported to be 4.0 minutes.[3] Of the six anatomic areas scanned by the rapid trauma ultrasound examination, only two are required to identify the presence of free fluid in the two pleural cavities. Therefore, tube thoracostomy for trauma patients may be expedited with use of ultrasonography.

Smaller quantities of pleural fluid can be detected with ultrasonography than with chest radiography. A minimum of 50 to 100 mL of pleural fluid can accurately be detected on an upright chest radiograph[12] and a minimum of 175 mL on a supine chest radiograph.[13] By contrast, it is estimated that ultrasonography can reveal a minimum of 20 mL of pleural fluid.[5]

The results of this study should not suggest that ultrasonography can replace the chest radiograph during the initial evaluation of trauma patients. Chest radiography holds several indispensable advantages because it can identify pneumothorax, mediastinal injuries, and bony injuries. However, trauma ultrasonography can complement the findings of chest radiography through rapid identification of hemothorax in the supine patient. If the trauma ultrasound examination is used initially to detect hemothorax, the standard chest radiograph of the trauma patient can be

performed after tube thoracostomy, thereby sparing the patient an additional chest radiograph. Also, ultrasonography can help to differentiate pleural fluid from pleural thickening or pulmonary contusion if the supine chest radiograph is equivocal.

Two previous articles in the English literature have examined the accuracy of ultrasonography for detection of hemothorax. Rothlin, et al[5] reported an 81% sensitivity, and our prospective study[3] demonstrated 96% sensitivity, 100% specificity, and 99% accuracy for detection of hemothorax by ultrasonography. However, neither study directly compared the accuracy of the trauma ultrasound examination with that of the chest radiograph.

Several potential limitations exist for this study. As a retrospective study, it is subject to all the biases associated with retrospective data analysis. Five patients were excluded from the study because tube thoracostomy was performed before the ultrasound examination. Also, the attending radiologists who interpreted the chest radiographs were not blinded to the clinical outcome of the patients.

Future studies should address the issues of (1) how much training is required for physicians to accurately detect hemothorax using ultrasonography; (2) whether patient positioning enhances the diagnosis of hemothorax by ultrasonography; and (3) how serial ultrasound examinations may enhance the diagnosis of hemothorax if the initial chest radiograph is negative.

In conclusion, ultrasonography is comparable to the initial chest radiograph for accuracy in detection of hemothorax and may expedite the diagnosis and treatment of hemothorax for major trauma patients.

REFERENCES

1. Rozycki GS, Ochsner MG, Jaffin JH, et al: Prospective evaluation of surgeons' use of ultrasound in the evaluation of trauma patients. *J Trauma* 1993;34:516-527.

2. Rozycki GS, Ochsner MG, Schmidt JA, et al: A prospective study of surgeon-performed ultrasound as the primary adjuvant modality for injured patient assessment. *J Trauma* 1995;39:492-500.

3. Ma OJ, Mateer JR, Ogata M, et al: Prospective analysis of a rapid trauma ultrasound examination performed by emergency physicians. *J Trauma* 1995;38:879-885.

4. Plummer D, Brunette D, Asinger R, et al: Emergency department echocardiography improves outcome in penetrating cardiac injury. *Ann Emerg Med* 1992;21:709-712.

5. Rothlin MA, Naf R, Amgwerd M, et al: Ultrasound in blunt abdominal and thoracic trauma. *J Trauma* 1993;34:488-495.

6. Kimura A, Otsuka T: Emergency center ultrasonography in the evaluation of hemoperitoneum: A prospective study. *J Trauma* 1991;31:20-23.

7. Hoffmann R, Nerlich M, Muggia-Sullam M, et al: Blunt abdominal trauma in cases of multiple trauma evaluated by ultrasonography: A prospective analysis of 291 patients. *J Trauma* 1992;32:452-458.

8. Tso P, Rodriguez A, Cooper C, et al: Sonography in blunt abdominal trauma: A preliminary progress report. *J Trauma* 1992;33:39-44.

9. Tiling T, Bouillon B, Schmid A, et al: Ultrasound in blunt abdomino-thoracic trauma, in Border JR, Allgoewer M, Hansen ST, et al (eds): *Blunt Multiple Trauma: Comprehensive Pathophysiology and Care.* New York: Marcel Dekker, 1990:415-433.

10. Browner WS, Newman TB, Cummings SR: Designing a new study. III: Diagnostic tests, in Hulley SB, Cummings SR (eds): *Designing Clinical Research.* Baltimore: Williams & Wilkins, 1988:89-91.

11. Gardner MJ, Allman DG: Calculating confidence intervals for proportions and their differences, in Gardner MJ, Altman DG (eds): *Statistics With Confidence: Confidence Intervals and Statistical Guidelines.* London: British Medical Journal, 1989:28-29.

12. Rubens MB: The pleura: Collapse and consolidation, in Sutton D (ed): *A Textbook of Radiology Imaging,* ed 4. Edinburgh: Churchill Livingstone, 1987:393.

13. Juhl JH: Diseases of the pleura, mediastinum, and diaphragm, in Juhl JH, Crummy AB (eds): *Essentials of Radiologic Imaging,* ed 6. Philadelphia: Lippincott, 1993:1026.

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Brief Commentary

Ultrasonography, although still the "new kid on the block," is rapidly becoming a standard diagnostic modality in the evaluation of the injured patient. In this retrospective study, Ma and Mateer investigated the use of two additional thoracic views in an attempt to detect intrathoracic blood. Their results demonstrate that ultrasound is 96% sensitive, 100% specific, and 99% accurate. The authors concluded that ultrasonography is comparable to chest radiography.

Although the authors have shown that intrathoracic blood can be detected on ultrasonography, they have not demonstrated that we need to. The chest radiograph is one of the least expensive and most important survey radio-

graphs; it quickly identifies several potentially life-threatening conditions such as aortic injury, simple pneumothoraxes, and hemothoraxes. Although thoracic ultrasound may complement radiography by rapidly detecting a hemothorax, it is not clear that this information is necessary or clinically useful. Resource allocation is also an issue that must be addressed. If we are to begin using ultrasonography as a standard screen for hemothorax, how many ultrasound machines will be needed in a busy Level I trauma center? One can easily imagine the situation on a busy night when the diagnosis of a mediastinal vascular injury is delayed because the ultrasound machine was not immediately available and the clinician had a false sense of security after a negative ultrasound assay.

Ultrasonography may be superior to chest radiography because it can detect approximately 20 mL of pleural fluid, but we question the clinical significance of a 20-mL hemothorax. In 15 years at a busy urban trauma center, we cannot remember one patient who has returned with a fibrothorax or trapped lung because we missed a hemothorax not detected on radiography.

The authors have demonstrated that ultrasound can detect intrathoracic blood. However, in 1997, clinical decision-making must be guided by algorithms other than "We can do it; therefore we must do it." We are all approached by salespeople with the next-generation ventilator, monitoring equipment, or some other new tool to help us practice our trade. Yet very few data exist to suggest that any of these new technologies has actually salvaged a patient. Although ultrasound may have a role in the evaluation of thoracic trauma, the issue is far from settled.

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