Potential Errors in the Diagnosis of Pericardial Effusion on Trauma Ultrasound for Penetrating Injuries

MICHAEL BLAIVAS, MD, DANIEL DEBEHNKE, MD, MARY BETH PHELAN, MD

Abstract. **Objective:** To evaluate ultrasound error in patients presenting with penetrating injury with a potential for pericardial effusion. **Methods:** Residents and faculty from an emergency medicine training program at Level 1 trauma center with an active ultrasound program were asked to view digitized video clips of subxiphoid cardiac examinations in patients with chest trauma. Participants were asked to fill out a standardized questionnaire on each video clip asking whether a pericardial effusion was present. Other questions included size of effusion and presence of tamponade. The study also asked participants to rate their confidence in their impressions. Data were analyzed using interquartile ranges and confidence levels. **Results:** All participants had difficulty distinguishing between epicardial fat pads and true pericardial effusions. The overall sensitivity was 73% and specificity was 44%. Confidence shown by participants in their answers increased with level of training or experience, regardless of whether they were correct or incorrect. Additional views were frequently requested to help decide whether an effusion was present. **Conclusions:** A serious potential exists for misdiagnosing epicardial fat pads as pericardial effusion in critically ill trauma patients. Emergency physicians need to be aware of this and should consider one of two suggested alternative methods to improve the accuracy of diagnosis. **Key words:** medical errors; trauma ultrasound; ultrasound; emergency medicine; emergency ultrasound; penetrating trauma. ACADEMIC EMERGENCY MEDICINE 2000; 7:1261–1266

THE MEDIA has recently focused on medical errors, and the topic has even drawn the attention of the White House.[1] As the medical community is asked to focus on this problem, individual physicians and entire health systems struggle to find ways of curbing the rate of medical errors and subsequent morbidity. The possibility of medical errors is perhaps highest in stressful situations with critically ill patients such as those presenting with penetrating trauma.

The focused abdominal sonography for trauma (FAST) examination was initially developed to evaluate patients with blunt abdominal trauma, but has been used successfully in evaluating penetrating injuries.[2,3] The most common version of the FAST examination consists of four views. The most well known is the Morison's pouch view of the liver and right kidney. The heart is visualized from a subxiphoid approach giving a basic four-chamber view, which allows the sonographer to detect pericardial fluid. The splenorenal region is then evaluated followed by visualization of the bladder. The traditional examination contained two additional views. These were the paracolic gutter views on the right and left side.[4]

Penetrating chest injuries can result in cardiac penetration and rapid death from cardiac tamponade or exanguination. The subxiphoid view in the FAST examination allows the sonographer to rule out a pericardial effusion. In an unstable patient with a penetrating chest, back, or upper abdominal wound, the visualization of a pericardial effusion is often enough to lead to a pericardial window in the operating suite or even a thoracotomy in the emergency department (ED). Since cardiac injuries have such high mortality if not detected quickly, it is imperative that the treating clinician intervene rapidly in the case of a hypotensive patient with a pericardial effusion following a penetrating chest or back wound. A number of studies have shown the efficacy of ultrasound in the evaluation of cardiac injuries[2,5]; ultrasound allows rapid detection and treatment. One center reported reaching a 100% survival rate for penetrating cardiac injuries after the introduction of ED ultrasound.[2]

Since a full echocardiogram cannot be performed on a critically ill trauma patient, the treating clinician may be relying on a single view to

From the Department of Emergency Medicine, Medical College of Wisconsin, Milwaukee, WI (MB, DD, MBP).
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Address for correspondence and reprints: Michael Blaivas, MD, RDMS, Department of Emergency Medicine, North Shore University Hospital, 300 Community Drive, Manhasset, NY 11030; fac 516-562-3680; e-mail: blaivas@pyro.net

determine the presence of pericardial effusion. While this one view is accurate in many patients, some patients present a diagnostic dilemma that introduces room for medical error, especially if the emergency physician (EP) is not trained in additional cardiac views not traditionally used in the FAST examination. The presence of an epicardial fat pad is not a rare finding in large patients. Epicardial fat is the occurrence of fat over the apical portion of the heart that is visualized between the liver and the myocardium on a subxiphoid ultrasound examination. This fat pad can be of varying echogenicity and may appear anechoic, thus simulating the presence of fluid (Fig. 1). Such a finding on a FAST examination of a hemodynamically unstable patient with a penetrating chest, back, or upper abdominal wound could result in operative intervention, when no true cardiac injury is present.

We evaluated whether ultrasound-trained residents and attending EPs with varying degrees of ultrasound training and experience would mistake an epicardial fat pad for a pericardial effusion from a single subxiphoid view of difficult trauma patients. Our hypothesis was that epicardial fat pads could cause significant difficulty in interpretation for practitioners using the single cardiac view taught with the FAST examination. We also suggest two simple methods for avoiding this pitfall, both of which add little time to the standard trauma ultrasound examination.

METHODS

Study Design. This was a prospective observational study of subjects viewing ultrasound video footage of actual trauma cases. The study was considered exempt from informed consent by the institutional review board.

Study Setting and Population. The study was conducted in an urban teaching ED with an emergency medicine (EM) residency program. The ED has a census of approximately 40,000 visits per year. The hospital is Level 1 trauma center and has full specialty backup. An ultrasound machine is available in the trauma bays for immediate patient evaluation.

The ED is staffed by board-certified EM attending physicians as well as EM residents. Both residents and attending physicians perform bedside ultrasound examinations. An intradepartmental certification exists that rates residents and attending physicians into different user levels. An active ultrasound education program is present within the department and residents as well as faculty go through didactic and hands-on training courses. Regular lectures on ultrasound topics are provided for residents and faculty.

Residents and faculty were enrolled into the study if they had undergone hands-on and didactic training and were involved in performing ultrasound examinations in the ED. The didactic training consisted of at least three hours of lecture using still ultrasound images as well as digitized, real-time, ultrasound video clips of actual trauma ultrasound examinations. Hands-on training consisted of at least five hours of hands-on training with at least two models of ultrasound machines. During this time the participants were supervised through the performance of repeat FAST examinations. Normal models were used as well as peritoneal dialysis patients who were able to instill fluid into their abdomens to simulate a positive trauma ultrasound examination. Study subjects were enrolled on a convenience basis.

Study Protocol. A total of 22 residents and faculty were enrolled into the study. All subjects were

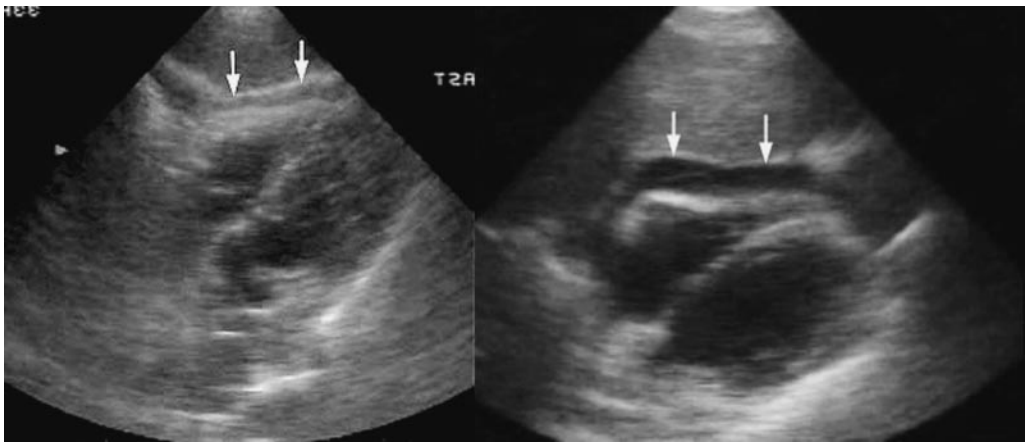

Figure 1. A comparison of an epicardial fat pad on the left with a pericardial effusion on the right. Note the hypoechoic area in each case, representing possible fluid (*arrow*).

TABLE 1. Questions Asked Regarding Each of the 11 Video Cases Presented

What is the quality of the image? *1 2 3 4 5 6 6 8 9 10* (1 is very poor; 10 best quality)
Is there a pericardial effusion present? *yes no*
If an effusion is present, how big is it: *small* (5 to 9 mm) *moderate* (10 to 15 mm) *large* (16 mm or more)
How sure are you? 1 2 3 4 5 6 7 8 9 10 (1 is not sure at all; 10 is has to go to the OR now)
Do you feel there is evidence of cardiac tamponade? *yes no*
How sure are you about tamponade? 1 2 3 4 5 6 7 8 9 10 (1 is not at all; 10 is very sure)
Would finding change your management? *yes no*
Would you like other views to feel more certain? *yes no*
If you would like other views, which ones? *parasternal long parasternal short apical four chamber*

presented with repeating digitized video clips of real-time ultrasound examinations on trauma patients with penetrating wounds to the chest, back, or upper abdomen. The video clips were specifically selected because of the difficulty in interpretation they presented to an experienced ultrasonographer (MB)* during actual patient evaluation. Each participant was provided with a total of 11 cases, which were randomly ordered. The cases contained normal examinations, examinations showing pericardial effusions, and examinations demonstrating epicardial fat pads. Two clips were of true pericardial effusions, both caused by penetrating wounds to the heart. Five were of patients with epicardial fat pads and no pericardial fluid. Four cases were of patients with no pericardial fluid or epicardial fat pad.

The study participants were given a clinical scenario that applied to all 11 cases. The study subjects were asked to imagine that they were in a trauma bay with an unstable and critically ill trauma patient who had multiple injuries, including a penetrating chest, upper abdominal, or back wound. The patient's vitals were worsening and the presiding trauma surgeon requested a rapid FAST examination. The focus of the examination is the subxiphoid view of the heart, which is part of the standard trauma ultrasound examination.

All ultrasound examinations used in this study had been previously corroborated with either chest computed tomography or echocardiography provided by the cardiology service. Study participants were asked to give their level of training as PGY1, PGY2, PGY3, or attending. They were also asked for the number of ultrasound examinations they had performed and the number of hours of didactic lectures and hands-on classes attended. Standard questions (Table 1) were asked for each of the 11-video cases. The participant's level of confidence in interpreting the exam was measured with a ten-point Likert scale.

Data Analysis. Standardized data collection sheets were given to participants. No identifying data were collected. All patient information was entered into a Microsoft Excel 5.0 spreadsheet (Microsoft Corporation, Redmond, WA). Data were pooled and then analyzed as independent variables. Data were analyzed using descriptive statistics from a commercially available software package (Analyse-it 1.44, Analyse-it Inc., Leeds, Great Britain). Accuracy, sensitivity, and specificity with 95% confidence intervals were calculated.

RESULTS

Five attending physicians and 17 residents participated in this study. All participants completed 11 video case presentations. Each video clip was approximately 20 seconds long and was repeated six times in a continuous loop. Participants were questioned about presence and significance of any pericardial effusion. Tables 2 through 4 summarize the results. The difficult video segments proved challenging for all participants in discerning epicardial fat pad from effusion. The overall accuracy for discriminating an epicardial fat pad from a pericardial effusion was 30% (95% CI = 23% to 38%). Normal examinations and those with pericardial effusion were detected in 73% (95% CI = 64% to 82%) and 73% (95% CI = 58% to 84%) of cases, respectively.

Sensitivity ranged from 63% to 93% for groups depending on level of training and experience. Specificity ranged from 31% to 61%. Both sensitivity and specificity tended to increase with increasing level of training or experience. The level of confidence also increased with experience and training level. Attending physicians were the most confident regardless of whether their answers were correct or incorrect. Each group appeared to have similar confidence levels for right and wrong answers.

The difficulty of the video cases was illustrated when the majority of participants requested additional views to help define the presence and extent of the effusion. The most common additional view requested was the parasternal long approach. When the study participants thought that an effusion was present, all believed that their manage-

*MB and MBP are RDMS (registered diagnostic medical sonographer)-certified.

TABLE 2. Sensitivity and Specificity by Level of Training and Experience

Level of Training or Experience	Specificity	Sensitivity
EM 1	31%	75%
EM 2	46%	64%
EM 3	61%	63%
Attending	47%	90%
Minimal experience	30%	65%
Moderate experience	52%	75%
Large experience	49%	93%
ALL SUBJECTS	44%	73%

ment of the patient would be altered by the finding. There was unanimous agreement that echocardiographic evidence of tamponade was present in the single case that showed impending cardiac tamponade with collapse of the right ventricle in the presence of a large effusion.

DISCUSSION

Penetrating trauma victims can make up a large percentage of all trauma patients in select trauma centers. These patients are frequently critically ill and management may be complicated by multiple wounds, any of which could explain the reason for a patient's hypotension. One of the greatest concerns is the possible presence of pericardial effusion from a penetrating cardiac injury. The FAST examination has been instrumental in detecting presence of cardiac injuries and can markedly reduce deaths.[2,5]

As with any test being performed under time pressure, especially in patients who may have recently eaten or have a stomach dilated with air, a potential for error exists in the diagnosis of pericardial fluid in an unstable penetrating trauma patient. Our results suggest that even with trained EPs at a center with an ultrasound program, the possibility of error is present in difficult ultrasound cases. The presence of epicardial fat is more common in obese patients, who are inherently more difficult to image. The results of this error may lead to unnecessary pericardial window or even thoracotomy.[6] It is important to note that the purpose of this study was not to provide a random sample of trauma patients but to specifically choose those with difficult-to-interpret findings.

A single cardiac view may not be adequate in patients with presence of an epicardial fat pad. Cardiology-performed echocardiograms include multiple views, and the parasternal long view (Fig. 2) is considered to be the most accurate for detection of pericardial effusion.[7] This view is best obtained in a left lateral decubitus position, and in some cases, visualization in a supine trauma patient may be poor. Fortunately, penetrating trauma patients are more likely to be moved on their left side than blunt trauma victims, thus improving visualization. However, penetrating chest wounds can often hamper the parasternal long approach if a pneumothorax or subcutaneous air is present.

TABLE 3. Median Level of Confidence for Right and Wrong Answers by Experience Level

Experience Level	Median Level of Confidence	Confidence Interval	Standard Deviation	IQR
Minimal experience, right answer	5.0	4.0, 6.0	2.4	4
Minimal experience, wrong answer	4.5	4.0, 6.0	2.4	4
Moderate experience, right answer	7.5	4.0, 8.0	1.9	2.75
Moderate experience, wrong answer	6.0	4.0, 8.0	2.6	3.5
Large experience, right answer	9.0	7.0, 9.0	2.3	2
Large experience, wrong answer	9.0	6.0, 10.0	2.9	4

TABLE 4. Median Level of Confidence for Right and Wrong Answers by Level of Training

Training Level	Median Level of Confidence	Confidence Interval	Standard Deviation	IQR
EM 1, right answer	4.5	4.0, 5.0	2.1	3.6
EM 1, wrong answer	5.0	4.0, 6.0	2.3	4
EM 2, right answer	5.5	5.0, 8.0	2.0	2.8
EM 2, wrong answer	6.0	5.0, 7.0	2.4	3.3
EM 3, right answer	6.5	5.0, 8.0	2.2	4
EM 3, wrong answer	5.5	4.0, 8.0	2.7	2.3
Attending, right answer	8.0	6.0, 9.0	2.3	2.3
Attending, wrong answer	8.0	6.0, 10.0	2.8	3.4

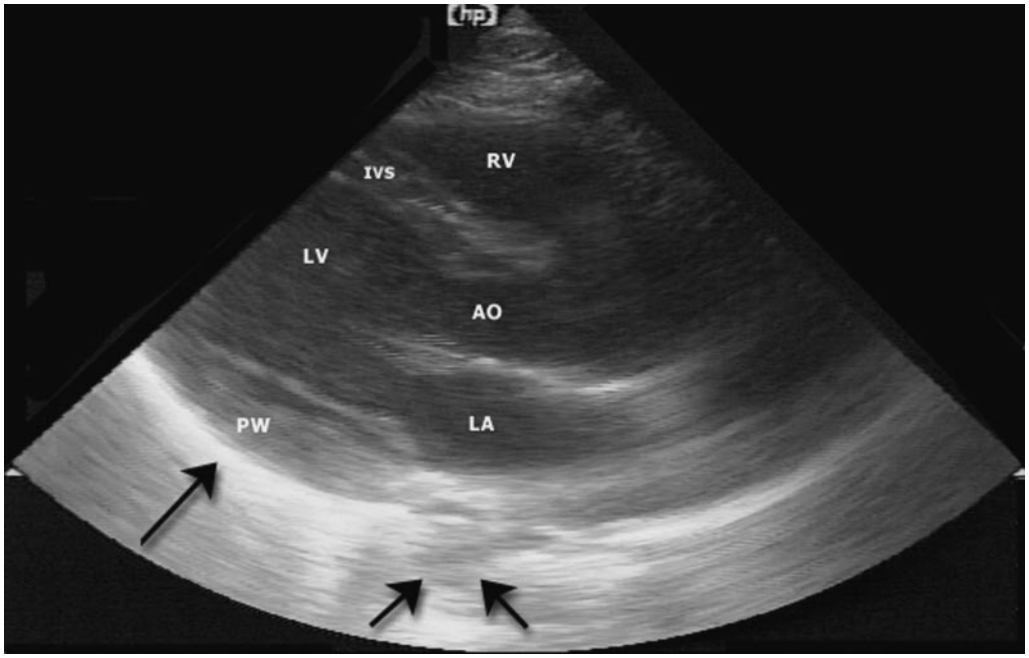

Figure 2. A parasternal long view of the heart. The pericardium is well seen posteriorly (*long arrow*), as well as the descending aorta (*short arrow*). Fluid gathers preferentially in this location and the space between the myocardium and descending aorta increases as fluid accumulates. IVS = intraventricular septum; PW = posterior wall of the left ventricle; LV = left ventricle; RV = right ventricle; LA = left atrium; AO = aortic outlet tract.

An alternative view that can help avoid mistaking an epicardial fat pad for pericardial effusion is modification of the subxiphoid view. The probe is angled perpendicular to the skin visualizing the inferior vena cava (IVC) entering the right atrium. This view allows the sonographer to visualize the right side of the heart next to the diaphragm. Any amount of pericardial fluid that is not loculated will be seen. Further, the visualization of the IVC affords the sonographer an ability to gauge the hemodynamic effect of any pericardial fluid collection present.[8] The IVC should collapse at least 50% with a sudden inspiration, such as when the patient is asked to sniff. Collapse of less than 50% would indicate increased central pressure.[8] In the presence of pericardial fluid with a penetrating chest, back, or abdominal wound, lack of appropriate collapse signals increased central pressures and possibly impending tamponade. This maneuver of imaging the IVC as it enters the heart can be performed within seconds and adds a negligible amount of time to the FAST examination.

In a relatively stable patient, the treating physicians can afford to obtain a formal echocardiogram to confirm the presence of an effusion and evaluate its significance. In a critically wounded patient with no other explanation for hypotension, such ancillary testing may not be provided in a timely manner. Although some may argue that it is worth the risk and cost to perform an unnecessary pericardial window in order to safeguard the patient, the suggested simple modification in the trauma examination may be helpful in decreasing unnecessary morbidity.

Our findings should serve to caution the EP against being too confident on a new technology, so as to make decisions based solely on its results. Overreliance on technology could lead to devastating error, as was suggested by our study. Further, continuing education and quality assurance regarding the use of ultrasound technology in patient care cannot be stressed enough. A physician who is trained only in the FAST examination and is not experienced in performing other cardiac views may be limited in his or her ability to obtain other images that would help determine pericardial effusion vs epicardial fat pad. Therefore, continuing expansion of one's ultrasonographic repertoire is necessary.

Limitations and Future Questions

This study has several limitations. The studies selected were difficult to interpret, even for the most experienced of sonographers, and may have represented an unrealistic difficulty. The incidence of pericardial fat pad is unknown and may be variable regionally. The video clips were limited to about 20 seconds each, although they repeated continuously six times. This may not have afforded the study participants enough of a view to judge the presence of an effusion accurately. However, this is

believed to be unlikely, since the images used were the best portion of each taped examination. Each of these examinations was taped in its entirety. The point of this study was to challenge the participants that reliance on incomplete ultrasound data can lead to error, and that other ultrasound views are often necessary. No analysis of statistical significance was made of the differences between levels of confidence, training, or experience.

It could be argued that the level of ultrasound experience at our program is minimal; however, in our experience and according to studies evaluating ultrasound education at academic EM programs, our experience level is average.[9] A future multicenter study to evaluate the rate of such errors would be of use. Further, a pre- and postintervention with an educational model should be studied.

CONCLUSIONS

Emergency medicine residents and attending physicians with modest ultrasound training are susceptible to incorrectly diagnosing epicardial fat pads as pericardial effusions in trauma patients with penetrating wounds to the chest, back, or upper abdomen. This phenomenon was seen with sonographically difficult patients. It is reasonable to add one or two additional, rapid views of the heart when the presence of an effusion is possible in an unstable penetrating trauma patient. The importance of continuing ultrasound education, quality assurance, and curriculum development cannot be overstressed.

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