ULTRASOUND DETECTION OF PNEUMOTHORAX WITH MINIMALLY TRAINED SONOGRAPHERS: A PRELIMINARY STUDY

Jonathan D. Monti, MPAS, PA-C; Bradley Younggren, MD, FACEP; Robert Blankenship, MD, FACEP

Department of Emergency Medicine / Charles A. Anderson Simulation Center, Madigan Army Medical Center, Ft Lewis, WA

KEYWORDS
ultrasound, pneumothorax, military

ABSTRACT

Background: Prompt recognition and treatment of a tension pneumothorax is critical to reducing mortality in both military and civilian settings. Physician assistants, Special Operations Forces (SOF) and conventional force Medics are often the first medical providers to care for combat trauma patients with penetrating chest trauma and frequently have limited diagnostic capabilities available to them due to mission constraints. The purpose of this study is to examine the potential for non-physician providers to determine the absence or presence of a pneumothorax in a porcine model, with the use of a portable ultrasound machine, after receiving minimal training. **Methods**: Physician assistants, SOF and conventional force Medics, veterinary technicians, and food service inspectors, all naïve to ultrasound, were recruited for this study. Participants underwent a brief presentation on detection of a pneumothorax by ultrasound and were then asked to perform a thoracic ultrasound examination on euthanized, ventilated swine. Some of the swine were induced with a pneumothorax prior to these examinations, and all participants were blinded to the absence or presence of a pneumothorax. **Results**: Twenty-two participants examined a total of 44 hemithoraces. A total of 21 out of 22 pneumothoraces were correctly identified with one false-negative. All 22 normal hemithoraces were correctly identified for a sensitivity of 95.4% (95 % CI 0.75-0.99), and a specificity of 100% (95% CI 0.81-1.00), with PPV of 100%, NPV of 95.6%. **Conclusions**: Non-physician healthcare providers can accurately detect a pneumothorax with portable ultrasound after receiving minimal focused training.

BACKGROUND

Penetrating chest trauma and complications due to tension pneumothorax have historically been, and continue to be, leading causes of preventable death on the battlefield.[1-2] Prompt recognition and treatment of tension pneumothorax is critical to reducing mortality.[3] Traditional methods of detection of pneumothorax include plain radiography and computed tomography (CT). However, these capabilities are rarely available at far-forward locations. Multiple studies have determined that thoracic ultrasound is more sensitive than plain radiographs in detection of pneumothorax, with sensitivities approaching that of CT.[4-9] However, each of these studies have involved physicians formally trained and experienced in ultrasound.

In a forward-deployed setting, physician assistants, Special Operations Forces (SOF) and conventional force Medics often operate independent of direct physician supervision. They are often the first medical providers to care for combat trauma patients with penetrating chest trauma and frequently have limited diagnostic capabilities available to them due to mission constraints. The purpose of this study is to examine the potential for non-physician providers to determine the absence or presence of a pneumothorax in a porcine model, with the use of a portable ultrasound machine, after receiving minimal ultrasound training.

Methods

Physician assistants, SOF and conventional force Medics, veterinary technicians, and food service inspectors were recruited for this study. Participants were screened to ensure they had received no prior formal ultrasound training and specifically had no experience with the ultrasound detection of pneumothorax. Each participant underwent a brief slideshow presentation (approximately 10 minutes in length) on the detection of pneumothorax. The presentation, given by a physician assistant, addressed the "sliding lung sign" (Figure 1), "comet-tail" artifact (Figure 2), and "seashore" and "stratosphere" signs (Figures 3 and 4 respectively), and included video clips of each of these diagnostic findings, as well as an orientation to the machine.

Adult swine were shared with another ongoing study, after approval by Madigan Army Medical Center's Institutional Animal Care and Use Committee, and were maintained in accordance with the *Guide for the Care and Use of Laboratory Animals* published by the National Research Council / Institute of Laboratory Animal Research (ILAR).[10] A total of eight swine were used in this study. Upon completion of data collection for the other ongoing study, the swine were humanely euthanized but remained ventilated. Pigs were placed in the sternal recumbency position. Thoracentesis was then performed on one side of the pig's thorax, and air was infiltrated into the thoracic cavity until the "sliding lung" sign was obliterated. An average of 4.3cc/kg was required to obliterate the "sliding lung" sign. Findings were confirmed by a trained sonographer prior to participant scanning.

Upon completion of the presentation, participants were told that the pig may have normal lungs bilaterally, pneumothoraces bilaterally, or a single pneumothorax on either side. Participants, using a Sonosite Vet™ ultrasound machine (Sonosite 180™ equivalent) with 10-5MHz linear transducer, scanned the lateral thorax bilaterally, and asked to interpret their findings at bedside. Data was recorded and entered into a spreadsheet for analysis and then compared to the actual absence and presence of pneumothorax as confirmed by study staff.

Results

Twenty-two participants examined a total of 44 hemithoraces. A total of 21 out of 22 pneumothoraces were correctly identified with one false-negative. All 22 normal hemithoraces were correctly identified. The sensitivity of finding a pneumothorax by ultrasound in this study was 95.5% (95% CI 75% to 99%). The specificity in this study was 100% (95% CI 81%-100%). The positive predictive value (PPV) was 100%; the negative predictive value (NPV) was 95.6%.

Discussion

After a brief training session, participant's naïve to ultrasound detection of pneumothoraces were able to detect a pneumothorax with excellent accuracy (sensitivity [95.4%]) as compared to the actual presence or absence of pneumothorax. This sensitivity surpasses that of plain radiographs and approaches that of the gold standard of computed tomography. This sensitivity was also roughly equivalent to a study involving surgical residents and attending physicians who had undergone formal ultrasound training.[11] This supports our hypothesis that minimally trained users can accurately detect a pneumothorax with ultrasound. This data has obvious applications for military medical providers operating independently with limited diagnostic capabilities available to them.

Rapid detection of a pneumothorax with portable, handheld ultrasound may lead to life-saving interventions and/or evacuation to a higher echelon of care. Prevention of an unnecessary high-risk aerial or ground evacuation might also be avoided. Furthermore, the identification of a normal lung would allow the provider to safely avoid needle or tube thoracostomy, thus avoiding an unnecessary procedure and the associated morbidity and mortality associated with it. Ultrasound machines are now widely available in highly portable platforms. In addition to portability, ultrasound machines offer the advantages of being non-invasive, non-radiating, and useful in a loud environment when auscultation of breath sounds may be difficult or impossible.

The authors recognize that there is no role for emergency thoracic ultrasound in the setting of tension pneumothorax. If tension physiology exists or is suspected, there should be no delay in intervention by a trained medical professional. The authors also recognize that there is no role for emergency ultrasound while providing care under fire on the battlefield. The tenets of tactical combat casualty care should be adhered to at all times, and at no time should ultrasound evaluation be performed while directly engaged by enemy forces.

Conclusions

Despite these advantages, the use of portable ultrasound on the battlefield continues to be limited. Likely factors for their limited use include 1) prohibitive cost and, 2) inadequate training of far-forward providers in its various emergency applications. These potential applications include the extended focused assessment with sonography for trauma (EFAST), central venous access, regional nerve blocks, abscess evaluation, emergency ocular ultrasound, and endotracheal tube placement.

Providing physician assistants and independently operating Medics with training in the various emergency ultrasound applications would greatly enhance these providers' ability to care for their patients at far-forward locations. As this study demonstrates, extensive formal ultrasound training may not be required for these providers to safely and accurately use such applications. Future studies with a larger sample size, particularly in austere conditions (ie. rotary wing aircraft) may be useful to further validate this hypothesis. Future studies validating the accuracy of non-physician providers in other emergency ultrasound applications such as the EFAST, ultrasound detection of long-bone fractures, and confirmation of endotracheal tube placement may also be useful. Considerations should be made for incorporating concise ultrasound training into the Interservice Physician Assistant Program and Special Forces Medical Sergeant or Special Operations Combat Medic courses. A case could also be made for the addition of portable ultrasound machines to the medical equipment sets (MES) of conventional forces battalion aid stations, forward support medical companies, and Special Forces A-Team medical equipment sets.

Finally, this study has obvious implications for rural medicine, where a myriad of healthcare providers may be called upon to make interpretations of emergency ultrasound images. This study demonstrates that even individuals who are uncomfortable making diagnostic decisions can effectively acquire such images, which can then be transmitted to an available emergency physician assistant, emergency physician, or radiologist for interpretation.

Limitations

This was a preliminary study and therefore, the sample size is small. Further studies which include a larger sample size may be useful. The amount of air introduced to induce pneumothorax was not uniform, which may have resulted in various sizes of pneumothorax between models. The anatomy of swine, al-

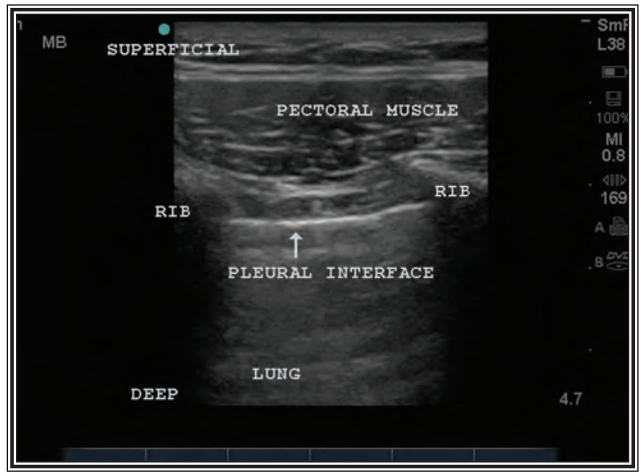

Figure 1: Still image depicting the anatomy of the pleural interface/intercostal space and presence of sliding lung artifact indicative of normal lung without presence of pneumothorax.

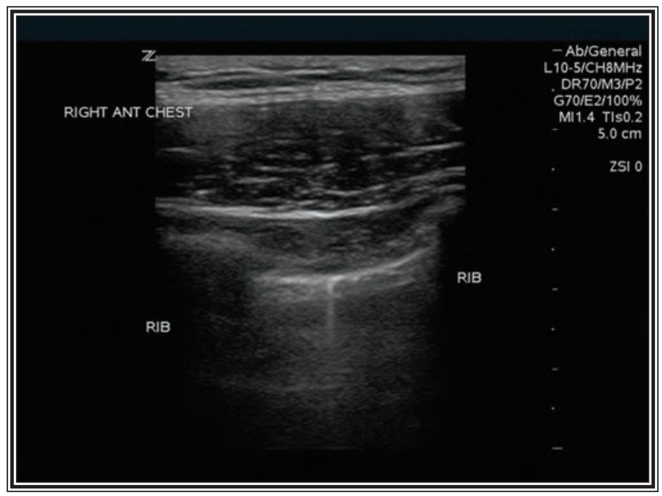

Figure 2: Still image depicting presence of comet-tail sign which, when present, indicates absence of pneumothorax.

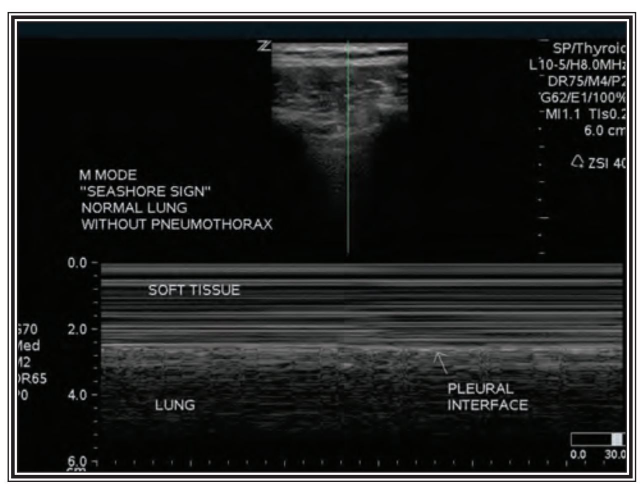

Figure 3: Still image in M-Mode depicting "seashore sign" indicating absence of pneumothorax.

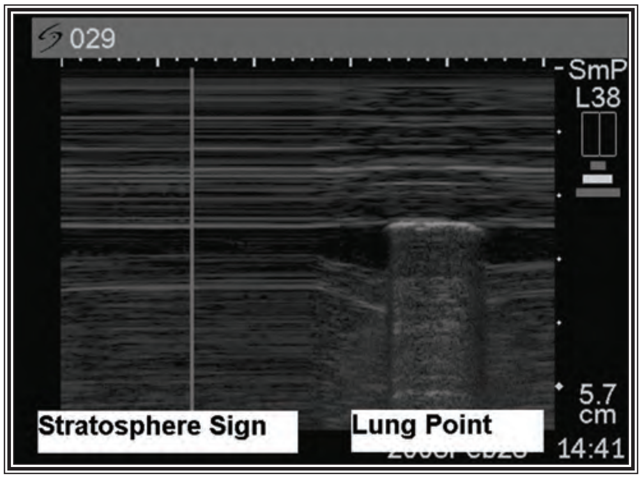

Figure 4: Still image in M-Mode depicting both the "stratosphere sign" and "lung point," indicating the presence of pneumothorax.

though similar, is not identical to that of humans; therefore, the scanning technique was slightly different. There was no direct comparison to any other imaging modalities in this study. Rather, the standard for comparison used was the actual presence or absence of pneumothorax as confirmed by study staff.

Acknowledgements

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or reflecting the views of the Department of the Army or the Department of Defense. The authors have no relationships to disclose regarding this product. This presentation is not, and in no way, should be construed as an endorsement of this product by the Department of the Army or Department of Defense.

References

1. Bellamy, RF. (1984). The causes of death in conventional land warfare: Implications for combat casualty care research. *Mil Med*; 149:55–62.
2. McPherson, JJ; Feigin, DS; Bellamy, RF. (2006). Prevalence of tension pneumothorax in fatally wounded combat casualties. *J Trauma*; 60(3):573-8.
3. Barton, ED; Rhee, P; Hutton, KC. (1997). The pathophysiology of tension pneumothorax in ventilated swine. *J Emerg Med.* Mar-Apr; 15 (2): 147-53.
4. Sartori, S, et al. (2007). Accuracy of transthoracic sonography in detection of pneumothorax after sonographically guided lung biopsy: Prospective comparison with chest radiography. *Am J Roentgenol*; 188(1):37-41.
5. Blaivas, M; Lyon, M; Duggal, S. (2005). A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med;* 12(9):844-9.
6. Rowan, KR; Kirkpatrick, AW; Liu, D; Forkheim, KE; Mayo, JR; Nicolaou, S. (2002). Traumatic pneumothorax detection with thoracic US: Correlation with chest radiography and CT—initial experience. *Radiology*; 225(1):210-4.
7. Kirkpatrick, AW; Sirois, M; Laupland, KB; et al. (2004). Hand-held thoracic sonography for detecting post-traumatic pneumothoraces: The Extended Focused Assessment with Sonography for Trauma (EFAST). *J Trauma*; 57(2):288-95.
8. Lichtenstein, DA; Meziere, G; Lascols, N; et al. (2005). Ultrasound diagnosis of occult pneumothorax. *Crit Care Med*; 33(6):1231– 8.
9. Dulchavsky, SA; et al. (2001). Prospective evaluation of thoracic ultrasound in the detection of pneumothorax. *J Trauma;* 50(2): 201-5.
10. Institute of Laboratory Animal Resources. *Guide for the Care and Use of Laboratory Animals* (National Academies Press, Washington, DC, 1996).
11. Knudtson, JL; Dort, JM; Helmer, SD; Smith, RS. (2004). Surgeon-performed ultrasound for pneumothorax in the trauma suite. *J Trauma*; 56(3):527-30.

CPT(P) Jonathan Monti, SP, USA, is a staff emergency medicine physician assistant at Evans Army Community Hospital. He recently completed the US Army/Baylor University Emergency Medicine Physician Assistant Fellowship at Madigan Army Medical Center. He holds a Bachelor's Degree from Gannon University, a Master's degree from the University of Nebraska, and Doctorate of Science from Baylor University. He has multiple deployments in support of Operations Iraqi and Enduring Freedom.

MAJ Bradley Younggren has been the associate program director of the Madigan-University of Washington, now Madigan Program in Emergency Medicine for over four years. He is currently the acting Medical Director, Andersen Simluation Center, Vice Chair of the Army Central Simulation Committee, and serves as the specialty advisor in simulation for emergency medicine. He is also very involved in the use of emergency ultrasound having lectured at the national level on various applications of emergency ultrasound.

Dr. Robert Blankenship is a board certified emergency physician. He did his emergency medicine residency at Carl R. Darnall Army Medical Center. During his 11 years of active duty he served as an Emergency Medicine Assistant Residency Director, Ultrasound Director, and the Transitional Year Program Director at Madigan Army Medical Center. Dr. Blankenship also developed the Army's First Tactical Ultrasound Course in 2007 after returning from Iraq where he was awarded the Bronze Star for his service with 1-66 Armor, 4th Infantry Division, Fort Hood Texas.