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Brief Report

An initial description of a sonographic sign that verifies intrathoracic chest tube placement

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Abstract

Purpose: An initial description of a sonographic finding predictive of intrathoracic chest tube placement.

Methods: This was a prospective observational study using unembalmed cadaveric models. Chest tubes were randomly placed intra- and extrathoracically and evaluated using ultrasound. Chest tube location was confirmed using blunt dissection followed by tactile and visual confirmation. Sonographers were blinded to chest tube position. Sonographic images obtained in a transverse orientation revealed a subcutaneous hyperechoic arc, created by the chest tube, at the insertion site. The path of the hyperechoic arc was followed cephalad. Disappearance of the hyperechoic arc signified intrathoracic chest tube placement. In contrast, continuation of a subcutaneous hyperechoic arc for the full length of the chest tube signified extrathoracic chest tube placement (the Disappearance/Intrathoracic, Continuation/Extrathoracic sign).

Results: Ultrasound was used to evaluate 48 chest tube placements. All chest tube locations were identified correctly. In differentiating intra- vs extrathoracic chest tube placement, the Disappearance/Intrathoracic, Continuation/Extrathoracic sign revealed a sensitivity of 100% (95% confidence interval, 83%-100%) and a specificity of 100% (95% confidence interval, 83%-100%).

Conclusions: In this small study, bedside ultrasound appears to be highly sensitive and specific in differentiating intra- versus extrathoracic chest tube placement.

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1. Introduction

In the emergency department (ED), tube thoracostomy is a standard treatment for patients with intrapleural collections of air, blood, exudates, or transudates. Expeditious removal of these abnormal collections is often necessary in the management of the acutely ill or injured patients in the ED or other clinical settings. Unrecognized extrathoracic chest tube placement is a potentially dangerous complication, especially in the hemodynamically unstable patient and for those who are intubated undergoing positive pressure ventilation [1-4]. The incidence of extrathoracic chest tube placement is estimated to be between 0.5% and 2.6% [5-12]. Although rare, rapid detection of this complication is imperative in the management of critically ill patients.

Verification of chest tube placement is performed immediately after completion of the procedure. Indicators of intrathoracic tube placement include the ability to pass a finger along the tube into the pleural space or to rotate the

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tube without resistance after insertion [13]. Other clinical indicators include tube condensation, audible air movement with respiration, and free flow of blood or fluid within the tube [13]. A single-view anteroposterior, portable chest radiograph is used for definitive intrathoracic verification. The ability of such radiographs to detect an extrathoracic chest tube placement is poor [6,10,12,14,15]. Studies have shown computed tomography is much more sensitive and specific in the diagnosis of malpositioned chest tubes when compared with plain radiography [6,10,12]. The risks of transporting critical patients to the computed tomography scanner to confirm chest tube placement often outweigh the benefits. A rapid and reliable method of verifying intrathoracic chest tube placement at the bedside would eliminate potential complications of undetected extrathoracic placement.

No prior studies address the use of ultrasound to detect intra- vs extrathoracic chest tube location. The objectives of this study were to describe a sonographic finding in a cadaveric model that verifies intrathoracic chest tube position and to establish the sensitivity and specificity of this finding.

2. Methods

2.1. Study design, setting, and selection of participants

A prospective observational study was conducted using 2 unembalmed cadavers from the UC Davis School of Medicine Donated Body Program. The study was conducted at the Sacramento County Coroner's Office. The study and protocol were exempt from informed consent and hospital institutional review board approval due to the use of cadaveric material.

2.2. Study protocol

The overall study design involved random placement of chest tubes in either an intra- or extrathoracic location in each cadaver. Subsequently, investigators blinded to the original placement would evaluate the chest tube location using ultrasound.

Two unembalmed cadavers, within 48 hours of death, were used for all chest tube placement and sonographic assessment. The cause of death of the cadaveric subjects was unknown.

Each investigator sequentially placed a 40F thoracostomy tube into the left and right hemithorax of each cadaver, resulting in 4 chest tube placements per investigator. Chest tubes were advanced toward the apex of the lung. Distance of tube insertions was determined by measurement of the distance from the clavicle to the incision site of each hemithorax. The last drainage hole of each tube was inserted into the pleural space or subcutaneous tissue. A random number chart was used to determine intra- or extrathoracic chest tube position. The investigator who randomly placed the chest tube then confirmed its position. Using blunt dissection, tube position was verified using both direct tactile and visual confirmation. This was the study's gold standard to determine chest tube position.

Before ultrasonographic interrogation, the hemithorax was draped to remove visual cues that may have been suggestive of intra- or extrathoracic placement. The investigator who performed chest tube placement did not participate in the subsequent round of ultrasonographic examinations.

Sonographers were 2 board-certified emergency physicians with hospital credentialing or extensive experience in emergency ultrasound, 1 emergency ultrasound fellow, and 1 senior emergency medicine resident. Each provider underwent a 30-minute training session to review the ultrasonographic findings and techniques involved. A SonoSite Titan (SonoSite, Inc, Bothell, WA) ultrasound machine with a linear-array 10-MHz transducer was used to obtain all images in real time.

Investigators performing the ultrasound examinations were blinded to the position of the chest tube and the results of the other investigators' examinations. Each investigator performed the ultrasound evaluation without assistance on each of the 4 hemithoraces.

2.3. Measurements

Images were obtained in a transverse orientation beginning at the chest tube insertion site (Fig. 1). A hyperechoic arc, created by the chest tube, was noted subcutaneously at

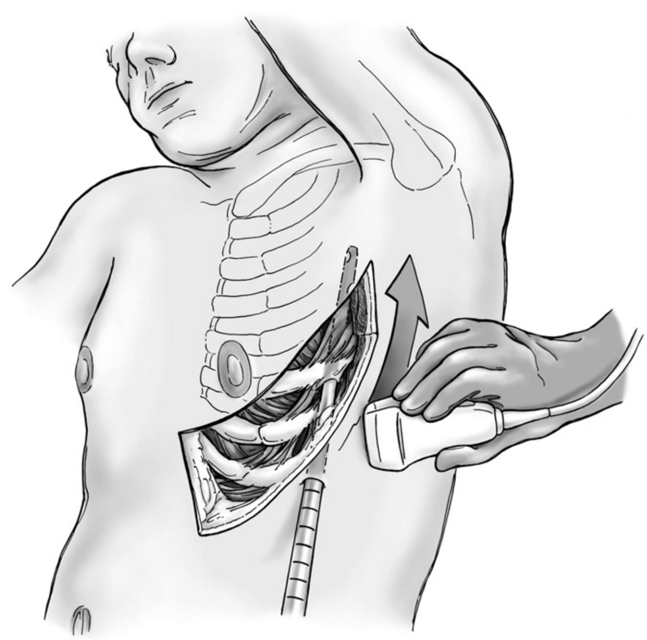

Fig. 1 Ultrasound images of the chest tube insertion site are attained in the transverse orientation. The chest tube is located, and its path is followed cephalad.

the insertion site (Fig. 2). The linear probe was then moved cephalad following the path of the hyperechoic arc. Disappearance of the hyperechoic arc indicated that the chest tube had entered the pleural space and was therefore no longer detectable subcutaneously by ultrasound (Fig. 3). Continuation of the subcutaneous hyperechoic arc for the full length of the inserted portion of the chest tube signified extrathoracic tube placement. This set of findings was referred to as the Disappearance/Intrathoracic, Continuation/ Extrathoracic (DICE) sign. Although there was no set time limit for investigators to complete the sonographic examinations, all examinations (from the initial placement of the ultrasound probe on the cadaver's skin surface until a decision on chest tube location was made) were completed in less than 1 minute.

Investigators were interviewed by an emergency medicine research assistant regarding chest tube position immediately after completion of each sonographic examination. The research assistant was blinded to the position of the chest tube. Investigators were required to indicate whether the chest tube was intrathoracic, extrathoracic, or indeterminate in position. The research assistant entered the data in the study's Excel spreadsheet.

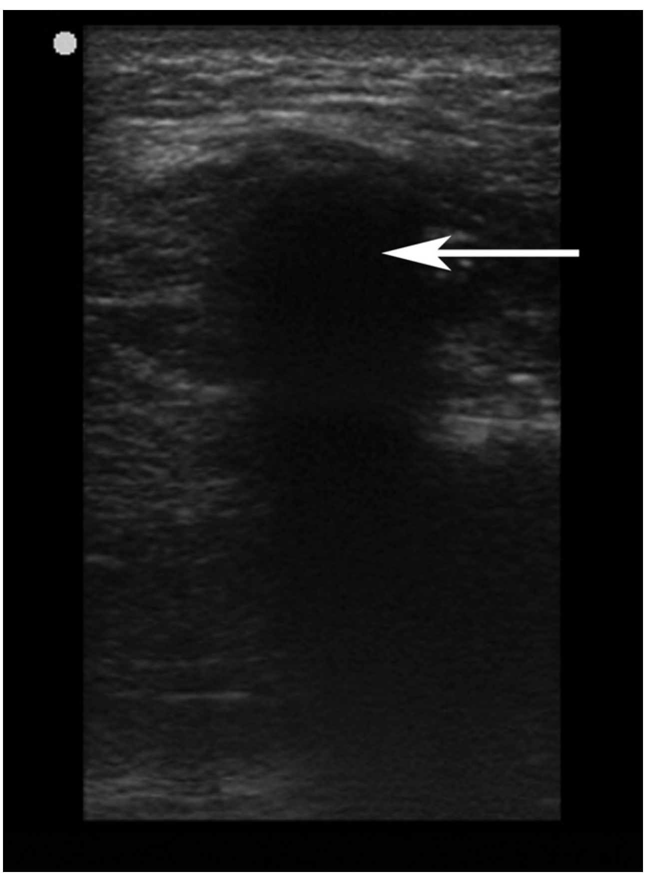

Fig. 2 Transverse ultrasound image at the chest tube insertion site reveals a hyperechoic arc with far-field shadowing (white arrow). This finding represents the chest tube within the subcutaneous tissue.

Fig. 3 Transverse ultrasound image cephalad to the chest tube insertion site. Chest tube is now intrathoracic, and the hyperechoic arc has disappeared. The fifth rib with far-field shadowing (white star) is seen deep to the subcutaneous tissue.

The primary outcome measures of this study, the sensitivity and specificity, referred to the investigators' ability to distinguish extrathoracic from intrathoracic chest tube position using bedside ultrasonography. This was compared to the gold standard of direct visual and tactile confirmation of chest tube position.

2.4. Data analysis

Statistical analysis included sensitivity and specificity. Data were analyzed using Stata/SE 9.2 (Stata Corporation, College Station, TX).

3. Results

The 2 unembalmed cadaveric subjects (4 hemithoraces) and 4 investigators yielded 16 total chest tube placements. Eight chest tubes were placed in the extrathoracic position and 8 chest tubes placed in the intrathoracic position. Each investigator placed 4 chest tubes and sonographically evaluated 12 chest tube positions. A total of 48 chest tube placements were evaluated. All 4 investigators correctly identified the chest tube position in each of the 12 hemithoraces they evaluated.

In differentiating extrathoracic vs intrathoracic placement of thoracostomy tubes, use of the DICE sign in an unembalmed cadaveric model showed a sensitivity of 100% (95% confidence interval, 83%-100%) and a specificity of 100% (95% confidence interval, 83%-100%).

4. Discussion

To our knowledge there are no studies that have looked specifically at the use of bedside ultrasound in the evaluation of chest tube position. We describe a promising technique for confirming the intrathoracic placement of chest tubes using an easily recognizable bedside ultrasonographic finding. This finding, the sonographic DICE sign, after chest tube insertion was highly sensitive and specific in the differentiation of intrathoracic versus extrathoracic chest tube position.

Each modality used for chest tube confirmation has limitations. A chest radiograph may be misleading if the chest tube dissects through the tissue planes of the chest wall posteriorly and appears to be correctly placed on an anteroposterior view [15]. Computed tomography, although more accurate than chest radiography, requires a patient to be transported to evaluate chest tube position [6,10,12]. In an unstable patient, this may not be a feasible or reasonable option. In addition, in the intubated patient, an extrathoracically placed chest tube that is missed on the initial evaluation in a patient undergoing positive pressure ventilation has the potential for disastrous complications [1-4,11]. In these cases, bedside ultrasound has the potential to provide real-time dynamic images during chest tube placement, which may serve as a useful adjunct for the confirmation of chest tube location.

5. Limitations

This small pilot study of a previously unreported ultrasonographic technique for determining position of chest tube placement has several limitations. First, this study used unembalmed cadaveric subjects; it may be difficult to apply our results to the general ED population. Second, the sample size was small. Although 48 chest tube placements were evaluated, this was conducted on only 2 cadaveric subjects (4 hemithoraces). This small number of study subjects does not provide a perfect representation of the diverse body morphology and habitus found in ED patients. Ultrasonic verification is likely to be considerably more difficult in obese patients and those with subcutaneous emphysema. In particular, a short placed chest tube, a common problem of tube thoracostomy in morbidly obese patients, may potentially lead to a false-positive result. This result could occur if a short placed subcutaneous chest tube ends before entering the pleural space and is interpreted as intrathoracic according to our DICE sign. In this circumstance, the presence or absence of other clinical indicators of intrathoracic chest tube placement should be observed. The chest tube can be further advanced observing for the continuation of the hyperechoic arc sign along the thorax. The persistence of the hyperechoic arc sign with tube advancement would indicate a short placed extrathoracic tube. Both our cadavers were of average build. It is also possible that the blunt dissection used in the confirmation of chest tube location may affect our results as well. The cause of death in our cadaveric subjects was unknown. Finally, investigators participating in this study were familiar with the use of ultrasound in clinical practice. Consequently, a 30-minute training session may not be adequate, and the study results may not translate to the novice ultrasound user.

6. Conclusion

In conclusion, bedside ultrasound, in a cadaveric model, appears to be a highly sensitive and specific tool for differentiating intrathoracic vs extrathoracic chest tube location. Further studies in the ED setting are required to fully determine the clinical applications and benefits of using bedside ultrasound to confirm chest tube position.

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