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Original Contribution

The bubble study: ultrasound confirmation of central venous catheter placement☆,☆☆,★,★★

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ABSTRACT

Study objective: The objective was to determine if ultrasound (US) can more rapidly confirm central venous catheter (CVC) position in comparison to chest radiography (CXR) in the emergency department.
Methods: The study included a convenience sample of emergency department patients with supradiaphragmatic CVCs and a CXR for confirmation. Ultrasound was used for CVC confirmation by visualizing microbubble artifact in the right atrium after injection of saline through the distal port. To evaluate for pneumothorax (PTX), "sliding sign" of the pleura was noted on US of the anterior chest. Blinded chart review was performed to assess CXR timing, catheter position and CVC complications. Student's *t* test was used to compare US time to CXR performance time and radiologist reading time.
Results: Fifty patients were enrolled; 4 were excluded because of inadequate views. Forty-six patients were included in the final analysis. Mean total US time was 5.0 minutes (95% confidence interval [CI], 4.2-5.9) compared to 28.2 minutes (95% CI, 16.8-39.4) for CXR performance with a mean difference of 23.1 minutes (95% CI, −34.5 to −11.8; $P < .0002$). When comparing only US CVC confirmation time to CXR time, US was an average of 24.0 minutes (95% CI, −35.4 to −12.7; $P < .0001$) faster. Comparing total US time to radiologist CXR reading time, US was an average of 294 minutes faster (95% CI, −384.5 to -203.5; $P < .0000$). There were a total of 3 misplaced lines and 2 patients with PTX, all of which were identified correctly on US.
Conclusion: Ultrasound can confirm CVC placement and rule out PTX significantly faster than CXR, expediting the use of CVCs in the critically ill.

1. Introduction

Central venous catheterization of the subclavian (SC) and internal jugular (IJ) veins occurs commonly in the emergency department (ED) and is necessary for patients requiring vasoactive medications, hemodynamic monitoring, or multiple drug infusions. Although the placement of central venous catheters (CVCs) is done routinely, it is not without complications that include catheter tip misplacement (5%-9%), pneumothorax (PTX; 0.1%-3%), and arterial puncture (3%-9%) [1–3]. Despite being made safer through ultrasound (US) guidance [4–6], there is still a CVC tip misplacement range of 3.3% to 14% [7] and an iatrogenic PTX rate of 0% to 3.3% [3,5,8,9]. Traditionally, a postprocedural portable chest radiograph (CXR) is performed for CVC confirmation and to rule out PTX; however obtaining one can take up to several hours, delaying use of the CVC in critical patients.

In recent years, numerous studies have attempted to shorten the delay to CVC use and expedite patient care through alternative methods of CVC confirmation [10,11]. Many of these alternatives to CXR involve the use of bedside US. Although several of these US protocols are useful in the intensive care unit (ICU), the time and extensive training required may not be as feasible in a busy ED. However, Liu and Bahl [12] outlined a quick and easy approach to using US to both identify CVC tip placement and rule out PTX by looking at 2 basic US views. Evaluating the anterior chest wall for the lung sliding sign has been well documented to be more sensitive than supine CXR in detecting PTX (98.1% vs 75.5%) [13]. Furthermore, bedside echocardiography can accurately identify catheter tip position by the use of saline flush to aid in the visualization in the right atrium (RA). The visualization of turbulence or microbubbles within the RA within 2 seconds of the distal port flush confirms adequate CVC placement with a 96% sensitivity and 93% specificity [12,14,15].

The primary objective of this study was to determine if bedside US could more rapidly confirm CVC tip position and rule out PTX than

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standard portable CXR in a busy, urban ED. We hypothesized that US confirmation of CVC placement would be faster than CXR confirmation.

2. Materials and methods

2.1. Study design and settings

We performed a prospective, observational, single-cohort study using a convenience sample of ED patients who had an above-the-diaphragm CVC placed from December 2012 to November 2013. The study was performed in the UF Health Jacksonville ED, which is a high-acuity, academic, urban ED that treats approximately 90 000 patients per year. The research protocol was approved by the University of Florida College of Medicine–Jacksonville Institutional Review Board.

2.2. Selection of participants

Participants were identified for inclusion by emergency physicians (either attending physicians or residents) working in the ED. If a potential participant was identified, one of the physician investigators was contacted to evaluate the patient for inclusion in the study. Inclusion criteria were (1) age 18 years and above, (2) placement of a CVC in either the SC or IJ vein with a confirmatory CXR ordered, and (3) patients who were neurologically intact and able to consent for themselves. Patients were excluded if they were pregnant or incarcerated. Patients deemed eligible were approached for enrollment, and written informed consent was obtained per Institutional Review Board requirements.

2.3. Bedside US for CVC confirmation

All bedside USs in this study were performed by 1 of 2 emergency medicine resident physicians. The principal investigator (PI) was the ED US director at the University of Florida–Jacksonville, who has formal emergency US training and certification as a registered diagnostic medical sonographer. Each of the 2 resident investigators had completed a mandatory 1-month US rotation as outlined by the 2008 American College of Emergency Physicians recommendations for resident education [16]. Each had completed a minimum of 25 Extended Focused Assessment with Sonography for Trauma examinations, demonstrating the standard subxiphoid cardiac view and lung US evaluating for the presence of PTX, before the implementation of the study. Furthermore, each physician received a 30-minute review of the specific views required for this study, subxiphoid cardiac view and anterior lung view, to ensure that images would be saved properly.

Our ED uses the 16-cm triple-lumen CVC (Vantex; Edward Lifescience Corp, Irvine, CA) and the 20-cm sepsis catheter (PreSep; Edward Lifesciences Corp, Irvine, CA) for CVC placement. All US views were obtained using a Sonosite (Sonosite, Bothwell, WA) M-Turbo US machine utilizing 2 probes: phased array and linear probes. Two US views were obtained and recorded. The subxiphoid 4-chamber view of the heart was obtained using the phased array probe, demonstrating the RAs and ventricle (RV) and the left atria and ventricle. Once obtained, the RA was inspected for the presence of the CVC tip. Its presence or absence was noted on the data sheet. Then the distal port of the CVC was flushed with a prefilled 10-mL sterile saline flush by either a nurse or an ED technician while the physician continued to monitor the heart in the subxiphoid plane, looking for the appearance of turbulence or microbubbles in the RA as the saline infused into the heart (Fig. 1, Video 1). Two 6-second video clips were taken to demonstrate the turbulence and were started at the infusion of the saline flush. If microbubbles were not immediately visualized, then the delay to visualization was noted in the comments on the data sheet. All video clips were digitally recorded and stored for later review.

Next, US of the anterior chest was performed to evaluate for PTX. Using a linear probe in the sagittal plane and starting at the clavicle, each rib interspace was interrogated to the diaphragm, visualizing the slide of the pleura indicating a normal lung (Fig. 2A, Video 2). The absence of lung slide was noted as a PTX, and an attempt was made to visualize the leading edge of the PTX (Fig. 2B, Video 3). Video clips and still m-mode images were taken on each side representing what the physician noted during the examination. Video clips and m-mode images of each side of the chest were recorded digitally and stored for later review.

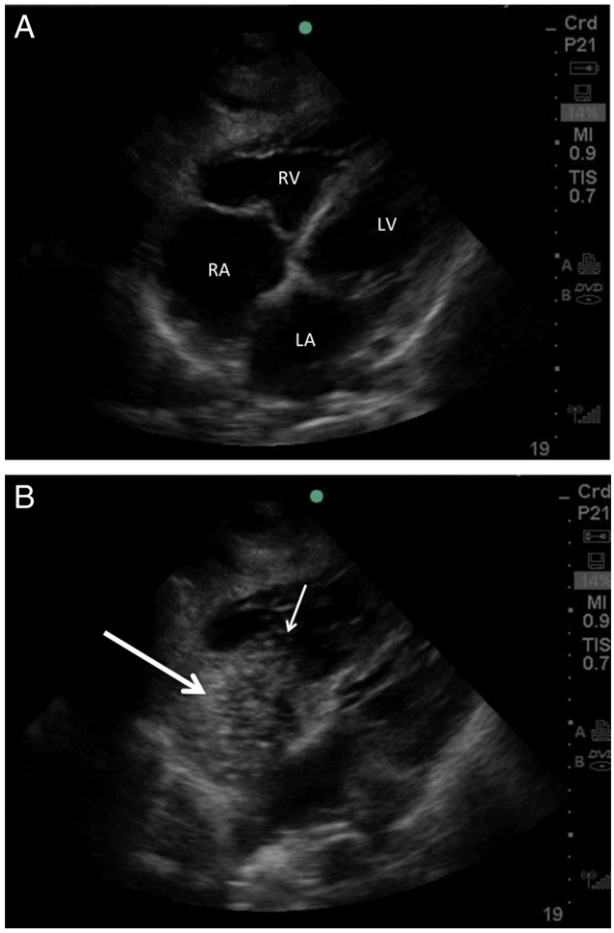

Fig. 1. (A) Ultrasound view of the heart in the subxiphoid window during saline flush of distal CVC port. The RA and RV are noted at time 0, at start of saline flush. (B) Microbubbles visible within the RA (bold arrow) and leading into the RV (small arrow) during the saline flush at the 1-second mark indicating CVC tip in correct position in the SVC.

2.4. Main measurements

Information collected on the data sheet included patient name, medical record number, date of birth, CVC location and side, CVC placement as correct or incorrect, PTX present or absent, time for cardiac US examination, time for total US examination, and notes. Physicians who performed the bedside US were blinded from the results of the postprocedural CXR. However, if the sonographer identified a line complication, the treating team was notified.

2.5. Chart review

An expert sonographer (the PI) who was blinded to all clinical information and outcome data independently reviewed all recorded video clips and images to ensure completeness. The review also included an