Saline Flush Test

Can Bedside Sonography Replace Conventional Radiography for Confirmation of Above-the-Diaphragm Central Venous Catheter Placement?

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Objectives—Resuscitation often requires rapid vascular access via central venous catheters. Chest radiography is the reference standard to confirm central venous catheter placement and exclude complications. However, radiographs are often untimely. The purpose of this study was to determine whether dynamic sonographic visualization of a saline flush in the right side of the heart after central venous catheter placement could serve as a more rapid confirmatory study for above-the-diaphragm catheter placement.

Methods—A consecutive prospective enrollment study was conducted in the emergency departments of 2 major tertiary care centers. Adult patients of the study investigators who required an above-the-diaphragm central venous catheter were enrolled during the study period. Patients had a catheter placed with sonographic guidance. After placement of the catheter, thoracic sonography was performed. The times for visualization of the saline flush in the right ventricle and sonographic exclusion of ipsilateral pneumothorax were recorded. Chest radiography was performed per standard practice.

Results—Eighty-one patients were enrolled; 13 were excluded. The mean catheter confirmation time by sonography was 8.80 minutes (95% confidence interval, 7.46–10.14 minutes). The mean catheter confirmation time by chest radiograph availability for viewing was 45.78 minutes (95% confidence interval, 37.03–54.54 minutes). Mean sonographic confirmation occurred 36.98 minutes sooner than radiography ($P < .001$). No discrepancy existed between sonographic and radiographic confirmation.

Conclusions—Confirmation of central venous catheter placement by dynamic sonographic visualization of a saline flush with exclusion of pneumothorax is an accurate, safe, and more efficient method than confirmation by chest radiography. It allows the central line to be used immediately, expediting patient care.

Key Words—emergency; emergency ultrasound; lung; procedural; transthoracic

Central venous catheter placement continues to be a mainstay for vascular access in urgent and emergent conditions in both the emergency department (ED) and critical care settings. Central venous catheters allow for delivery of life-saving medications, hemodynamic monitoring, placement of therapeutic devices, and central venous sampling. During acute resuscitations, whether traumatic or medical, rapid and effective access with central venous catheters may be life saving.

A recent meta-analysis demonstrated no significant difference in risk for line-associated infection between subclavian and internal jugular central venous catheter placement when performed in a controlled environment.[1] With increasing use of sonographic guidance,

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Abbreviations
ED, emergency department

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the internal jugular vein has become the preferred site for emergent cannulation because of its easy visualization, compressibility, and distance from the pleura.[2] Sonographic guidance for central venous access has already been shown to significantly reduce complications and improve success rates, which have been extensively reported.[3]

Traditionally, plain film chest radiography has been used to confirm proper placement of the catheter tip in the superior vena cava, as well as exclude pneumothorax, after placement of above-the-diaphragm central venous catheters. However, plain radiographs are often untimely and unpredictable in both EDs and intensive care units in large hospitals. They expose patients to ionizing radiation and have proven to be inferior to focused sonography for detection of apical and anterior pneumothorax in the supine patient.[4]

Given these limitations, the use of thoracic sonography has gained momentum in the confirmation of proper central venous catheter placement and evaluation for pneumothorax over the past few years. The use of point-of-care sonography in evaluation of pneumothorax has already been well described.[4] The use of sonographic guidance for internal jugular central venous catheters has also been shown to significantly reduce the number of iatrogenic pneumothoracies.[5] The ease of evaluating for pneumothorax with sonography lends itself conveniently for not only prevention but also detection of this iatrogenic complication.

The application of sonography for the confirmation of central venous catheter placement originates from the bubble study, or contrast echocardiography, which has been used since the 1960s by cardiologists to evaluate for atrial and ventricular septal defects. The traditional bubble test is performed with agitated saline. The operator transfers the contents of a single 10-mL normal saline flush between 2 syringes using a 3-way stopcock. This action generates microbubble formation and should be repeated until the fluid in the syringes is opaque without any visible bubbles. The saline is rapidly injected through the central venous catheter to prevent degradation of the microbubbles. Two-dimensional cardiac sonography is then performed to visualize the echogenic flow of the saline bubbles through the heart. Since bubbles created by hand agitation are too large to pass through the pulmonary venous system into the left heart, visualizing the echogenic flow on the left side of the heart indicates the presence of a septal defect. These studies are performed numerous times daily without significant complication rates.[6] Although there are limited data on complication rates, they are anecdotally reported to be scant. One study stated that the rate was as low as 0.062%.[6]

Recently, this idea has been extrapolated to the use of sonography for confirmation of central venous catheter placement in the ED. Liu and Bahl[7] presented a case in which an internal jugular catheter was confirmed by using a saline flush without agitation and visualizing the turbulent flow in the right atrium and ventricle. The authors correctly presumed that turbulent flow through the venous system in addition to the already inherent microbubbles in nonagitated saline was sufficient for confirmation of catheter placement.

Regarding pneumothorax, studies have also demonstrated a high degree of feasibility for using sonography as a more timely and reasonable substitute for excluding this complication. It has been show that sonographic evaluation of lung windows is superior to supine chest radiography.[8]

Another study comparing the confirmation of the central venous catheter position by direct visualization of a guide wire and catheter tip in the right atrium to chest radiography found similar data: that study reported a mean time for sonographic confirmation of 10.8 minutes compared to 75.3 minutes when using standard chest radiography.[3] However, this technique has the potential for damage to the right atrium or the causation of an ectopic heart rhythm.

Recent anesthesiology literature has demonstrated feasibility of central line placement with a combination of guided placement followed by transesophageal echocardiography to fully evaluate the position of the catheter tip within the superior vena cava. Such literature is promising; however, the procedure is invasive and difficult to perform in the emergency setting.[9]

Given the emergent need for confirmation of central venous catheter placement and exclusion of pneumothorax before catheter use, we developed a prospective study to investigate the use of the saline flush test in combination with thoracic sonography (both heart and lung) to safely and timely confirm proper above-the-diaphragm central venous catheter placement and exclude pneumothorax.

Materials and Methods

Design

We conducted a prospective study in the EDs at North Shore University Hospital, a tertiary care center and level I trauma center with an annual census of 90,000 ED patients, and Long Island Jewish Medical Center, a tertiary care center with an annual census of 82,000 ED patients.

Eligibility

All adult patients (age ≥18 years) treated by the study investigators and receiving an above-the-diaphragm central venous catheter (internal jugular) in the ED as part of their

routine care were included in the study. Children (age <18 years) were excluded from the study. Additionally, patients with incomplete data collection were excluded from analysis. Thirteen patients were excluded from the study.

Study Procedures

All above-the-diaphragm central venous catheters were placed by using dynamic sonographic guidance with no deviation from the standard of care by hospital-credentialed emergency physicians. After successful placement, study interventions involved performing focused cardiac sonography at the time of a saline flush of the central line. At the time of the saline flush, dynamic sonograms in the parasternal long-axis or subxyphoid views were obtained with a P4-1c phased array probe (Zonare Medical Systems, Mountain View, CA), recorded, and saved to Q-Path (Telexy Healthcare, Everett, WA), a middleware archiving solution. These data were then transferred to a data collection form during a weekly ultrasound quality assurance meeting where credentialed ED ultrasound faculty review all sonographic videos recorded from the prior week.

Visualization of the needle entering the internal jugular vein and visualization of the nonagitated saline flush within the right side of the heart served as confirmation of proper catheter placement, and times were recorded. A Zonare L8-3 or L0-5 linear array transducer was used to evaluate for ipsilateral lung sliding to exclude pneumothorax. A portable confirmatory chest radiograph was ordered immediately after line placement was obtained on all patients without any change to current practice. A waiver of informed consent was granted by the Institutional Review Board for this study, as the standard of care was not altered, and the study interventions would not adversely affect the rights and welfare of the patients.

Data Collection

For all study patients, sonograms were saved and stored on the Q-Path archiving system. Time 0 was recorded as the time of visualized insertion of the central venous catheter (needle visualization in the vessel). The time of confirmation of catheter placement by the saline flush was recorded as the time when bubbles were visualized sonographically within the right side of the heart. The visualization of lung sliding or absence of lung sliding in the anterior second and third intercostal fields of the ipsilateral lung was also recorded. Finally, the time of confirmation of catheter placement by chest radiography was recorded as the time of chest radiographic performance. The time that chest radiography was performed was also recorded and counted as the time to emergency physician reading. This criterion was included because at our institution, a DRX Revolution portable chest radiography machine (Carestream Health, Inc, Rochester, NY) is used with a digital viewer on the machine and, as such, can be interpreted by the physician at the time it is performed. All enrolled patients had their sonographic findings compared to confirmatory chest radiography.

The presence or absence of pneumothorax was based on visualized lung sliding or its absence. Chest radiography was performed for the same purpose. All data points and images were collected and entered into a password-protected electronic research database, to which only the principal investigator and subinvestigators had access.

Statistical Analysis

The mean time to confirmation of central venous catheter placement by sonography and the mean time to confirmation by radiography were calculated with 95% confidence intervals. Means for confirmation time were compared by a Student *t* test. $P < .05$ was considered statistically significant. The statistical analysis was performed with SPSS version 22.0 software (IBM Corporation, Armonk, NY).

Results

Eighty-one patients were enrolled in this study between December 1, 2012, and March 27, 2014. Thirteen patients were excluded from data analysis due to missing data. All missing data occurred secondary to sonographic video clips that were not appropriately recorded. However, the physician placing the central venous catheter in each instance visualized the sonographic confirmation. Those were excluded, as times would have then been approximate.

The average time to confirmation of central venous catheter placement by sonography (saline flush visualized and pneumothorax excluded) was 8.80 minutes (95% confidence interval, 7.46–10.14 minutes) from the time of needle insertion to the completion of the outlined protocol. The average time to confirmation of catheter placement by chest radiography was 45.78 minutes (95% confidence interval, 37.03–54.54 minutes). On average, sonographic confirmation of proper line placement occurred 36.98 minutes sooner than radiographic confirmation ($P > .001$).

The saline flush was visualized in the right side of the heart in all patients, and no discrepancy existed between sonographic and radiographic confirmation of catheter placement. Lung sliding was confirmed in the ipsilateral lung field in all patients, and no discrepancy existed between sonographic and radiographic exclusion of pneumothorax. No adverse effects were reported.

Discussion

The purpose of this study was to determine whether this approach would save time in a emergent setting. Since most ED patients receiving central venous catheters are acutely ill, this approach can facilitate the safe and rapid administration of life-saving medications, fluids, and blood products to critically ill patients with as much certainty as a chest radiograph for confirmation.

There were no discrepancies between chest radiographic and real-time sonographic evaluation. Sonographic confirmation was 36.98 minutes faster than an immediate portable chest radiograph, which is critical and potentially life saving in the emergency setting.

All but 1 of the cases that were excluded were confirmed visually by a credentialed emergency physician using the above technique; however, there were issues with coordination of the recording of the video clip and the push of the saline flush given that the timing of the video clips was limited to 10 seconds. The remaining case was a case of insertion of a transvenous pacemaker, during which the emergency physician failed to record the flush, as he was focused on the effort to expedite the placement of the pacemaker, which was completed successfully.

It is already the standard of care that sonography be used to guide the insertion of central venous catheters.[5] We suggest that visualized insertion of a central line in combination with visualization of the saline flush in the right side of the heart serves as an accurate and efficient confirmation of central line placement. Combining this approach with sonographic evaluation for pneumothorax should be performed uniformly for this procedure. The data presented here seem to suggest that this approach appears to be as accurate as chest radiography, although no complications were identified with either technique.

The results of our study correlate with other studies of sonographic confirmation of central venous catheter placement. Vezzani et al[10] described a similar technique using agitated saline. Both studies demonstrate the ability of sonography to confirm central venous catheter placement. Initial descriptions of using saline to identify the cardiac chamber described the use of agitated saline.[10,11] In our study, we elected to use nonagitated saline, as described in a study by Weekes et al.[12] That study used normal saline flushes and, as in this study, evaluated for turbulence of flow in the right heart chambers. They described it as the rapid atrial swirl sign. This technique was chosen, as it is standard practice to flush central venous catheters with normal saline during placement. The techniques of flushing the line with either agitated or nonagitated saline appear to confirm catheter placement with high sensitivity and specificity for central access above and below the diaphragm.[10–12]

In an emergency situation, the most important information regarding a recently placed central venous catheter is proper placement in the venous system and exclusion of pneumothorax. We postulate that, by using this technique, it is possible to both confirm the venous placement of the catheter and rule out iatrogenic pneumothorax.

A secondary effect of this protocol would be to decrease the number of chest radiographs performed both in the ED and in the intensive care unit, thus reducing the use of important resources. In addition, sonography does not expose patients to the cumulative effects of ionizing radiation.

There were several limitations to this study. There were no cases in which pneumothorax was identified by either chest radiography or sonography. However, there was no disagreement between sonographic findings and those from chest radiography. As we rely more on sonographic guidance, it is expected that the incidence of iatrogenic pneumothorax will continue to decrease. There were no cases in which the catheter was inserted into the arterial system or in which other complications were identified. These are possibilities that cannot be confirmed by our protocol and in theory could be of concern if the catheter tip were located in the subclavian vein or contralateral internal jugular vein for certain infusions. However, when venous placement is visualized, and a saline flush is visualized within the right heart, it is important to note that, logically, the tip of the catheter must be in the venous system and is suitable for use in a truly emergent situation.

In summary, although further investigation, including patient outcome studies, is warranted, we propose that sonographically guided central venous catheter placement should remain the standard of care. In addition, a right heart saline flush should be visualized, and the lack of ipsilateral pneumothorax should be evaluated every time a central venous catheter is placed. The use of this technique should prove to be both timely and accurate for central venous catheter confirmation in the emergency setting.

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