

Ultrasound versus Chest X-Ray for Confirmation of Central Venous Catheter Tip Position: A Comparative Study

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ABSTRACT

Introduction

Malposition of the central venous catheter (CVC) tip is common. Chest radiography is the gold standard for confirmation, but ultrasound offers a faster, radiation-free alternative. This study evaluated ultrasound's accuracy time required compared to chest X-ray (CXR) for CVC tip confirmation.

Methods

A total of 109 patients (15-65 years) undergoing CVC insertion via the right internal jugular vein were enrolled. Consent was obtained. Sonographic confirmation used a bubble study, while CXR provided radiographic confirmation. Sensitivity, specificity, predictive values, interrater reliability, and agreement between methods were assessed. The mean confirmation time required to perform the ultrasound assessment was compared to that of conducting the CXR.

Results

Ultrasound demonstrated a high diagnostic accuracy, with a sensitivity of 91.6% and specificity of 96.91%. It also showed a positive predictive value of 78.57% and a negative predictive value of 98.95%, indicating its reliability in confirming catheter placement. Additionally, interrater reliability was strong ($k = 0.82$), and the percent agreement between evaluators was 96.3%. Compared to CXR, ultrasound significantly reduced the confirmation time, verifying catheter placement approximately 88.29 minutes earlier.

Conclusion

These findings highlight ultrasound's efficiency and accuracy in clinical settings for CVC confirmation. Ultrasound confirmation using the saline flush method is one of the techniques for verifying CVC tip placement. It is also comparable to other modalities including chest radiography, for reducing confirmation time and improving efficiency.

Keywords

Central venous catheter; chest X-ray; ultrasound

INTRODUCTION

Central venous catheter (CVC) insertion is done using the Seldinger technique which was first used in the 1950s. However, anatomical differences posed a risk to traditional landmark approaches. Ultrasonography (USG) usage for catheter placement has been shown to increase accuracy, decrease complications, and improve visibility.¹⁻³ Correct CVC placement is vital for life-saving procedures and monitoring. Malposition rates are 4.12% (left internal jugular vein) and 1.1% (right internal jugular vein). Despite USG guidance, mispositioning occurs, requiring post-insertion confirmation.^{4,5}

The gold standard for identifying pneumothorax and verifying catheter insertion for more than 50 years has been a chest X-ray (CXR). However, it can postpone interventions, is time-consuming, and exposes patients to radiation. Research indicates that USG is a quicker, safer substitute that provides bedside availability of real-time imaging.^{6,7}

The bubble study is a low-risk contrast sonography that uses agitated saline to safely check catheter position. Catheters placed incorrectly may result in extravasation, arrhythmias, or thrombosis. It is advised to position it correctly in the superior vena cava (SVC), avoiding the right atrium.⁸ A catheter tip that extends more than 2 cm over the carina or into the right atrium on CXR is referred to as malposition. If the microbubble flow from the SVC occurs in the four-chamber image within two seconds, the USG bubble study confirms the tip position.⁹

The purpose of this study was to compare the speed and accuracy of USG with CXR to confirm the position of the CVC tip utilizing dynamic saline flush visualization in the right atrium.

METHODS

We did a prospective observational study and included 109 patients aged 16-65 years from the operating room and intensive care unit of Tribhuvan

University Teaching Hospital who needed central venous catheterization for various indications. Approval was obtained from the Institutional Review Committee of the Institute of Medicine, and informed written consent was obtained either from patients or their visitors. The patients in whom an acceptable acoustic view could not be obtained were excluded from the study. The total duration of the study was 7 months.

After completion of central vein catheterization, a phased array transducer of frequency 3-5 MHz was used for cardiac imaging. One 10-ml disposable syringe containing 9 ml of 0.9% normal saline and 1 ml of air was taken, and the syringe was agitated to form an opaque homogenous mixture of microbubbles without visible air. At the same time, a subcostal or parasternal four-chamber view was obtained. Then the syringe was connected to the distal port of the central venous catheter, and all the contents of the syringe were injected rapidly. Zero time was marked at the time of flush. A phased array probe was used to detect a bubble in the right atrium. The time interval between the flush and the appearance of the bubble was noted. Interpretation of the test was performed by using the criteria described by Vezzani and Colleagues (Table 1).⁹

Sonographic completion time was the time interval between starting of ultrasound (transducer placed on chest or abdomen) to the completion of interpretation or confirmation

Portable CXR was ordered immediately after insertion of catheter in intensive care unit or it was ordered after shifting the patient from operation theater to recovery room or intensive care unit (ICU) or postoperative ward if the catheter was inserted intraoperatively. Zero time was noted at the time of order of portable CXR. Chest X-ray film was taken in supine or semi-recumbent position and it was reported by the radiologist. Radiographic completion time was the time interval between the order of chest X-ray and the arrival of the film.

For calculation of concordance between CXR

Table 1. Classification and interpretation of microbubbling test

Characteristics	Interpretation
No bubbles	Negative Test
Few bubbles or appearance time > 2 secs	Test to be repeated: if confirmed, possible misplacement (probably in the superior venacava or internal jugular vein)
Numerous bubbles indistinguishable separately turbulent flow coming from atrium within 2 secs	Negative test: intra-atrial positioning
Numerous bubbles indistinguishable separately linear flow coming from superior vena cava within 2 secs	Positive test: CVC tip is correctly placed in the SVC

Table 2. Calculation of study parameters

CVC tip position by Ultrasound	CVC tip position by Chest X-ray		Total
	Correct position	Mal-position	
Correct position	A (true positive)	B (false positive)	(A + B)
Malposition	C (false negative)	D (true negative)	(C + D)
Total	(A + C)	(B + D)	(A+B+C+D)

and ultrasound, the statistics kappa (k) value was used. P-value of <0.05 was considered significant. Analysis was performed using SPSS 16.0 version.

A 2 x 2 table was used to calculate sensitivity, specificity, positive predictive value, and negative predictive value of USG (Table 2).

- Sensitivity of USG: $[A/(A+C)] \times 100$
- Specificity of USG: $[D/(D+B)] \times 100$
- Positive predictive value of USG: $[A/(A+B)] \times 100$
- Negative predictive value of USG: $[D/(C+D)] \times 100$
- % Agreement: $[(A+D)/(A+B+C+D)] \times 100$

RESULTS

A total of 109 patients were included in this study, out of whom 56.9% were male and 43.1% were female patients. The indications for central venous catheterization were mostly for inotropes/vasopressor infusion (89%), other indications being fluid management, central venous pressure measurement, and total parenteral nutrition use.

The minimum and maximum time taken for the confirmation of central venous catheter tip by chest radiography was 25 minutes and 350 minutes, respectively (mean 90.47 minutes).

The minimum and maximum time by ultrasound were 45 seconds (0.75 minutes) and 200 seconds (3.33 minutes) respectively and mean time taken was 130.83 seconds (2.18 minutes).

Sonographic confirmation was found to be earlier than radiographic confirmation. On average, USG confirmed catheter tip position 88.29 minutes sooner than CXR.

A comparison between USG and CXR is shown in Table 3 followed by subsequent analysis of different parameters.

- Sensitivity of USG = 91.67 %
- Specificity of USG = 96.91 %

- Positive predictive value (PPV) of USG = 78.57 %
- Negative predictive value (NPV) of USG = 98.95 %
- Kappa value (k) = 0.825 (P value <0.001)
- % Agreement (Pa) = 96.30

Interrater reliability between radiologist and principal investigator was estimated by kappa statistics. Kappa value was 0.825 which showed strong level of interrater agreement. Interrater percent agreement between the diagnosis of central venous catheter tip position by chest X-ray and that of ultrasound was 96.30%. (P <0.001).

DISCUSSION

The purpose of this study was to evaluate the accuracy and mean time efficiency of ultrasound vs the gold standard chest radiograph for verifying the placement of the central venous catheter (CVC) tip. The majority of the study's patients needed an immediate catheter placement for resuscitation because they were either critically unwell or undergoing surgery. In situations like these, where getting and analysing a chest CXR takes time, ultrasound (USG) made it possible to validate the position of the catheter tip 88.29 minutes faster than CXR, allowing for safe and prompt catheter use.

In this study, every CVC insertion was guided by ultrasound. The combination of real-time saline flush visualization in the right atrium with real-time USG during insertion has proven to be an accurate and effective technique. USG confirmation has a sensitivity of 91.67% and a specificity of 96.91%. Additionally, prior research has demonstrated that USG correctly locates the catheter tip and aids in avoiding potentially fatal consequences like pneumothorax. Hourmozdi et al. came to the conclusion that routine CXR following USG-guided CVC insertion is superfluous because it has minimal clinical value and delays resuscitation.¹⁰

Both operator expertise and anatomical considerations affect the success of CVC placement. Although real-time USG makes vessel localization easier for novices as well, it may make malposition

Table 3. Comparison of CVC tip position finding by CXR and USG

CVC tip position by USG	CVC tip position by CXR		Total
	Correct position	Mal-position	
Correct position	11	3	14
Malposition	1	94	95
Total	12	97	109

rates higher for unskilled operators in emergency situations. It is advised to perform at least 50 procedures to become proficient in ultrasound-guided cannulation.^{11,12} Intra-atrial malposition was common in this study, most likely as a result of trainees performing procedures putting catheters deeper than was required. The final location of the CVC tip is, however, also determined by patient's height and vessel's length, which is another significant anatomical factor. The fact that every CVC in the research was positioned more than 15 cm from skin is probably what led to the rise in intra-atrial malpositions. Furthermore, compared to CXR, USG is less accurate since it can identify intra-atrial malposition more readily than extra-atrial malposition.⁷

The linear flow of microbubbles reached the right atrium in two seconds, indicating that three intravascular malpositions in the proximal superior vena cava (SVC) found on CXR were false positives on USG. One false negative occurred when USG showed turbulent flow from the atrium within two seconds of the saline flush, despite CXR showing a well-positioned catheter. Nevertheless, USG revealed every intra-atrial malposition found by CXR. The lead investigator conducting sonographic confirmation and the radiologist had an interrater agreement of 96.30%.

The accuracy of USG is dependent on the length of the catheter, and the study did not include children. Given that adults and children employ different catheter lengths, the widely accepted two-second cut-off for the development of saline flush in the right atrium, as reported by Vezzani et al., may not be applicable in all cases. Using a 500-millisecond cut-off rather of two seconds, Meggiolaro et al. discovered 100% sensitivity and 99% specificity for CVC malposition detection. This significantly increased USG's detection rate of proximal intravascular malposition in the SVC.¹³

Contrarily, Cortellaro et al. found that whereas USG had a higher specificity (98%) and negative predictive value (94%) than CXR, it had a lower sensitivity (33%) and positive predictive value (67%). USG missed the majority of intravascular misplacements in their investigation, but it did detect all intracardiac malposition.¹⁴ Nonetheless, our study's kappa statistic (0.82) shows a great agreement between CXR and USG results.

While USG offers a safer procedure with fewer complications, it is comparable to the landmark method.¹⁵ All CVC insertions in our study were performed successfully the first time, with the exception of intra-atrial malposition, which had no negative effects. Catheter tips placed at the SVC-atrial junction are regarded as safe and do not raise the risk of complications during medical crises.

Patient height, body habitus, and the insertion

site all affect the ideal catheter depth. However, because of time constraints, standard insertion lengths are employed in emergency situations. An appropriate insertion length for right internal jugular vein cannulation is 15 cm, based on typical adult height. However, Rash Kujur et al. recommended 12 cm for Indian patients and 16 cm for Western populations, however McGee et al. recommended 16 cm as safe.¹⁶⁻¹⁸ Adult CVC insertions in our sample were longer than 15 cm, which may account for the increased rate of intra-atrial malposition. To find the ideal catheter insertion length for the adult Nepali population, more research is required. Additionally, multicentric studies conducted across the nation may yield more accurate data about regional variances.

CONCLUSION

Our study shows that the sensitivity and specificity of ultrasound for confirmation of the CVC tip were high, and there was close concordance between CXR and ultrasound. The mean completion time for confirmation by ultrasound was shorter than the completion time for confirmation by CXR. This study concluded that ultrasound can be used for rapid and accurate confirmation of the catheter tip as an alternative to CXR.

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CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

DECLARATION

This study has been presented at the 20th Conference of the Society of Anaesthesiologists of Nepal (SANCON) in 2019 as an oral paper in the free paper session and abstract published in the souvenir of the conference. It has not, however, been published as scientific literature in journals anywhere else.

AUTHOR CONTRIBUTIONS

LNM: Conceptualization, Methodology, Data collection, Writing –Original Draft; ASB: Conceptualization, Data Curation, Investigation, Resources, Writing – Review & Editing; BDP: Supervision, Validation, Critical Review of

Manuscript; SPA Manuscript Editing and critical review; AS: Critical review of manuscript

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