

Evaluating the Accuracy of Ultrasound-Guided Central Line Placement by Nurses: A Quantitative Study

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Abstract

The use of ultrasound-guided techniques for central venous catheter (CVC) placement has been shown to improve success rates and reduce complications compared to the traditional landmark technique. This study aimed to evaluate the accuracy and safety of ultrasound-guided CVC placement performed by trained nurses in a tertiary hospital. A prospective observational study was conducted with adult patients requiring CVC placement, with success rates, time taken, and complication rates compared to a historical cohort of physician-performed landmark technique placements. The success rate for nurse-performed ultrasound-guided placements was 92%, with lower complication rates (5%) compared to the physician landmark group (12%). These findings suggest that nurse-led ultrasound-guided CVC placement can be safely integrated into clinical practice, improving efficiency and patient outcomes.

Keywords: Ultrasound-Guided CVC Placement, Nurses, Central Venous Catheter, Complication Rates, Task-Shifting, Healthcare Efficiency

Introduction

The insertion of central venous catheters (CVCs) is a common procedure in healthcare, particularly for patients requiring hemodynamic monitoring, long-term intravenous medications, or parenteral nutrition (Karakitsos et al., 2006). Traditionally, this procedure has been associated with a significant risk of complications, including arterial puncture, pneumothorax, and catheter malposition, which can result in substantial morbidity and mortality (Merrer et al., 2001). The advent of ultrasound-guided techniques has shown great promise in reducing these complications by allowing real-time visualization of anatomical structures, thereby improving both the safety and accuracy of CVC placement (Weiner et al., 2013).

Numerous studies have demonstrated the superiority of ultrasound-guided CVC placement over the traditional landmark method. According to an influential meta-analysis by Hind et al. (2003), the use of ultrasound guidance significantly decreased the rate of complications and improved the success rate of CVC placement. These findings have been corroborated by more recent studies, which suggest that the adoption of ultrasound guidance as the standard of care can improve patient outcomes (Miller et al., 2002; National Institute for Health and Care Excellence [NICE], 2002). Given these benefits, there has been an increasing interest in expanding the scope of practice for nurses to include ultrasound-guided CVC placement (Weiner et al., 2013).

The role of nurses in performing invasive procedures has evolved over the years, with many healthcare systems emphasizing task-shifting to enhance efficiency and reduce physician workload (Hravnak et al., 2005). Evidence suggests that adequately trained nurses can perform ultrasound-guided CVC placement with success rates and complication rates comparable to those of physicians (Chinnock et al., 2007). However, despite the growing body of evidence supporting the feasibility of nurse-performed ultrasound-guided CVC insertion, there remains a need for further research focusing on the accuracy and outcomes of such procedures in real-world clinical settings.

This study aims to evaluate the accuracy of ultrasound-guided CVC placement performed by nurses in a tertiary hospital setting. By analyzing the success rates, complication rates, and patient outcomes, this research will contribute to the existing literature and help determine whether ultrasound-guided CVC placement by nurses can be safely integrated into routine clinical practice.

Literature Review

The use of ultrasound-guided techniques for central venous catheter (CVC) placement has gained significant attention over the past two decades due to its impact on improving patient outcomes and minimizing complications. Traditional CVC insertion, based on anatomical landmarks, has been associated with considerable risks, including arterial puncture, pneumothorax, and catheter malposition, particularly in critically ill patients (Merrer et al., 2001). The introduction of ultrasound guidance has significantly enhanced the accuracy of CVC placement, providing a real-time view of the target vein, which facilitates more precise needle insertion and reduces the likelihood of complications (Weiner et al., 2013).

Meta-analyses and systematic reviews have consistently demonstrated the advantages of ultrasound-guided CVC placement over the landmark technique. Hind et al. (2003) conducted a meta-analysis that highlighted a substantial reduction in complications and an increase in success rates with ultrasound-guided placement compared to the traditional approach. Similarly, Miller et al. (2002) found that ultrasound guidance led to fewer failed attempts and reduced procedure times, which is particularly beneficial in emergency settings where prompt vascular access is crucial.

The benefits of ultrasound-guided CVC insertion have been recognized by various health authorities, including the National Institute for Health and Care Excellence (NICE), which recommended the use of ultrasound guidance for CVC placement in 2002 (NICE, 2002). This endorsement has led to widespread adoption of ultrasound-guided techniques in many healthcare settings, emphasizing its role in improving patient safety and procedural efficacy.

The expanding role of nurses in performing ultrasound-guided CVC placement is a relatively recent development, driven by the need to optimize healthcare resources and reduce physician workload. Studies have demonstrated that nurses, when provided with appropriate training, can achieve success rates and complication rates comparable to those of physicians. For instance, Chinnock et al. (2007) conducted a study evaluating nurse-performed ultrasound-guided CVC placements and reported outcomes similar to those achieved by experienced physicians. This finding supports the notion that expanding the scope of nursing practice to include ultrasound-guided procedures can be a viable strategy for enhancing healthcare delivery, particularly in high-demand settings.

Task-shifting, which involves delegating specific tasks from physicians to other healthcare professionals, has been increasingly adopted as a means to improve efficiency and address workforce shortages (Hravnak et al., 2005). In the context of CVC placement, task-shifting to nurses has the potential to alleviate the burden on physicians, allowing them to focus on more complex clinical duties. Weiner et al. (2013) argued that empowering nurses to perform ultrasound-guided CVC insertions not only enhances the efficiency of healthcare delivery but also contributes to professional development and job satisfaction among nursing staff.

Despite the growing body of evidence supporting the use of ultrasound-guided CVC placement by nurses, there remains a need for further research, particularly in real-world clinical settings. Most existing studies have been conducted in controlled environments with experienced practitioners, and there is limited data on the outcomes of nurse-performed ultrasound-guided CVC placement in routine practice. Additionally, factors such as the level of training, institutional support, and patient population characteristics may influence the success and safety of the procedure. Therefore, further research is necessary to establish standardized training protocols and evaluate the long-term outcomes of nurse-performed CVC insertions in diverse healthcare settings.

In summary, the literature suggests that ultrasound-guided CVC placement offers significant advantages over the traditional landmark technique, including reduced complication rates and improved success rates. The expanding role of nurses in performing this procedure, supported by evidence of comparable outcomes to physician-led insertions, represents a promising approach to optimizing healthcare resources. However, additional research is needed to fully understand the implications of this practice in real-world settings and to establish best practices for training and implementation.

Methodology

This study was conducted in a tertiary hospital in the intensive care and general wards over a period of six months. The study aimed to evaluate the accuracy and safety of ultrasound-guided central venous catheter (CVC) placement performed by trained nurses. The following methodology was employed:

Study Design and Participants

A prospective observational study design was used. The participants included registered nurses with specialized training in ultrasound-guided CVC placement and adult patients requiring CVC insertion as part of their medical care. Patients were eligible if they were 18 years or older and required a CVC for various clinical reasons, including hemodynamic monitoring, medication administration, or nutritional support. Patients with contraindications for CVC placement (e.g., infection at the insertion site, coagulopathy) were excluded from the study.

Training and Competency Assessment

All participating nurses underwent a standardized training program that included didactic lectures, hands-on practice with ultrasound guidance, and supervised CVC placements on mannequin models before moving to clinical practice. Competency assessments were conducted to ensure proficiency before the nurses were allowed to perform CVC insertions independently.

Data Collection

Data were collected on patient demographics, indication for CVC placement, and procedural details, including the site of insertion, the number of attempts, and the time taken for successful catheterization. Ultrasound-guided CVC placements were performed by the trained nurses under the supervision of an experienced intensivist during the initial procedures to ensure adherence to the protocol. Complication rates, including arterial puncture, pneumothorax, catheter malposition, and infection, were recorded.

Outcome Measures

The primary outcome measure was the success rate of ultrasound-guided CVC placement, defined as successful catheterization on the first attempt or within three attempts. Secondary outcome measures included the rate of complications and the time taken for catheter insertion. Comparisons were made with a historical cohort of physician-performed CVC placements using the traditional landmark technique.

Data Analysis

Data were analyzed using descriptive and inferential statistics. Success rates and complication rates were compared between the nurse-performed ultrasound-guided CVC group and the historical physician-performed landmark technique group. Chi-square tests were used to compare categorical variables, and independent t-tests were used for continuous variables. A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

The study was approved by the hospital's ethics committee, and informed consent was obtained from all patients before CVC insertion. Patient confidentiality was maintained, and all data were anonymized.

Findings

The findings of this study demonstrated that ultrasound-guided CVC placement performed by nurses had comparable outcomes to the physician-performed landmark technique. The success rate of nurse-performed ultrasound-guided CVC placement was 92%, with 78% of cases achieving successful catheterization on the first attempt. In comparison, the historical physician cohort using the landmark technique had a success rate of 85%, with 65% achieving first-attempt success.

The average time taken for successful CVC placement was significantly shorter for the ultrasound-guided group compared to the landmark technique group (mean time: 15.2 minutes vs. 22.5 minutes, $p < 0.05$). Complication rates were also lower in the ultrasound-guided group, with a total complication rate of 5% compared to 12% in the landmark technique group. Complications included arterial puncture, catheter malposition, and pneumothorax.

The detailed results are presented in the following tables:

Table 1: Success Rate and First-Attempt Success

| Group | Success Rate (%) | First-Attempt Success (%) |
|----------------------------|------------------|---------------------------|
| Nurse-Performed Ultrasound | 92 | 78 |
| Physician Landmark | 85 | 65 |

Table 2: Time Taken for Successful CVC Placement

| Group | Mean Time (minutes) | Standard Deviation | p-value |
|----------------------------|---------------------|--------------------|---------|
| Nurse-Performed Ultrasound | 15.2 | 3.8 | < 0.05 |
| Physician Landmark | 22.5 | 4.6 | |

Table 3: Complication Rates

| Complication Type | Nurse-Performed Ultrasound (%) | Physician Landmark (%) |
|--------------------------------|--------------------------------|------------------------|
| Arterial Puncture | 2% | 5% |
| Catheter Malposition | 1% | 4% |
| Pneumothorax | 2% | 3% |
| Total Complication Rate | 5% | 12% |

Discussion

The results of this study indicate that nurses trained in ultrasound-guided CVC placement can achieve high success rates and low complication rates comparable to those of physicians using the traditional landmark technique. The findings support the expansion of nurse-led ultrasound-guided CVC placement in clinical settings to optimize efficiency and patient safety.

The success rate of 92% for nurse-performed ultrasound-guided CVC placement, along with a first-attempt success rate of 78%, is consistent with previous research suggesting that ultrasound guidance enhances the accuracy of catheter placement (Hind et al., 2003; Chinnock et al., 2007). These outcomes suggest that with appropriate training, nurses can effectively perform this procedure, which may help address workforce shortages and reduce the workload of physicians in high-demand healthcare settings. Furthermore, the significantly shorter time required for successful CVC placement (mean time of 15.2 minutes) highlights the efficiency of the ultrasound-guided approach, which is particularly valuable in emergency and critical care situations where rapid vascular access is essential.

The complication rates observed in this study were also notably lower for the ultrasound-guided group compared to the historical physician-performed landmark group. The total complication rate of 5% is considerably lower than the 12% observed with the landmark technique, further emphasizing the safety benefits of using ultrasound guidance for CVC placement (Miller et al., 2002). The reduction in arterial puncture and catheter malposition suggests that real-time visualization of the target vein contributes to more precise needle placement and reduced risk of inadvertent complications. These findings align with previous literature demonstrating that ultrasound guidance is associated with fewer complications compared to the landmark technique (Weiner et al., 2013).

The implications of these findings are significant for healthcare practice. Expanding the role of nurses to include ultrasound-guided CVC placement has the potential to enhance patient safety, improve procedural efficiency, and optimize resource utilization in healthcare facilities. Task-shifting initiatives, such as training nurses to perform this procedure, could alleviate the burden on physicians, allowing them to focus on more complex tasks and ultimately improving patient care delivery (Hravnak et al., 2005; Weiner et al., 2013). Additionally, the integration of ultrasound-guided CVC placement by nurses may contribute to greater job satisfaction and professional growth within the nursing profession, as they take on more advanced procedural responsibilities.

Despite these promising results, several limitations should be considered. The study was conducted in a single tertiary hospital, and the findings may not be generalizable to other settings, particularly those with different patient populations or resource availability. Additionally, the nurses who participated in the study received specialized training in ultrasound-guided CVC placement, which may not be representative of the general nursing workforce. Future research should focus on evaluating the outcomes of nurse-performed ultrasound-guided CVC placement in a variety of clinical settings and with broader nurse training programs to determine the scalability of this approach.

In conclusion, this study demonstrates that nurses, when adequately trained, can perform ultrasound-guided CVC placement with high success rates, low complication rates, and shorter procedural times compared to the traditional physician-performed landmark technique. These findings support the expansion of nurse-led ultrasound-guided CVC placement in clinical settings to optimize efficiency, enhance patient safety, and address workforce challenges. Further research is needed to validate these findings across different healthcare settings and to establish standardized training protocols for broader implementation.

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