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Central Venous Catheterization in the ICU: A Comparison of Anatomical Landmark and Ultrasound-Guided Techniques

Ardian Pratiaksa[1]*, Purwoko[1], Muhammad Husni Thamrin[1], Bambang Novianto Putro[1], Fitri Hapsari Dewi[1]

[1]Department of Anesthesiology, Faculty of Medicine, Universitas Sebelas Maret, Surakarta, Indonesia

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***Corresponding author:**
Ardian Pratiaksa

E-mail address:
ardpratiaksa@gmail.com

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A B S T R A C T

Introduction: Central venous catheterization (CVC) is frequently required in intensive care units (ICUs) for administering medications, fluids, and monitoring central venous pressure. However, CVC insertion can lead to complications such as arterial puncture, hematoma formation, and pneumothorax. Ultrasound guidance has been advocated to reduce these complications, but its effectiveness in the ICU setting remains debated. This study compared the complication rates of anatomical landmark-guided versus ultrasound-guided CVC insertion in ICU patients. **Methods:** A prospective cohort study was conducted in the ICU of a tertiary care hospital. Patients requiring CVC were divided into two groups: anatomical landmark-guided and ultrasound-guided insertion. The primary outcome was the incidence of complications, including arterial puncture, hematoma, and pneumothorax. Secondary outcomes included cannulation time and the number of cannulation attempts. **Results:** A total of 39 patients were included in the study. The incidence of complications was significantly lower in the ultrasound-guided group (2 complications) compared to the anatomical landmark group (7 complications) (p=0.017). The most common complication was arterial puncture, occurring in 7 patients in the anatomical landmark group and 2 patients in the ultrasound-guided group. **Conclusion:** Ultrasound guidance significantly reduces the risk of complications during CVC insertion in the ICU. This technique should be considered the standard of care for CVC insertion in this setting.

1. Introduction

Central venous catheterization (CVC) is a common procedure performed in the intensive care unit (ICU) to gain access to the central venous system. It is often essential for administering medications, fluids, and nutritional support, as well as monitoring central venous pressure and facilitating other critical interventions such as renal replacement therapy. While CVC is generally considered a safe procedure, it is not without risk, and complications can range from minor to life-threatening. The traditional approach to CVC insertion relies on anatomical landmarks to guide the placement of the catheter. This technique, while widely practiced, has been associated with a significant risk of complications, including arterial puncture, hematoma formation, pneumothorax, and even catheter malposition. These complications can lead to increased morbidity, mortality, and healthcare costs.[1-3]

In recent years, the use of ultrasound guidance for CVC insertion has gained popularity as a means to improve patient safety and reduce complications. Ultrasound guidance allows for real-time visualization of the target vein and surrounding structures, enabling more precise needle placement and reducing the risk of inadvertent puncture of adjacent arteries or nerves. Studies have demonstrated that ultrasound-guided

CVC insertion can significantly reduce the incidence of complications, particularly arterial puncture and hematoma formation. Despite the growing body of evidence supporting the use of ultrasound guidance for CVC insertion, its adoption in clinical practice has been somewhat variable. Some clinicians remain hesitant to embrace this technique due to concerns about cost, training requirements, and the perception that it may be more time-consuming than the traditional landmark-guided approach. However, the potential benefits of ultrasound guidance in terms of patient safety and reduced complications cannot be ignored.[4-7]

Several studies have investigated the use of ultrasound guidance for CVC insertion in various clinical settings, including the emergency department, operating room, and ICU. While the majority of these studies have demonstrated a reduction in complications with ultrasound guidance, some have shown conflicting results. This variability may be attributed to differences in study design, patient populations, operator experience, and the specific ultrasound techniques employed. In the ICU setting, patients are often critically ill and may have complex medical conditions that can increase the risk of complications during CVC insertion. These patients may have altered anatomy, coagulopathy, or other comorbidities that make them more susceptible to complications. Therefore, it is crucial to optimize the safety of CVC insertion in this vulnerable population.[8-10] This study aimed to compare the complication rates of anatomical landmark-guided versus ultrasound-guided CVC insertion in ICU patients. We hypothesized that ultrasound guidance would be associated with a lower incidence of complications, particularly arterial puncture and hematoma formation. The findings of this study have important implications for clinical practice and may help to inform guidelines for CVC insertion in the ICU.

2. Methods

This study employed a prospective cohort design to investigate the impact of ultrasound guidance on central venous catheterization (CVC) outcomes in critically ill patients admitted to the intensive care unit (ICU). The study was conducted at a tertiary care hospital with a dedicated ICU facility. Ethical approval for this study was obtained from the hospital's Institutional Review Board, ensuring adherence to the principles of the Declaration of Helsinki and safeguarding the rights and well-being of the participants. The study population comprised adult patients (18 years or older) admitted to the ICU who required CVC insertion for the management of their critical condition. Patients were eligible for inclusion if they had a clinical indication for CVC placement, such as the need for vasopressor support, central venous pressure monitoring, or the administration of concentrated medications or fluids. Exclusion criteria were carefully defined to minimize confounding factors and ensure the safety of the participants. Patients were excluded if they had any contraindications to CVC insertion, such as local infection at the insertion site, active bleeding diathesis, or severe anatomical distortions that could impede the procedure. Additionally, patients who were unable to provide informed consent or who had a known allergy to local anesthetics were excluded from the study. The study was conducted in the ICU setting, where patients typically require close monitoring and intensive medical care. The ICU environment provides the necessary infrastructure and expertise to manage critically ill patients and address any potential complications arising from CVC insertion. The study period spanned several months to ensure an adequate sample size and account for potential variations in patient demographics and clinical presentations.

To minimize selection bias and ensure comparability between the two study groups, patients were randomly assigned to either the anatomical landmark-guided group or the ultrasound-guided group. Randomization was performed using a computer-generated sequence, with allocation concealment maintained until the moment of CVC insertion. This rigorous randomization process aimed to create balanced groups with respect to potential confounding factors that could influence the study outcomes. Due to the nature of the interventions, blinding of the operators performing the CVC insertion was not feasible. However, the primary outcome of the study, the incidence of complications, was assessed by an independent observer who was blinded to the group assignment. This blinding strategy aimed to reduce the risk of observer bias and enhance the objectivity of the outcome assessment.

In the anatomical landmark-guided group, CVC insertion was performed using the traditional Seldinger technique, relying on surface anatomy and palpation to identify the target vein. Experienced intensivists or trained healthcare professionals skilled in landmark-guided CVC insertion performed the procedures. The insertion site was selected based on clinical considerations and operator preference, with the internal jugular or subclavian veins being the most common sites. The procedure was performed under strict aseptic conditions to minimize the risk of infection. The skin was prepared with an antiseptic solution, and sterile drapes were used to create a sterile field. Local anesthesia was administered to ensure patient comfort during the procedure. The operator then used anatomical landmarks to guide needle insertion, aiming to puncture the target vein and thread a guidewire through the needle. Once the guidewire was in place, the catheter was advanced over the guidewire into the vein. The catheter was then secured in place, and a chest radiograph was obtained to confirm proper placement and rule out complications such as pneumothorax. In the ultrasound-guided group, CVC insertion was performed using real-time ultrasound imaging to visualize the target vein and surrounding structures. This dynamic guidance aimed to enhance the accuracy of needle placement and reduce the risk of complications. The procedures were performed by operators with expertise in ultrasound-guided CVC insertion, ensuring proficiency in both ultrasound image acquisition and interpretation. A high-frequency linear ultrasound probe was used to visualize the target vein in real-time. The probe was positioned to obtain a clear view of the vein and its relationship to adjacent arteries and nerves. Sterile ultrasound gel was used to ensure acoustic coupling and minimize the risk of infection. The operator then inserted the needle under direct ultrasound visualization, carefully guiding it towards the target vein. Once the needle entered the vein, blood return was confirmed, and a guidewire was advanced through the needle. The catheter was then placed over the guidewire and secured in place. As with the landmark-guided group, a chest radiograph was obtained to verify catheter position and exclude complications.

The primary outcome of this study was the incidence of complications related to CVC insertion. Complications were defined as any adverse events occurring within 48 hours of the procedure that could be directly attributed to CVC insertion. The following complications were specifically monitored and recorded; Arterial Puncture: Inadvertent puncture of an artery during CVC insertion, potentially leading to hematoma formation or ischemia; Hematoma: Accumulation of blood within the tissues surrounding the insertion site, resulting from vessel injury or inadequate hemostasis; Pneumothorax: Entry of air into the pleural space, potentially causing lung collapse and respiratory distress; Catheter Malposition: Incorrect placement of the catheter, potentially leading to ineffective therapy or complications such as cardiac arrhythmias or vessel perforation; Infection: Microbial contamination of the insertion site or catheter, potentially leading to local or systemic infection. Secondary outcome measures included; Cannulation Time: The total time taken from initial needle insertion to successful catheter placement and confirmation of proper positioning; Number of Cannulation Attempts: The number of needle insertions required to achieve successful venous access and catheter placement.

Data were collected prospectively using standardized data collection forms to ensure consistency and accuracy. Trained research personnel recorded patient demographics, medical history, procedural details, and complications. Data were entered into a secure electronic database with restricted access to maintain confidentiality and data integrity. Statistical analysis was performed using appropriate statistical software. Descriptive statistics were used to summarize patient characteristics and baseline data. Categorical variables were compared using the chi-square test or Fisher's exact test, as appropriate. Continuous variables were compared using the Student's t-test or the Mann-Whitney U test, depending on the distribution of the data. The primary outcome, the incidence of complications, was analyzed using logistic regression to adjust for potential confounding factors. Multivariable analysis was performed to identify independent predictors of complications. A p-value of less than 0.05 was considered statistically significant.

3. Results

Table 1 presents the baseline characteristics of the 39 subjects enrolled in the study, divided into two groups: the Anatomical Marker (AM) group with 20 participants, and the Ultrasound Guidance (USG) group with 19 participants. The average age of participants was similar in both groups (AM: 55.05 years, USG: 54.89 years), with no statistically significant difference (p=0.714). This suggests that age is unlikely to be a confounding factor influencing the outcomes of the study. The distribution of males and females was not significantly different between the two groups (p=0.267). The AM group had a slightly higher proportion of males (65%) compared to the USG group (47.4%). The majority of participants in both groups fell within the normoweight category. There was no significant difference in BMI distribution between the groups (p=0.753). The most common diagnosis in both groups was sepsis shock, with a slightly higher proportion in the USG group (89.5%) compared to the AM group (70%). However, this difference was not statistically significant (p=0.458). The right subclavian vein was the predominant site for CVC insertion in both groups (AM: 90%, USG: 78.9%), with no statistically significant difference between the groups (p=0.218).

Table 1 . Basic characteristics of subjects.

Characteristic	AM Group (n=20)	USG Group (n=19)	p-value
Age (years)	55.05 ± 7.91	54.89 ± 6.31	0.714*
Gender			0.267**
* Male	13 (65%)	9 (47.4%)	
* Female	7 (35%)	10 (52.6%)	
BMI (kg/m^2)			0.753**
* Underweight	1(5%)	0	
* Normoweight	11(55%)	13(68.4%)	
* Overweight	8 (40%)	6(31.6%)	
Diagnosis			0.458**
* Sepsis shock	14(70%)	17(89.5%)	
* Other	6(30%)	2(10.5%)	
Vein location			0.218**
* Right subclavian	18(90%)	15(78.9%)	
* Other	2(10%)	4(21.1%)	

*Mann Whitney test (data does not meet the assumption of normality or ordinal data); **Chi-Square test/Fisher exact test (nominal data).

Table 2 presents the complications observed during central venous catheter (CVC) insertion for the two study groups: the Anatomical Marker (AM) group and the Ultrasound Guidance (USG) group. The overall incidence of complications was significantly lower in the USG group (10.5%) compared to the AM group (45.0%). This difference was statistically significant (p=0.017), indicating a clear advantage of using ultrasound guidance in reducing the risk of complications during CVC insertion. Arterial puncture was the most common complication observed in both groups. However, the USG group had a significantly lower incidence of arterial puncture (10.5%) compared to the AM group (35.0%). This finding highlights the benefit of ultrasound guidance in visualizing the target vein and avoiding inadvertent arterial puncture. Hematoma formation was observed in 2 patients (10.0%) in the AM group, while no hematomas occurred in the USG group. Although the sample size is small, this result suggests that ultrasound guidance may also help reduce the risk of hematoma formation.

Table 2. Complications of central venous catheter insertion.

Complication	AM Group (n=20)	USG Group (n=19)
Any complication	9 (45.0%)	2 (10.5%)
- Punctured artery	7 (35.0%)	2 (10.5%)
- Hematoma	2 (10.0%)	0 (0.0%)
p-value	**0.017***	-

*Chi-square test, p<0.05.

Table 3 compares two key outcomes of central venous catheter (CVC) insertion between the Anatomical Marker (AM) group and the Ultrasound Guidance (USG) group: the number of puncture attempts and the duration of insertion; Number of Puncture Attempts: The USG group required significantly fewer puncture attempts (mean 1.47) compared to the AM group (mean 2.30). This difference was statistically significant (p=0.005). The median number of attempts in the USG group was 1 (range 1-2), while in the AM group, it was 2 (range 1-5). This further emphasizes the precision offered by ultrasound guidance in achieving successful venous access; Duration of Insertion (min): Although the USG group had a shorter mean insertion time (14.11 minutes) compared to the AM group (15.70 minutes), this difference was not statistically significant (p=0.164). The median insertion time was also slightly shorter in the USG group (14 minutes) compared to the AM group (16 minutes).

Table 3. Comparison of central venous catheter insertion outcomes between anatomical marker and ultrasound-guided techniques.

Outcome measure	Anatomical marker (AM)	Ultrasound-guided (USG)	Mean difference (AM-USG)	p-value
Number of puncture attempts				
Mean ± SD	2.30 ± 1.03	1.47 ± 0.51	0.83	0.005*
Median (Range)	2 (1-5)	1 (1-2)		
Duration of insertion (min)				
Mean ± SD	15.70 ± 3.87	14.11 ± 1.59	1.59	0.164*
Median (Range)	16 (12-30)	14 (12-18)	-	-

*Mann Whitney test.

4. Discussion

The primary finding of this study, a significant reduction in the overall complication rate in the ultrasound-guided group compared to the anatomical landmark group, serves as a cornerstone in the argument for the widespread adoption of ultrasound guidance in central venous catheter (CVC) insertion. This observation, echoing the conclusions of numerous other studies, firmly establishes the critical role of ultrasound guidance in mitigating the inherent risks associated with this common procedure across various clinical settings. The traditional approach to CVC insertion, relying primarily on anatomical landmarks and palpation, has long been recognized as carrying a non-negligible risk of complications. These complications, though varying in severity, can significantly impact patient outcomes and healthcare costs. Inadvertent puncture of an artery, a frequent complication of landmark-guided CVC insertion, can lead to hematoma formation, arterial spasm, and even arteriovenous fistula formation. In severe cases, arterial puncture may necessitate surgical intervention or result in limb ischemia. Hematomas, another common complication, can occur due to vessel injury or inadequate hemostasis during CVC insertion. While often benign, hematomas can cause pain, and discomfort, and in some cases, may compress adjacent structures, leading to nerve injury or vascular compromise. Pneumothorax, a more serious complication, involves the entry of air into the pleural space, potentially causing lung collapse and respiratory distress. This complication may require chest tube insertion or other interventions to evacuate the air and re-expand the lung. Incorrect placement of the catheter, another potential complication, can lead to ineffective therapy, vascular perforation, or cardiac arrhythmias. Catheter malposition may necessitate repositioning or replacement of the catheter, increasing the risk of further complications. These complications, collectively, contribute to increased patient morbidity, prolonged hospital stays, and higher healthcare costs. Furthermore, they can cause significant patient anxiety and discomfort, diminishing the overall quality of care. In contrast to the traditional landmark-guided approach, ultrasound guidance offers a paradigm shift in CVC insertion, transforming it from a blind procedure to a visually guided one. Ultrasound allows for clear visualization of the target vein, differentiating it from adjacent arteries, nerves, and other structures. This accurate identification minimizes the risk of inadvertent puncture of non-target tissues. Ultrasound enables assessment of the size and depth of the target vein, aiding in the selection of appropriate needle size and insertion angle. This tailored approach reduces the risk of vessel injury and complications. Ultrasound provides dynamic guidance during needle insertion, allowing practitioners to visualize the needle tip in relation to the vessel wall and surrounding tissues. This real-time feedback ensures precise needle placement and minimizes the risk of complications. Ultrasound can be used to confirm proper catheter placement within the vein, reducing the need for post-procedure radiographic confirmation and minimizing the risk of catheter malposition. This enhanced visualization, afforded by ultrasound guidance, translates into a significant reduction in the overall complication rate. By minimizing the risk of arterial puncture, hematoma formation, pneumothorax, and catheter malposition, ultrasound guidance contributes to improved patient safety, shorter hospital stays, and reduced healthcare costs. Furthermore, ultrasound guidance can enhance the efficiency of CVC insertion by reducing the number of needle passes required to achieve successful venous access. This can lead to faster procedure times, minimizing patient discomfort and anxiety. Ultrasound guidance has revolutionized central venous catheter (CVC) insertion by providing dynamic, real-time visualization of the target vein and surrounding anatomical structures. This transformative capability has elevated CVC insertion from a procedure reliant on anatomical landmarks and blind needle advancement to a precisely guided intervention, minimizing the risk of complications and improving patient safety. The traditional approach to CVC insertion, relying primarily on anatomical landmarks and palpation, has inherent limitations that can compromise the safety and efficiency of the procedure. Individual anatomical variations can make it challenging to accurately identify the target vein and surrounding structures based on surface landmarks alone. This variability can increase the risk of inadvertent puncture of adjacent arteries, nerves, or other vital structures. Obesity, edema, or anatomical distortions can obscure surface landmarks, making it difficult to accurately estimate the location and depth of the target vein. This can lead to multiple needle passes and an increased risk of complications. In landmark-guided CVC insertion, the needle is advanced blindly towards the target vein, relying on tactile feedback and anatomical knowledge. This blind approach increases the risk of inadvertent puncture of non-target tissues and complications. Ultrasound guidance addresses these limitations by providing real-time visualization of the target vein and surrounding structures. Ultrasound provides a clear image of the target vein, differentiating it from adjacent arteries, nerves, and other structures. This clear visualization eliminates the guesswork associated with landmark-guided insertion and ensures accurate needle placement. Ultrasound enables assessment of the size, depth, and course of the target vein, as well as the presence of any anatomical variations or abnormalities. This information aids in the selection of appropriate needle size, insertion angle, and approach, optimizing the safety and efficiency of the procedure. Ultrasound provides dynamic guidance during needle advancement, allowing practitioners to visualize the needle tip in relation to the vessel wall and surrounding tissues. This real-time feedback ensures precise needle placement, minimizing the risk of inadvertent puncture of non-target structures. Ultrasound can be used to confirm intraluminal placement of the guidewire and catheter, reducing the need for post-procedure radiographic confirmation and minimizing the risk of catheter malposition. This enhanced precision, afforded by ultrasound guidance, translates into a significant reduction in the likelihood of complications. By minimizing the risk of arterial puncture, hematoma formation, pneumothorax, and catheter malposition, ultrasound guidance contributes to improved patient safety and better procedural outcomes. Furthermore, ultrasound guidance can enhance the efficiency of CVC insertion by reducing the number of needle passes required to achieve successful venous access. This can lead to faster procedure times, minimizing patient discomfort and anxiety. The precision offered by ultrasound guidance is particularly crucial in critically ill patients who may present with anatomical variations, coagulopathies, or other comorbidities that increase their susceptibility to complications. Critically ill patients may have anatomical variations due to previous surgeries, trauma, or underlying medical conditions. These variations can make it challenging to accurately identify the target vein using landmarks alone, increasing the risk of complications. Ultrasound guidance allows for clear visualization of the anatomy, even in the presence of variations, ensuring precise needle placement. Critically ill patients may have coagulopathies due to liver disease, sepsis, or other conditions. These coagulopathies increase the risk of bleeding complications during CVC insertion. Ultrasound guidance helps to minimize the risk of bleeding by allowing for precise needle placement and reducing the number of needle passes. Critically ill patients may have other comorbidities, such as obesity, edema, or anatomical distortions, that can obscure surface landmarks and make CVC insertion more challenging. Ultrasound guidance overcomes these challenges by providing clear visualization of the target vein and surrounding structures, even in the presence of obscuring factors. Arterial puncture, a dreaded complication associated with central venous catheter (CVC) insertion, can lead to a cascade of adverse events, ranging from minor discomfort to life-threatening consequences. The ability of ultrasound guidance to significantly minimize the risk of arterial puncture represents a critical advantage of this technique, enhancing patient safety and improving procedural outcomes. Inadvertent puncture of an artery during CVC insertion can have a range of deleterious effects. Arterial puncture can lead to the formation of hematomas, which are collections of blood outside of blood vessels. Hematomas can cause pain, swelling, and discoloration, and in severe cases, may compress adjacent structures, leading to nerve injury or vascular compromise. Arterial puncture can disrupt blood flow to tissues, leading to ischemia, or a lack of oxygen. Ischemia can cause pain, numbness, tingling, and in severe cases, tissue necrosis or gangrene. In some cases, arterial puncture can lead to the formation of an arteriovenous fistula, an abnormal connection between an artery and a vein. Arteriovenous fistulas can cause high-output cardiac failure, limb swelling, and in rare cases, may require surgical intervention. A pseudoaneurysm is a collection of blood that forms outside of an artery, contained by the surrounding tissues. Pseudoaneurysms can cause pain, swelling, and pulsatile masses, and may require surgical repair. Arterial puncture can increase the risk of infection, as bacteria can enter the bloodstream through the puncture site. Infections can lead to sepsis, a life-threatening condition. Ultrasound allows for clear differentiation between arteries and veins based on their anatomical characteristics and Doppler flow patterns. Arteries typically appear as pulsatile, thick-walled structures with bright, echogenic walls, while veins appear as non-pulsatile, thin-walled structures with anechoic (black) lumens. This clear distinction allows practitioners to confidently target the vein while avoiding the artery. Ultrasound provides real-time visualization of the needle trajectory, allowing practitioners to guide the needle away from arterial structures and towards the target vein. This dynamic guidance minimizes the risk of inadvertent arterial puncture. Ultrasound can be used to confirm venous access by visualizing blood flow within the vein using Doppler ultrasound. This confirmation ensures that the needle is correctly positioned within the vein before advancing the guidewire and catheter. The reduction in arterial puncture rates associated with ultrasound guidance translates into significant benefits for patients. By minimizing the risk of hematoma formation, ischemia, and other complications associated with arterial puncture, ultrasound guidance reduces patient morbidity and improves overall outcomes. Ultrasound guidance enhances the safety of CVC insertion by minimizing the risk of serious complications such as arteriovenous fistula formation and pseudoaneurysm formation. By reducing the need for corrective measures and repeat procedures, ultrasound guidance can improve the efficiency of CVC insertion, minimizing procedure time and patient discomfort. The ability of ultrasound guidance to significantly reduce the incidence of arterial puncture underscores its importance in CVC insertion. As evidence continues to mount supporting the safety and efficacy of ultrasound guidance, it is increasingly being recognized as the standard of care for CVC insertion in many clinical settings. By embracing ultrasound guidance, healthcare providers can minimize the risk of arterial puncture and its associated complications, enhancing patient safety and improving procedural outcomes. This commitment to patient safety and quality care reflects the ongoing evolution of medical practice, driven by evidence-based practices and technological advancements. Hematomas, a common complication associated with central venous catheter (CVC) insertion, can cause discomfort, anxiety, and in some cases, may lead to more serious complications. While our study did not find a statistically significant difference in hematoma formation between the ultrasound-guided and anatomical landmark groups, the observed trend towards a reduction in the ultrasound-guided group warrants further exploration. This trend suggests that ultrasound guidance, by facilitating more precise needle placement and visualization of the surrounding tissues, may contribute to minimizing vessel trauma and optimizing hemostasis, thereby reducing the incidence of hematoma formation. Hematomas arise from the accumulation of blood within tissues due to vessel injury. Repeated attempts to access the vein can increase the risk of vessel injury and hematoma formation. Puncture of an adjacent artery can lead to significant bleeding and hematoma formation. Excessive manipulation of the needle within the tissues can cause vessel trauma and bleeding. Failure to achieve adequate hemostasis after vessel puncture can result in ongoing bleeding and hematoma formation. Patients with underlying coagulopathies, such as those with liver disease or on anticoagulant therapy, are at increased risk of hematoma formation. Ultrasound provides real-time visualization of the needle tip in relation to the vessel wall, minimizing the risk of multiple punctures or inadvertent perforation. This precise needle guidance reduces vessel trauma and the likelihood of hematoma formation. Ultrasound allows for accurate assessment of the size and depth of the vessel, aiding in the selection of appropriate needle size and insertion angle. This tailored approach minimizes the risk of vessel injury and bleeding. Ultrasound enables real-time monitoring of the insertion process, allowing practitioners to identify any bleeding or hematoma formation early on. This immediate feedback enables prompt intervention to achieve hemostasis and prevent further complications. Ultrasound guidance facilitates accurate placement of the guidewire and catheter within the vessel lumen, minimizing the risk of vessel trauma and bleeding. Hematomas can cause pain, swelling, and discoloration, leading to patient discomfort and anxiety. Reducing hematoma formation improves patient comfort and satisfaction. Hematomas, while often benign, can occasionally lead to more serious complications, such as nerve injury or vascular compromise. Reducing hematoma formation minimizes the risk of these complications. By minimizing the need for corrective measures and repeat procedures, reducing hematoma formation can enhance the efficiency of CVC insertion, reducing procedure time and resource utilization.[11-15]

In the realm of healthcare, efficiency is a prized virtue, particularly in critical care settings where time is of the essence and resources are often stretched thin. Central venous catheter (CVC) insertion, a ubiquitous procedure in intensive care units (ICUs) and emergency departments, is no exception to this pursuit of efficiency. The ability of ultrasound guidance to significantly reduce the number of puncture attempts required to achieve successful venous access marks a substantial advancement in optimizing the efficiency of this vital procedure. The traditional landmark-guided approach to CVC insertion, while widely practiced, often involves a degree of uncertainty and a gamble with efficiency. Relying solely on anatomical landmarks and palpation to locate the target vein can be akin to navigating a maze blindfolded. Multiple needle insertions may be required to locate the elusive vein, increasing the risk of complications, prolonging the procedure, and escalating patient discomfort. Each needle insertion carries the potential for vessel injury, hematoma formation, and inadvertent puncture of adjacent arteries or nerves. These complications can necessitate corrective measures, further prolonging the procedure and increasing the risk of additional complications. Moreover, repeated needle sticks can cause significant pain and anxiety for patients, particularly those who are critically ill and already burdened with discomfort. In contrast to the landmark-guided approach, ultrasound guidance provides a beacon of efficiency, illuminating the path to venous access with real-time visualization. By providing a clear image of the needle tip and the target vessel, ultrasound guidance allows for more accurate and efficient needle placement, reducing the number of puncture attempts required and minimizing patient discomfort and potential trauma. Ultrasound guidance transforms CVC insertion from a blind procedure to a visually guided one, eliminating the guesswork and reducing the reliance on tactile feedback. Practitioners can visualize the needle tip as it advances towards the target vein, making real-time adjustments to ensure accurate placement. This precision minimizes the risk of multiple punctures, vessel injury, and hematoma formation, thereby enhancing the efficiency of the procedure. The reduction in puncture attempts associated with ultrasound guidance has ripple effects that extend beyond the immediate procedure, impacting patient outcomes, resource utilization, and healthcare costs. Fewer needle sticks translate into less pain and anxiety for patients, particularly those who are critically ill and may be less tolerant of discomfort. This improved patient experience can contribute to greater satisfaction and a more positive perception of care. Reducing the number of puncture attempts minimizes the potential for vessel trauma and associated complications, such as hematoma formation and arterial puncture. This, in turn, can reduce the need for corrective measures and repeat procedures, further enhancing efficiency. Fewer needle insertions can lead to faster procedure times, allowing healthcare providers to perform more CVC insertions in a given time frame. This increased efficiency can be particularly beneficial in busy clinical settings where timely access to central venous catheters is essential. Shorter procedure times and reduced complications can optimize resource utilization, reducing the need for additional personnel, equipment, and supplies. This can lead to cost savings and improved healthcare efficiency. In the fast-paced environment of critical care, where every second counts, the efficiency of medical procedures is paramount. While our study did not find a statistically significant difference in insertion duration between the ultrasound-guided and anatomical landmark groups, the observed trend towards shorter insertion times in the ultrasound-guided group hints at a potential advantage that warrants further exploration. This trend suggests that ultrasound guidance, by providing real-time visualization of the target vein and surrounding anatomy, may contribute to a more streamlined procedure, potentially reducing the overall time required for central venous catheter (CVC) insertion. CVC insertion is often performed in time-sensitive situations, where rapid access to the central venous system is crucial for administering medications, fluids, or initiating life-saving interventions. Delays in CVC insertion can have significant consequences for critically ill patients, potentially compromising their hemodynamic stability and overall outcomes. In such time-sensitive scenarios, every minute saved during CVC insertion can make a difference. Shorter insertion times can translate into faster delivery of essential therapies, quicker stabilization of critically ill patients, and improved resource utilization. The traditional landmark-guided approach to CVC insertion, while familiar and widely practiced, can be a potential time sink. Relying solely on anatomical landmarks and palpation to locate the target vein can lead to repeated adjustments and repositioning of the needle, prolonging the procedure and increasing patient discomfort. The lack of direct visualization in the landmark-guided approach can make it challenging to accurately estimate the depth and trajectory of the target vein. This can result in multiple needle passes, inadvertent puncture of adjacent structures, and the need for corrective measures, all of which contribute to increased procedure time. Ultrasound guidance offers a stark contrast to the landmark-guided approach, providing a clear roadmap of the underlying anatomy and guiding the needle with precision. This real-time visualization eliminates the guesswork and reduces the need for repeated adjustments and repositioning of the needle, potentially leading to shorter insertion times. By providing a clear image of the target vein, surrounding structures, and the needle tip, ultrasound guidance allows for more direct and efficient needle advancement. Practitioners can visualize the needle as it traverses the tissues, making real-time adjustments to ensure accurate placement and minimize the risk of complications. This streamlined approach can expedite the insertion process, reducing the overall time required for CVC placement. Shorter procedures translate into less time spent with a needle in the patient's skin, minimizing discomfort and anxiety. This is particularly important for critically ill patients who may be less tolerant of prolonged procedures. Shorter insertion times can increase patient throughput, allowing healthcare providers to perform more CVC insertions in a given time frame. This can be particularly beneficial in busy clinical settings where timely access to central venous catheters is essential. Shorter procedure times can optimize resource utilization, reducing the need for additional personnel, equipment, and supplies. This can lead to cost savings and improved healthcare efficiency. Shorter insertion times may also contribute to enhanced patient safety by reducing the duration of exposure to potential complications, such as bleeding or infection. Improved efficiency in central venous catheter (CVC) insertion offers a multitude of benefits that extend beyond the immediate procedure, impacting patient outcomes, resource utilization, and healthcare costs. By streamlining the CVC insertion process, healthcare providers can enhance patient safety, optimize resource allocation, and improve the overall quality of care. Shorter insertion times associated with improved efficiency in CVC insertion can significantly benefit critically ill patients. These patients often have compromised cardiovascular or respiratory function, making extended procedures more challenging and potentially destabilizing. Reduced procedure time translates to less time spent with a needle in the patient's skin, minimizing discomfort and anxiety. This is particularly crucial for critically ill patients who may be less tolerant of prolonged procedures due to their underlying medical conditions. Furthermore, shorter insertion times can expedite the delivery of essential medications and fluids, facilitating hemodynamic monitoring and reducing the overall stress on the patient. This can contribute to faster stabilization and improved outcomes in critically ill patients. Improved efficiency in CVC insertion can lead to increased patient throughput, allowing healthcare providers to perform more CVC insertions in a given time frame. This can be particularly beneficial in busy clinical settings, such as emergency departments and intensive care units, where timely access to central venous catheters is essential for managing critically ill patients. Increased patient throughput can help to reduce wait times for CVC insertion, ensuring that patients receive timely access to essential therapies and interventions. This can improve patient outcomes and enhance the overall efficiency of healthcare delivery. Shorter procedure times and reduced complications associated with improved efficiency in CVC insertion can optimize resource utilization, reducing the need for additional personnel, equipment, and supplies. This can lead to significant cost savings for healthcare institutions and improve the overall efficiency of healthcare delivery. Optimized resource utilization can also free up valuable healthcare resources, allowing them to be allocated to other critical areas of need. This can enhance the overall capacity of the healthcare system to provide timely and effective care to patients. The potential benefits of improved efficiency in CVC insertion are particularly relevant for critically ill patients who may not tolerate prolonged procedures well. These patients may have compromised cardiovascular or respiratory function, making extended procedures more challenging and potentially destabilizing. Ultrasound guidance, by potentially reducing procedure time and minimizing trauma, may be particularly advantageous in critically ill patients. It can help to expedite the delivery of essential medications and fluids, facilitate hemodynamic monitoring, and reduce the overall stress on the patient. Furthermore, improved efficiency in CVC insertion can contribute to a more holistic approach to care for critically ill patients. By minimizing discomfort, anxiety, and the risk of complications, healthcare providers can focus on providing compassionate and patient-centered care that addresses the physical and emotional needs of these vulnerable individuals.[16-20]

5. Conclusion

This study highlights the significant advantages of ultrasound guidance in central venous catheterization (CVC) for critically ill patients. The results demonstrate a considerable reduction in complications, particularly arterial punctures when ultrasound guidance is employed compared to traditional landmark-based methods. Ultrasound guidance not only enhances the precision and safety of CVC insertion but also improves the overall efficiency of the procedure. The reduction in the number of puncture attempts and the trend towards shorter insertion times underscore the potential of ultrasound guidance to optimize CVC insertion in critical care settings. Based on these findings, it is strongly recommended that ultrasound guidance be considered the standard of care for CVC insertion in critically ill patients. This shift towards ultrasound-guided CVC insertion can significantly improve patient safety, reduce complications, and enhance the overall quality of care in the critical care setting.

6. References

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