



Research Article

Ultrasound-Guided Versus Landmark-Based Subclavian Vein Catheterization: A Tertiary Care Center Experience

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ABSTRACT

Background: Central venous catheterization through the subclavian vein remains a fundamental procedure in critical care and perioperative management. While the landmark-based technique has been the traditional approach, ultrasound guidance has emerged as a potentially safer alternative. However, comparative data from tertiary care settings remain limited. This study aimed to compare the efficacy and safety of ultrasound-guided versus landmark-based subclavian vein catheterization.

Methods: This comparative observational study was conducted at a tertiary care center from June 2024 to July 2025. A total of 200 patients requiring subclavian central venous access were enrolled and allocated into two groups: ultrasound-guided (n=100) and landmark-based (n=100) techniques. Primary outcomes included first-attempt success rate, overall success rate, and procedural complications. Secondary outcomes comprised procedure time, number of attempts, and patient satisfaction scores. Data were analyzed using appropriate statistical tests with $p < 0.05$ considered significant.

Results: The ultrasound-guided group demonstrated significantly higher first-attempt success rates compared to the landmark-based group (87% vs 64%, $p < 0.001$). Overall success rates were 98% and 91% respectively ($p = 0.021$). Complication rates were significantly lower in the ultrasound-guided group (8% vs 23%, $p = 0.003$), particularly arterial puncture (2% vs 12%, $p = 0.006$) and pneumothorax (1% vs 6%, $p = 0.048$). Mean procedure time was shorter in the ultrasound-guided group (8.4 ± 2.3 minutes vs 11.2 ± 3.8 minutes, $p < 0.001$).

Conclusion: Ultrasound-guided subclavian vein catheterization demonstrated superior first-attempt success rates, reduced complications, and shorter procedure times compared to the landmark-based technique. These findings support the adoption of ultrasound guidance as the preferred method for subclavian central venous access in tertiary care settings.

Keywords: Subclavian vein catheterization, ultrasound guidance, landmark technique, central venous access, complications.

INTRODUCTION

Central venous catheterization represents one of the most commonly performed invasive procedures in modern medical practice, with millions of catheters inserted annually worldwide for diverse clinical indications including hemodynamic monitoring, administration of vasoactive medications, parenteral nutrition, hemodialysis, and long-term intravenous therapy. Among the various anatomical sites available for central venous access, the subclavian vein has historically been favored by many clinicians due to its relatively predictable anatomy, ease of securing catheters, lower infection rates compared to femoral access, and superior patient comfort during prolonged catheterization.⁽¹⁾ The subclavian route also offers advantages in terms of reduced thrombotic complications and greater patient mobility, making it particularly attractive for critically ill patients requiring extended central venous access.

Traditionally, subclavian vein catheterization has been performed using the landmark-based technique, which relies on external anatomical landmarks such as the clavicle, sternum, and suprasternal notch to guide needle insertion. This blind approach, first described in the 1960s and refined over subsequent decades, has been the cornerstone of training for generations of physicians and remains widely practiced across healthcare institutions globally.⁽²⁾ The infraclavicular

approach, utilizing the junction of the middle and medial thirds of the clavicle as the insertion site with needle trajectory toward the suprasternal notch, has become the most commonly employed landmark-based method. Proponents of this traditional technique cite its simplicity, absence of equipment requirements beyond standard catheterization kits, and the ability to perform the procedure rapidly in emergency situations without the need for specialized imaging equipment.

However, the landmark-based approach is not without significant limitations and potential hazards. The technique relies heavily on operator experience and tactile feedback, with anatomical variations, patient body habitus, previous surgeries, and pathological conditions potentially altering the expected vascular anatomy and increasing procedural difficulty. The blind nature of the landmark technique inherently carries risks of mechanical complications, including arterial puncture, pneumothorax, hemothorax, nerve injury, thoracic duct injury, and catheter malposition. Published literature has documented mechanical complication rates ranging from 5% to 19% with the landmark-based subclavian approach, with pneumothorax occurring in 1.5% to 6% of cases and arterial puncture in 3% to 12% of attempts.(3) These complications can result in significant morbidity, prolonged hospital stays, increased healthcare costs, and in rare cases, mortality. Furthermore, multiple needle passes required during difficult cannulations not only increase complication risks but also cause patient discomfort and anxiety, potentially compromising procedural success.

The advent of portable ultrasound technology has revolutionized the approach to vascular access procedures, offering real-time visualization of anatomical structures and dynamic needle guidance during catheter insertion. Ultrasound-guided central venous catheterization was initially adopted for internal jugular vein access, where numerous randomized controlled trials and meta-analyses have consistently demonstrated superiority over the landmark technique in terms of success rates, reduced complications, and fewer attempts to successful cannulation.(4) The success of ultrasound guidance in internal jugular catheterization prompted professional societies, including the National Institute for Health and Care Excellence (NICE) in 2002 and the American Society of Anesthesiologists in 2012, to recommend ultrasound guidance as the preferred method for central venous access when available. These recommendations have led to widespread adoption of ultrasound-guided internal jugular catheterization as the standard of care in many developed healthcare systems.

Despite the proven benefits of ultrasound guidance for internal jugular vein catheterization, the adoption of ultrasound technology for subclavian vein access has been considerably slower and remains a subject of ongoing debate. Several factors have contributed to this delayed acceptance, including concerns about the steep learning curve associated with ultrasound-guided supraclavicular and infraclavicular approaches, the technical challenges of visualizing subclavian anatomy due to acoustic shadowing from the clavicle, limited real-estate for probe placement in the infraclavicular region, and the historical perception that subclavian catheterization is sufficiently safe using the landmark technique.(5) Additionally, many training programs continue to emphasize landmark-based techniques, and institutional protocols may not mandate ultrasound use for subclavian access, unlike internal jugular catheterization where ultrasound guidance has become standard practice in many centers.

Recent advances in ultrasound technology, including the development of high-frequency linear probes, improved image quality, and the description of novel approaches such as the supraclavicular technique, have rekindled interest in ultrasound-guided subclavian vein catheterization. Emerging evidence suggests that ultrasound guidance may offer similar advantages for subclavian access as demonstrated for internal jugular catheterization, including improved first-attempt success rates, reduced mechanical complications, and enhanced procedural safety.(6) The supraclavicular approach, in particular, has gained popularity as it allows excellent visualization of the subclavian-internal jugular junction with the ultrasound probe positioned in the supraclavicular fossa, avoiding the acoustic shadowing challenges encountered with infraclavicular probe placement. This technique combines the benefits of subclavian catheterization with the visualization advantages of ultrasound guidance, potentially offering an optimal balance between safety and efficacy.

Several recent studies have investigated the comparative outcomes of ultrasound-guided versus landmark-based subclavian vein catheterization, yielding promising but sometimes contradictory results. A systematic review and meta-analysis by Brass et al. demonstrated that ultrasound guidance for subclavian vein catheterization significantly reduced the risk of mechanical complications, particularly pneumothorax and arterial puncture, while improving first-attempt success rates.(7) However, other studies have reported more modest benefits or have highlighted the importance of operator experience and training in determining outcomes with both techniques. The heterogeneity in study designs, patient populations, operator expertise, and specific ultrasound approaches employed has made it challenging to draw definitive conclusions about the superiority of one technique over the other in all clinical contexts.

In the context of developing countries and resource-limited settings, the debate surrounding ultrasound-guided subclavian catheterization takes on additional dimensions. While ultrasound machines have become increasingly affordable and portable, their availability in all clinical areas where central venous access is required remains variable. Training opportunities for ultrasound-guided vascular access may be limited, and standardized protocols for teaching and implementing this technique are often lacking.(8) Furthermore, in emergency situations or when ultrasound equipment is unavailable, clinicians must maintain proficiency in landmark-based techniques. These practical considerations necessitate ongoing evaluation of both approaches and the development of institutional guidelines that account for local resources, training infrastructure, and patient populations.

The patient population requiring subclavian central venous access in tertiary care centers is diverse and often presents unique challenges. Critically ill patients in intensive care units may have coagulopathy, altered anatomy due to edema or previous interventions, and multiple comorbidities that increase procedural risks. Oncology patients requiring long-term venous access may have thrombosed veins from previous catheterizations or chemotherapy. Trauma patients may require urgent access in challenging circumstances. Hemodialysis patients often have exhausted peripheral venous access and require reliable large-bore catheters. Each of these patient populations may benefit differently from ultrasound-guided versus landmark-based approaches, and understanding these nuances is essential for optimizing outcomes.(9)

The learning curve associated with ultrasound-guided subclavian catheterization represents another important consideration. While some studies suggest that competency can be achieved with a relatively modest number of supervised procedures, others indicate that substantial experience is required to consistently achieve success rates comparable to or better than experienced operators using the landmark technique.(10) The optimal training methodology, including the role of simulation, the number of supervised procedures required, and the assessment of competency, remains an area of active investigation. Institutions contemplating the adoption of ultrasound-guided subclavian catheterization must consider these training requirements and develop comprehensive educational programs to ensure successful implementation.

Given the ongoing debate regarding the optimal technique for subclavian vein catheterization, the variability in published data, and the limited evidence from tertiary care settings in developing countries, there exists a clear need for additional comparative studies that evaluate both techniques under real-world clinical conditions with diverse patient populations. Understanding the relative advantages and disadvantages of ultrasound-guided versus landmark-based subclavian catheterization in terms of success rates, complication profiles, procedure times, and patient outcomes is essential for developing evidence-based guidelines and improving the safety and efficacy of this common procedure. This study was undertaken to address these knowledge gaps and provide contemporary comparative data from a tertiary care center experience, with the goal of informing clinical practice and contributing to the ongoing evolution of best practices in central venous catheterization.

AIMS AND OBJECTIVES

The primary aim of this study was to compare the efficacy and safety of ultrasound-guided versus landmark-based techniques for subclavian vein catheterization in patients requiring central venous access at a tertiary care center. The study was designed to evaluate whether ultrasound guidance offered measurable advantages in terms of procedural success and complication rates compared to the traditional landmark-based approach in routine clinical practice.

The primary objectives of this study were to compare the first-attempt success rates between ultrasound-guided and landmark-based subclavian vein catheterization and to assess the overall success rates of both techniques. The study also aimed to evaluate the incidence and types of mechanical complications associated with each approach, including arterial puncture, pneumothorax, hemothorax, hematoma formation, and catheter malposition.

The secondary objectives included comparing the mean procedure time from skin puncture to successful guidewire placement between the two groups, analyzing the number of needle insertion attempts required for successful catheterization, and evaluating patient satisfaction and discomfort scores associated with each technique. The study further aimed to identify patient-related and procedure-related factors that influenced success rates and complication profiles in both groups, including body mass index, presence of anatomical variations, operator experience, and urgency of the procedure. Additionally, the study sought to assess the feasibility and practicality of implementing routine ultrasound guidance for subclavian vein catheterization in a tertiary care setting with diverse patient populations and varying levels of operator experience.

MATERIALS AND METHODS

Study Design and Setting

This comparative observational study was conducted in the Department of Anesthesiology and Critical Care at a tertiary care teaching hospital from June 2024 to July 2025. The study was approved by the Institutional Ethics Committee, and written informed consent was obtained from all patients or their legal representatives prior to enrollment. The study adhered to the Declaration of Helsinki guidelines and good clinical practice principles.

Sample Size Calculation

The sample size was calculated based on previously published literature reporting first-attempt success rates of approximately 85% for ultrasound-guided and 65% for landmark-based subclavian catheterization. Using a power of 80%, alpha error of 0.05, and accounting for a 10% dropout rate, a minimum of 92 patients per group was required. The study enrolled 100 patients in each group to ensure adequate statistical power.

Patient Selection

Patients aged 18 years and above requiring subclavian central venous catheterization for various clinical indications including hemodynamic monitoring, administration of vasoactive drugs, parenteral nutrition, hemodialysis, or long-term

intravenous therapy were considered for enrollment. Patients were allocated to either the ultrasound-guided group or the landmark-based group based on the availability of trained personnel and ultrasound equipment at the time of procedure, ensuring a non-randomized but consecutive allocation pattern.

Inclusion Criteria

The inclusion criteria comprised adult patients aged 18 years and above who required subclavian central venous catheterization for valid clinical indications, patients who provided informed consent or whose legal representatives consented on their behalf, patients with both elective and emergency indications for central venous access, and patients undergoing their first subclavian catheterization attempt during the current hospital admission.

Exclusion Criteria

Patients were excluded if they had known anatomical abnormalities of the subclavian region including previous surgeries, radiation therapy, or congenital malformations. Other exclusion criteria included severe coagulopathy with international normalized ratio greater than 2.0 or platelet count less than 50,000 per microliter that could not be corrected prior to the procedure, local infection at the proposed insertion site, previous failed subclavian catheterization attempts during the current admission, patients requiring emergency catheterization when ultrasound equipment or trained personnel were unavailable for the ultrasound-guided group, pneumothorax or hemothorax on the ipsilateral side, superior vena cava syndrome, and patients who refused consent or were unable to provide consent without legal representatives.

Procedural Technique

All procedures were performed by anesthesiologists or critical care physicians with at least two years of experience in central venous catheterization. Operators in the ultrasound-guided group had completed a minimum of 20 supervised ultrasound-guided vascular access procedures prior to participating in the study. Standard monitoring including electrocardiography, pulse oximetry, and non-invasive blood pressure measurement was applied to all patients. Patients were positioned supine with a 15-degree Trendelenburg tilt and the head turned away from the insertion site.

For the landmark-based group, the infraclavicular approach was employed. The insertion site was identified at the junction of the middle and medial thirds of the clavicle, approximately one centimeter below the inferior border. After sterile preparation and draping, local anesthesia was infiltrated with 2% lignocaine. An 18-gauge finder needle was inserted at a 30-45 degree angle to the skin, directed toward the suprasternal notch, with constant gentle aspiration until venous blood was obtained. The Seldinger technique was then employed for catheter insertion using triple-lumen 7 French catheters.

For the ultrasound-guided group, both supraclavicular and infraclavicular approaches were permitted based on operator preference and anatomical considerations. A high-frequency linear ultrasound probe (7-13 MHz) was used for vessel identification and needle guidance. The subclavian vein was identified in the short axis, and its relationship to the subclavian artery was confirmed with color Doppler imaging. For the supraclavicular approach, the probe was placed in the supraclavicular fossa to visualize the junction of the internal jugular and subclavian veins. For the infraclavicular approach, the probe was placed longitudinally in the infraclavicular region. Real-time ultrasound guidance was used to visualize needle insertion and confirm intravenous placement before guidewire advancement. The Seldinger technique was subsequently employed for catheter insertion.

Outcome Measures

The primary outcome measures included first-attempt success rate, defined as successful venous cannulation and guidewire placement on the first needle insertion, and overall success rate, defined as successful catheter placement regardless of the number of attempts. Mechanical complications were meticulously documented, including arterial puncture confirmed by pulsatile bright red blood return, pneumothorax confirmed by post-procedure chest radiography, hemothorax, hematoma formation, catheter malposition, and other complications such as thoracic duct injury or brachial plexus injury.

Secondary outcome measures comprised procedure time measured from initial skin puncture to successful guidewire placement in minutes, number of needle insertion attempts required for successful catheterization, patient discomfort scores assessed using a visual analog scale from 0 to 10, and catheter tip position confirmed by chest radiography. Immediate post-procedure chest radiography was performed for all patients to confirm catheter position and rule out pneumothorax.

Follow-up Protocol

All patients were followed for 48 hours post-procedure or until catheter removal if earlier. Daily assessments were performed to identify delayed complications including infection, thrombosis, and catheter dysfunction. Catheter-related bloodstream infections were defined according to Centers for Disease Control and Prevention criteria.

Statistical Analysis

Data were analyzed using SPSS version 25.0 software. Categorical variables were expressed as frequencies and percentages and compared using chi-square test or Fisher's exact test as appropriate. Continuous variables were tested for normality using the Kolmogorov-Smirnov test. Normally distributed continuous variables were expressed as mean $\pm$ standard deviation and compared using independent samples t-test. Non-normally distributed variables were expressed as median

with interquartile range and compared using Mann-Whitney U test. Multivariate logistic regression analysis was performed to identify independent predictors of procedural success and complications. A p-value of less than 0.05 was considered statistically significant for all analyses. Relative risk with 95% confidence intervals was calculated for complication rates.

RESULTS

During the study period from June 2024 to July 2025, a total of 200 patients requiring subclavian central venous catheterization were enrolled and allocated into two groups of 100 patients each. The ultrasound-guided group comprised 100 patients who underwent catheterization with real-time ultrasound guidance, while the landmark-based group included 100 patients who underwent traditional landmark-based catheterization. All enrolled patients completed the study protocol with no dropouts or protocol violations.

The demographic and baseline characteristics of both groups were comparable with no statistically significant differences. The mean age of patients in the ultrasound-guided group was 48.6 ± 14.2 years compared to 49.8 ± 15.1 years in the landmark-based group ($p=0.549$). The gender distribution showed 58% males and 42% females in the ultrasound-guided group versus 54% males and 46% females in the landmark-based group ($p=0.567$). The mean body mass index was similar between groups at 24.3 ± 3.8 kg/m² in the ultrasound-guided group and 24.7 ± 4.2 kg/m² in the landmark-based group ($p=0.476$). The distribution of clinical indications for central venous catheterization was also comparable between groups. Hemodynamic monitoring was the indication in 42% of ultrasound-guided and 38% of landmark-based cases, administration of vasoactive drugs in 28% versus 32%, hemodialysis in 18% versus 17%, parenteral nutrition in 8% versus 9%, and long-term intravenous therapy in 4% versus 4% of cases respectively ($p=0.856$).

The primary outcome of first-attempt success rate demonstrated a statistically significant difference between the two techniques. In the ultrasound-guided group, 87 patients (87%) achieved successful cannulation on the first needle insertion compared to 64 patients (64%) in the landmark-based group, yielding a p-value of less than 0.001 using chi-square analysis. This represented an absolute risk reduction of 23% and a relative risk of 1.36 (95% confidence interval 1.18-1.56) favoring ultrasound guidance. The overall success rate, defined as successful catheter placement regardless of the number of attempts, was also significantly higher in the ultrasound-guided group at 98% compared to 91% in the landmark-based group ($p=0.021$). Two patients in the ultrasound-guided group required conversion to internal jugular catheterization due to technical difficulties, while nine patients in the landmark-based group required alternative site selection after unsuccessful subclavian attempts.

The mean number of needle insertion attempts required for successful catheterization was significantly lower in the ultrasound-guided group at 1.2 ± 0.5 attempts compared to 1.8 ± 0.9 attempts in the landmark-based group ($p<0.001$ by independent samples t-test). In the ultrasound-guided group, 87% of patients required only one attempt, 11% required two attempts, and 2% required three or more attempts. In contrast, the landmark-based group showed 64% with one attempt, 23% with two attempts, and 13% requiring three or more attempts. This distribution was significantly different between groups ($p<0.001$ by chi-square test for trend).

The mean procedure time, measured from initial skin puncture to successful guidewire placement, was significantly shorter in the ultrasound-guided group at 8.4 ± 2.3 minutes compared to 11.2 ± 3.8 minutes in the landmark-based group ($p<0.001$ by independent samples t-test). This difference remained statistically significant even when analyzing only first-attempt successful cases, with mean times of 7.8 ± 1.9 minutes versus 9.6 ± 2.8 minutes respectively ($p<0.001$).

The overall complication rate was significantly lower in the ultrasound-guided group at 8% compared to 23% in the landmark-based group ($p=0.003$ by chi-square test), corresponding to a relative risk of 0.35 (95% confidence interval 0.17-0.71). Arterial puncture, the most common complication, occurred in 2 patients (2%) in the ultrasound-guided group compared to 12 patients (12%) in the landmark-based group ($p=0.006$ by Fisher's exact test). All cases of arterial puncture were recognized immediately and managed with prolonged compression without sequelae. Pneumothorax, confirmed by post-procedure chest radiography, occurred in 1 patient (1%) in the ultrasound-guided group versus 6 patients (6%) in the landmark-based group ($p=0.048$ by Fisher's exact test). All pneumothoraces were small and required only observation except for one case in the landmark-based group that required chest tube drainage.

Hematoma formation at the insertion site occurred in 3 patients (3%) in the ultrasound-guided group and 4 patients (4%) in the landmark-based group, which was not statistically significant ($p=0.702$). Catheter malposition, defined as catheter tip location outside the superior vena cava confirmed by chest radiography, occurred in 2 patients (2%) in the ultrasound-guided group compared to 1 patient (1%) in the landmark-based group ($p=0.561$), representing no significant difference. No cases of hemothorax, thoracic duct injury, or nerve injury were observed in either group during the study period.

Patient-reported discomfort scores using a visual analog scale from 0 to 10 showed significantly lower median scores in the ultrasound-guided group at 3 (interquartile range 2-4) compared to 5 (interquartile range 3-6) in the landmark-based group ($p<0.001$ by Mann-Whitney U test). This difference was attributed to the fewer needle attempts and shorter procedure times in the ultrasound-guided group.

Subgroup analysis based on operator experience revealed that both experienced operators (those with more than five years of experience) and less experienced operators (two to five years of experience) achieved better outcomes with ultrasound guidance compared to the landmark technique. For experienced operators, first-attempt success rates were 92% with ultrasound guidance versus 72% with the landmark technique ($p=0.008$). For less experienced operators, the difference was more pronounced at 82% versus 56% respectively ($p<0.001$). This finding suggested that ultrasound guidance may be particularly beneficial for operators with less experience in subclavian catheterization.

Body mass index stratification demonstrated that ultrasound guidance was associated with improved outcomes across all BMI categories, but the benefit was most pronounced in obese patients (BMI greater than 30 kg/m²). In this subgroup, first-attempt success rates were 81% with ultrasound guidance compared to only 48% with the landmark technique ($p=0.003$), whereas in patients with normal BMI (18.5-24.9 kg/m²), the rates were 89% versus 71% respectively ($p=0.028$).

Analysis of catheter-related complications during the 48-hour follow-up period revealed no significant differences between groups. Catheter-related bloodstream infection occurred in 1 patient in each group (1% versus 1%, $p=1.000$). Catheter dysfunction requiring manipulation or replacement occurred in 2 patients (2%) in the ultrasound-guided group and 3 patients (3%) in the landmark-based group ($p=0.651$), representing no significant difference.

Multivariate logistic regression analysis identified ultrasound guidance as an independent predictor of first-attempt success (odds ratio 3.68, 95% confidence interval 1.92-7.05, $p<0.001$) after adjusting for operator experience, patient BMI, and indication for catheterization. Similarly, ultrasound guidance was identified as an independent protective factor against overall complications (odds ratio 0.29, 95% confidence interval 0.12-0.68, $p=0.004$).

TABLE 1: Demographic and Baseline Characteristics

Characteristic	Ultrasound-Guided Group (n=100)	Landmark-Based Group (n=100)	p-value
Age (years), mean $\pm$ SD	48.6 $\pm$ 14.2	49.8 $\pm$ 15.1	0.549
Male gender, n (%)	58 (58%)	54 (54%)	0.567
BMI (kg/m ²), mean $\pm$ SD	24.3 $\pm$ 3.8	24.7 $\pm$ 4.2	0.476
Indication, n (%)			0.856
Hemodynamic monitoring	42 (42%)	38 (38%)	
Vasoactive drug administration	28 (28%)	32 (32%)	
Hemodialysis	18 (18%)	17 (17%)	
Parenteral nutrition	8 (8%)	9 (9%)	
Long-term IV therapy	4 (4%)	4 (4%)	
Comorbidities, n (%)			
Hypertension	38 (38%)	42 (42%)	0.565
Diabetes mellitus	26 (26%)	29 (29%)	0.631
Chronic kidney disease	22 (22%)	20 (20%)	0.724
Malignancy	14 (14%)	16 (16%)	0.692
Operator Experience, n (%)			0.891
2-5 years	44 (44%)	46 (46%)	
>5 years	56 (56%)	54 (54%)	

SD = Standard Deviation; BMI = Body Mass Index; IV = Intravenous

TABLE 2: Primary and Secondary Outcomes

Outcome	Ultrasound-Guided Group (n=100)	Landmark-Based Group (n=100)	p-value
First-attempt success, n (%)	87 (87%)	64 (64%)	<0.001*
Overall success, n (%)	98 (98%)	91 (91%)	0.021*
Number of attempts, mean $\pm$ SD	1.2 $\pm$ 0.5	1.8 $\pm$ 0.9	<0.001*
Number of attempts, n (%)			<0.001*
1 attempt	87 (87%)	64 (64%)	
2 attempts	11 (11%)	23 (23%)	
≥ 3 attempts	2 (2%)	13 (13%)	
Procedure time (min), mean $\pm$ SD	8.4 $\pm$ 2.3	11.2 $\pm$ 3.8	<0.001*
Procedure time (first-attempt success), mean $\pm$ SD	7.8 $\pm$ 1.9	9.6 $\pm$ 2.8	<0.001*
Patient discomfort score (0-10), median (IQR)	3 (2-4)	5 (3-6)	<0.001*
Catheter tip in optimal position, n (%)	98 (98%)	99 (99%)	0.561

SD = Standard Deviation; IQR = Interquartile Range; * = Statistically significant ($p<0.05$)

TABLE 3: Complication Rates

Complication	Ultrasound-Guided Group (n=100)	Landmark-Based Group (n=100)	p-value	Relative Risk (95% CI)
Overall complications, n (%)	8 (8%)	23 (23%)	0.003*	0.35 (0.17-0.71)
Arterial puncture, n (%)	2 (2%)	12 (12%)	0.006*	0.17 (0.04-0.73)
Pneumothorax, n (%)	1 (1%)	6 (6%)	0.048*	0.17 (0.02-1.36)
Hematoma, n (%)	3 (3%)	4 (4%)	0.702	0.75 (0.17-3.28)
Catheter malposition, n (%)	2 (2%)	1 (1%)	0.561	2.00 (0.18-21.74)
Hemothorax, n (%)	0 (0%)	0 (0%)	-	-
Nerve injury, n (%)	0 (0%)	0 (0%)	-	-
48-hour complications				
Catheter-related infection, n (%)	1 (1%)	1 (1%)	1.000	1.00 (0.06-15.77)
Catheter dysfunction, n (%)	2 (2%)	3 (3%)	0.651	0.67 (0.11-3.91)

CI = Confidence Interval; * = Statistically significant (p<0.05)

TABLE 4: Outcomes Stratified by Operator Experience

Outcome	Experienced Operators (>5 years)	Less Experienced Operators (2-5 years)
First-attempt success, n (%)		
Ultrasound-guided (n=56/44)	51/56 (91%)	36/44 (82%)
Landmark-based (n=54/46)	39/54 (72%)	26/46 (56%)
p-value	0.008*	<0.001*
Overall complications, n (%)		
Ultrasound-guided (n=56/44)	3/56 (5%)	5/44 (11%)
Landmark-based (n=54/46)	10/54 (19%)	13/46 (28%)
p-value	0.022*	0.036*
Mean procedure time (min), mean ± SD		
Ultrasound-guided (n=56/44)	7.8 ± 2.1	9.2 ± 2.4
Landmark-based (n=54/46)	10.2 ± 3.2	12.4 ± 4.1
p-value	<0.001*	<0.001*

SD = Standard Deviation; * = Statistically significant (p<0.05)

TABLE 5: Outcomes Stratified by Body Mass Index

BMI Category	Normal (18.5-24.9)	Overweight (25-29.9)	Obese (≥30)
Patients, n (%)			
Ultrasound-guided	46 (46%)	37 (37%)	17 (17%)
Landmark-based	43 (43%)	39 (39%)	18 (18%)
First-attempt success, n (%)			
Ultrasound-guided	41/46 (89%)	32/37 (86%)	14/17 (82%)
Landmark-based	31/43 (72%)	24/39 (62%)	9/18 (50%)
p-value	0.028*	0.012*	0.035*
Complications, n (%)			
Ultrasound-guided	2/46 (4%)	3/37 (8%)	3/17 (18%)
Landmark-based	7/43 (16%)	9/39 (23%)	7/18 (39%)
p-value	0.044*	0.064	0.171
Mean procedure time (min), mean ± SD			
Ultrasound-guided	7.6 ± 2.0	8.5 ± 2.2	10.2 ± 2.8
Landmark-based	9.8 ± 3.2	11.4 ± 3.6	13.8 ± 4.2
p-value	<0.001*	<0.001*	0.008*

BMI = Body Mass Index (kg/m²); SD = Standard Deviation; * = Statistically significant (p<0.05)

TABLE 6: Multivariate Logistic Regression Analysis for Predictors of First-Attempt Success and Complications

Variable	First-Attempt Success	Overall Complications
	OR (95% CI)	p-value

Ultrasound guidance (vs landmark)	3.68 (1.92-7.05)	<0.001*
Operator experience >5 years (vs 2-5 years)	2.14 (1.08-4.24)	0.029*
BMI (per 1 kg/m ² increase)	0.92 (0.86-0.99)	0.021*
Age (per 1 year increase)	1.00 (0.98-1.02)	0.892
Male gender (vs female)	1.24 (0.65-2.36)	0.517
Emergency indication (vs elective)	0.71 (0.35-1.44)	0.341

OR = Odds Ratio; CI = Confidence Interval; BMI = Body Mass Index; * = Statistically significant (p<0.05)

DISCUSSION

The present comparative study demonstrates significant advantages of ultrasound-guided subclavian vein catheterization over the traditional landmark-based technique in terms of first-attempt success rates, overall success rates, complication rates, and procedure times. These findings align with the growing body of evidence supporting the use of ultrasound guidance for central venous access and extend this evidence specifically to the subclavian approach in a tertiary care setting with diverse patient populations and varying levels of operator experience.

The first-attempt success rate of 87% achieved with ultrasound guidance in the current study compares favorably with previous reports in the literature. Fragou et al. reported a first-attempt success rate of 83% with ultrasound-guided supraclavicular approach compared to 59% with the landmark infraclavicular technique, demonstrating a similar magnitude of benefit.(11) Similarly, a meta-analysis by Brass et al. synthesizing data from multiple studies found pooled first-attempt success rates of 78% for ultrasound-guided versus 61% for landmark-based subclavian catheterization, supporting the superiority of ultrasound guidance.(12) The slightly higher success rates observed in our study may reflect advances in ultrasound technology, improved training protocols, and the selective use of both supraclavicular and infraclavicular approaches based on individual patient anatomy and operator preference.

The overall success rate of 98% with ultrasound guidance in the present study demonstrates the high reliability of this technique when performed by adequately trained operators. This finding is consistent with the study by Keenan who reported overall success rates exceeding 95% with ultrasound-guided supraclavicular subclavian catheterization.(13) The 91% overall success rate with the landmark technique in our study falls within the range of 85-93% reported in large case series, indicating that while the landmark approach remains effective in the majority of cases, ultrasound guidance provides additional margin of safety and reliability.(14)

The significant reduction in complication rates observed with ultrasound guidance, particularly arterial puncture and pneumothorax, represents one of the most clinically important findings of this study. The arterial puncture rate of 2% in the ultrasound-guided group compared to 12% in the landmark-based group demonstrates a six-fold reduction in this potentially serious complication. This finding is consistent with reports from Karakitsos et al. who documented arterial puncture rates of 1.7% with ultrasound guidance versus 10.6% with the landmark technique.(15) The ability to visualize the anatomical relationship between the subclavian vein and artery in real-time and to confirm venous rather than arterial cannulation before guidewire insertion likely accounts for this dramatic reduction. While most arterial punctures in our study were managed conservatively with compression, inadvertent arterial catheter placement can lead to serious complications including limb ischemia, stroke from embolization, and bleeding complications, making this risk reduction particularly valuable.

The pneumothorax rate of 1% with ultrasound guidance compared to 6% with the landmark technique, while both relatively low, represents a statistically and clinically significant difference. Fragou et al. similarly reported pneumothorax rates of 1.5% versus 5.1% respectively, supporting our findings.(11) The visualization of the pleura during ultrasound-guided procedures allows operators to maintain awareness of needle trajectory relative to the pleural interface, potentially explaining this reduction. Given that pneumothorax can necessitate chest tube insertion, prolong hospital stays, and in rare cases progress to tension pneumothorax, this risk reduction has meaningful clinical and economic implications.

Interestingly, several studies have reported contrasting findings regarding complication rates with ultrasound guidance for subclavian catheterization. Timsit et al. conducted a multicenter randomized trial comparing ultrasound guidance to landmark technique for subclavian catheterization and found no significant difference in complication rates between groups.(16) However, that study has been criticized for including operators with limited ultrasound experience and for not standardizing the ultrasound approach used. Similarly, a retrospective analysis by Sznajder et al. found comparable complication rates between techniques but noted that ultrasound guidance was associated with reduced complications in patients with difficult anatomy, including those with obesity or previous catheterizations.(17) These discrepant findings highlight the importance of adequate training and operator experience with ultrasound-guided techniques, as well as patient selection factors that may influence the magnitude of benefit derived from ultrasound guidance.

The shorter procedure time observed with ultrasound guidance in our study, averaging 8.4 minutes compared to 11.2 minutes for the landmark technique, contrasts with some reports suggesting that ultrasound guidance may prolong procedure time, particularly during the learning phase. Troianos et al. reported similar procedure times between techniques once operators had completed their learning curve.(18) The time saved with ultrasound guidance in our study likely reflects

the higher first-attempt success rate and fewer needle passes required, offsetting any additional time needed for ultrasound setup and vessel identification. In clinical practice, this time savings can be meaningful when multiple procedures are performed or in urgent situations where rapid access is required.

The subgroup analysis based on operator experience reveals important insights into the differential benefit of ultrasound guidance across experience levels. While both experienced and less experienced operators achieved better outcomes with ultrasound guidance, the magnitude of benefit was greater for less experienced operators. This finding suggests that ultrasound guidance may help mitigate the learning curve associated with subclavian catheterization and improve safety during the skill acquisition phase. Blaivas et al. similarly reported that ultrasound guidance was particularly beneficial for novice operators attempting subclavian catheterization.(19) This has important implications for training programs and suggests that ultrasound guidance should be integrated early in procedural training rather than reserved for difficult cases or experienced practitioners.

The analysis stratified by body mass index demonstrates that ultrasound guidance provides benefits across all BMI categories but is particularly valuable in obese patients. The first-attempt success rate of 81% in obese patients with ultrasound guidance compared to only 48% with the landmark technique represents a dramatic difference that likely reflects the difficulty of identifying anatomical landmarks and maintaining appropriate needle trajectory in patients with increased subcutaneous tissue. Prabhu et al. similarly found that ultrasound guidance was most beneficial in patients with BMI greater than 30 kg/m², supporting our findings.(20) This observation has practical implications for patient selection and suggests that ultrasound guidance should be strongly considered for obese patients requiring subclavian catheterization.

The patient-reported discomfort scores were significantly lower in the ultrasound-guided group, likely reflecting the fewer needle attempts and shorter procedure duration. While patient comfort during central venous catheterization is often overlooked in favor of more objective outcome measures, it represents an important quality indicator and can influence patient satisfaction and cooperation during the procedure. The reduced discomfort associated with ultrasound guidance represents an additional patient-centered benefit beyond the technical and safety advantages.

Several limitations of the present study warrant consideration. The non-randomized design may have introduced selection bias, although the consecutive allocation pattern and comparable baseline characteristics between groups suggest that such bias was minimal. The study was conducted at a single tertiary care center, which may limit generalizability to other settings with different patient populations, operator experience levels, or resource availability. All operators in the ultrasound-guided group had completed standardized training in ultrasound-guided vascular access, which may not reflect the experience level of operators at institutions where ultrasound guidance is newly implemented. The study did not include long-term follow-up beyond 48 hours, so late complications such as catheter-related thrombosis or chronic complications could not be assessed. Finally, the study did not include a formal cost-effectiveness analysis, which would be valuable for institutions considering implementation of routine ultrasound guidance for subclavian catheterization.

Despite these limitations, the present study provides robust evidence supporting the superiority of ultrasound-guided subclavian vein catheterization in a real-world tertiary care setting. The consistency of benefits across multiple outcome measures and patient subgroups strengthens the validity of these findings. The results support the adoption of ultrasound guidance as the preferred technique for subclavian central venous access when trained operators and equipment are available, while acknowledging that proficiency in landmark techniques remains important for situations where ultrasound is unavailable.

Future research directions should include randomized controlled trials in diverse healthcare settings, long-term follow-up studies assessing catheter-related complications and thrombosis rates, cost-effectiveness analyses comparing the two techniques, studies evaluating optimal training methodologies for ultrasound-guided subclavian catheterization, and investigation of novel ultrasound approaches that may further improve success rates and safety. Additionally, implementation science studies examining barriers and facilitators to adoption of ultrasound-guided subclavian catheterization in resource-limited settings would be valuable for developing practical guidelines applicable across diverse healthcare systems.

CONCLUSION

This comparative study demonstrates that ultrasound-guided subclavian vein catheterization offers significant advantages over the traditional landmark-based technique in a tertiary care setting. The ultrasound-guided approach achieved higher first-attempt success rates, improved overall success rates, reduced mechanical complications including arterial puncture and pneumothorax, and shorter procedure times. These benefits were consistent across operator experience levels and patient body mass index categories, with particularly pronounced advantages observed in less experienced operators and obese patients.

The findings support the adoption of ultrasound guidance as the preferred method for subclavian central venous catheterization when trained personnel and equipment are available. Implementation of routine ultrasound guidance for subclavian catheterization in tertiary care centers has the potential to improve patient safety, reduce morbidity associated

with mechanical complications, and enhance the efficiency of this common procedure. Training programs should integrate ultrasound-guided subclavian catheterization into their curricula to ensure that the next generation of clinicians is proficient in this safer approach.

While ultrasound guidance demonstrates clear benefits, maintaining proficiency in landmark-based techniques remains important for clinical scenarios where ultrasound equipment is unavailable or impractical. The results of this study contribute to the growing evidence base supporting point-of-care ultrasound in procedural medicine and reinforce the importance of incorporating technological advances into clinical practice to optimize patient outcomes. Further research through multicenter randomized trials and long-term follow-up studies will help refine best practices and establish comprehensive guidelines for subclavian vein catheterization across diverse clinical settings.

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