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Original Research Article

Optimal length of insertion of right subclavian venous catheter via supraclavicular approach: A prospective observational study

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Abstract

Background: Central venous catheterization (CVC) is a routine procedure in perioperative and intensive care. The subclavian vein is frequently selected due to its anatomical consistency and lower infection rates. Although the supraclavicular approach is less common, it offers a straighter course to the superior vena cava (SVC) and potentially reduces complications. Ensuring the catheter tip lies near the SVC-right atrium (RA) junction is vital. This study evaluated the accuracy of a surface landmark-based method for catheter placement, verified by transesophageal echocardiography (TEE) and chest radiography.

Materials and Methods: A prospective observational study was conducted over six months in a tertiary care center. 96 adult patients (ASA II-III), scheduled for elective surgeries with intraoperative TEE, were enrolled. Exclusion criteria included consent refusal, anatomical abnormalities, local infections, and coagulopathies. The right subclavian vein was accessed via the supraclavicular route. Insertion depth was estimated using surface measurements from the puncture site to the angle of Louis. Tip position was assessed by TEE (BICAVAL view) and postoperative chest radiographs, using the carina as a reference point. Tips within 1 cm above or below the SVC-RA junction or carina were considered correctly placed.

Results: Among the 96 participants (60 males, 36 females; mean age 49.16 ±16.19 years), catheter insertion depths ranged from 10.0 to 14.0 cm, with a mean of 12.47 ±0.71 cm. Chest X-ray confirmed appropriate placement in all patients. TEE showed optimal placement in 91.7% (88 cases), while 8 tips were outside the desired zone. One-sample t-tests showed significant differences from zero ($p < 0.001$) for catheter length and TEE-confirmed tip distance. No complications were observed.

Conclusion: The anatomical landmark-based technique for supraclavicular subclavian CVC insertion offers reliable tip positioning near the SVC-RA junction. This method is a practical and effective alternative, particularly in settings lacking ultrasound guidance.

Keywords: Central venous catheter, Supraclavicular subclavian vein, Anatomical landmarks, Transesophageal echocardiography, Catheter tip placement, Chest radiography.

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1. Introduction

Central venous catheter (CVC) placement is a widely practiced procedure in operating rooms and critical care units, employed for administering fluids, medications, and for monitoring hemodynamics. Common venous access points include the internal jugular, subclavian, and femoral veins.[1] Among these, the subclavian vein (SCV) is frequently selected because of its consistent size, anatomical stability, and a lower incidence of catheter-related infections.[2]

While the infraclavicular technique has traditionally been used to access the subclavian vein (SCV), it carries risks such as pneumothorax and arterial puncture.[3] The supraclavicular technique, on the other hand, provides a more direct path to the superior vena cava (SVC) and relies on clearer anatomical landmarks, which may help minimize insertion-related complications.[4]

Ensuring the catheter tip is correctly positioned in the lower SVC near the right atrium (RA) junction is crucial to

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avoid complications such as thrombosis, damage to the vessel wall, or misplacement.[1] While formulas based on height have been proposed to guide catheter depth, their specificity for SCV access remains limited.[5]

Several techniques are available to confirm tip placement, including chest radiography,[6] transesophageal echocardiography (TEE),[7] intracavitary electrocardiography,[8] and anatomical landmark-based estimation.[9] The present study aims to assess the reliability of surface landmark-guided catheter insertion by validating the tip position using imaging modalities.

2. Materials and Methods

This was a prospective observational study carried out over a six-month duration at a tertiary healthcare institution. Approval was granted by the Institutional Ethics Committee (Approval No. IESC/PGS/2023/146), and the trial was registered under the Clinical Trials Registry of India (CTRI/2024/06/068491).

Adult patients undergoing elective major surgeries under general anesthesia, for whom both central venous catheter (CVC) placement and transesophageal echocardiography (TEE) were intended as part of intraoperative monitoring, were enrolled. Informed written consent was secured from all participants. Eligible patients were over 18 years of age, either male or female, and categorized as ASA physical status II or III. Patients were excluded if they declined participation, were pregnant, had infection at the intended site of insertion, exhibited coagulopathy, had cervical spine trauma, or had anatomical distortion from prior thoracic surgery or tumors.

Using an anticipated 49% prevalence rate for CVC placement via Peres' formula, with a 10% allowable error and 95% confidence level, the calculated sample size was 96, using WINPEPI version 11.6.[10]

Demographic information including age, gender, height, weight, and BMI was documented in a structured format, and routine preoperative investigations were carried out. In the operating room, following induction of general anesthesia, three surface landmarks were identified and marked: the lateral third of the right clavicle (point A), the midpoint of the sternal notch (point B), and the midpoint of the Angle of Louis (point C).

The lengths from point A to B and B to C were documented. (**Figure 1**) The distance from Point A to Point C was measured along the skin contour using a flexible, non-stretchable measuring tape, with the patient in the supine position and neck turned to the opposite direction. As the Angle of Louis roughly corresponds with the carina and the superior vena cava–right atrium (SVC–RA) junction is situated below it, advancing the catheter beyond point C was anticipated to place the tip optimally. The supraclavicular approach was performed under sterile precautions with continuous monitoring. Any adverse events, such as arterial puncture or malposition, were noted. All measurements were performed by a single trained operator to minimise inter-observer variability.

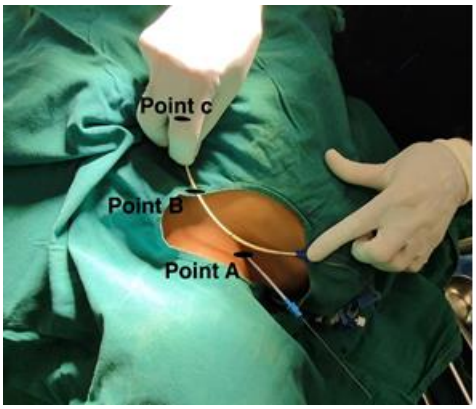

Figure 1: Showing measurement of catheter to be inserted using surface landmarks – labelled. Point A: Insertion point; Point B: Midpoint of sternal notch; Point C: Angle of Louis

After the catheter was inserted, a transesophageal echocardiography (TEE) probe was advanced into the esophagus. The bicaval view was obtained by rotating the probe angle between 80° and 110° and directing it toward the right side. The superior vena cava–right atrium (SVC–RA) junction was identified at the base of the crista terminalis. A segment extending from 2 cm above to 1 cm below this landmark was defined as the acceptable zone for catheter tip placement as recommended by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists (ASE/SCA guidelines) for minimizing complications such as arrhythmias or tamponade. (**Figure 2**) If the tip was visualized within this range, it was categorized as being in the optimal position. A postoperative chest X-ray was also performed to verify catheter tip location, with the carina serving as the radiological reference point; tips located within 1 cm above or below the carina were classified as correctly placed. (**Figure 3**) Any complications, whether procedural or postoperative—such as malposition, pneumothorax, hemothorax, hematoma, arrhythmia, or infection were systematically recorded.

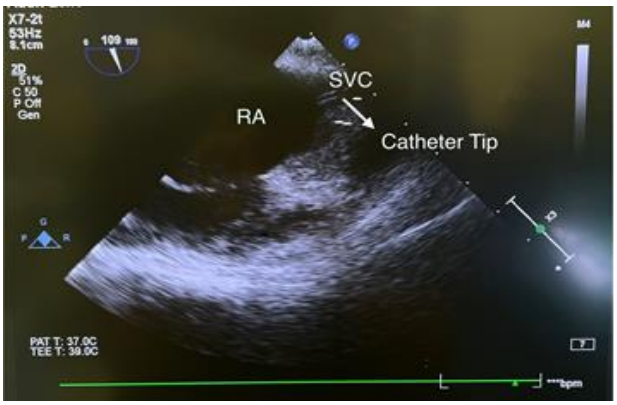

Figure 2: Transesophageal echo showing catheter tip

All data were analysed using IBM SPSS Statistics version 26. Continuous variables, including patient age, height, weight, and catheter insertion length, were summarised as mean±standard deviation (SD), along with range and 95% confidence intervals (CI). Categorical variables, such as sex and TEE-confirmed tip position (optimal vs. suboptimal), were presented as absolute frequencies and percentages.

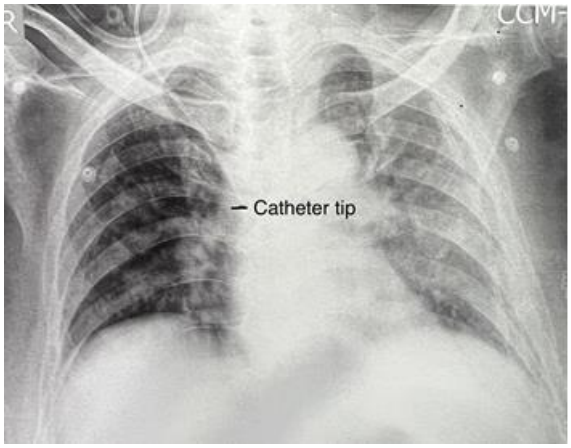

Figure 3: Post op chest x-ray showing catheter tip

3. Results

Of the original 102 patients considered, 6 were excluded due to vascular access failure (n=3), guidewire advancement issues (n=2), and inadvertent internal jugular cannulation (n=1).

A total of 96 patients were included in the study, comprising 60 males (62.5%) and 36 females (37.5%). Ages ranged from 18 to 87 years, with a mean of 49.16 years and a standard deviation of 16.19, suggesting moderate variability. Participant heights ranged from 135 cm to 184 cm, with a mean height of 163.78 cm and a standard deviation of 10.99 cm, indicating moderate variation in stature. Catheter insertion depths ranged between 10.0 cm and 14.0 cm, with an average depth of 12.47 cm and a standard deviation of 0.71 cm, reflecting consistent insertion practices.

Postoperative chest X-rays confirmed that all 96 catheters (100%) were within the predefined safe range of 1 cm above or below the carina, indicating accurate placement. TEE evaluation revealed that 88 catheters (91.7%) were within 1 cm above or below the SVC–RA junction, while 8 catheters (8.3%) were found outside this optimal range on echocardiography. This discrepancy highlights that chest radiography, although universally acceptable, may lack sensitivity for detecting minor cephalad malpositions, which can be identified more precisely with TEE.

Baseline demographic and procedural details of the study population, including age, height, BMI, insertion length, and tip position outcomes, are summarized in **Table 1**. The mean insertion length and TEE-confirmed tip distances, along with their 95% confidence intervals, are detailed in **Table 2**.

To explore the association between patient anthropometry and required catheter length, a Pearson correlation coefficient (r) was calculated between patient height and TEE-confirmed optimal insertion length. The analysis revealed a strong positive linear correlation ($r = 0.79$, $p < 0.001$), indicating that taller patients generally required longer catheter insertions to achieve proper tip positioning. This correlation highlights the anatomical relevance of height in predicting insertion depth and reinforces its potential use when ultrasound guidance is unavailable. A two-tailed p-value < 0.05 was considered statistically significant for all tests.(**Figure 4**)

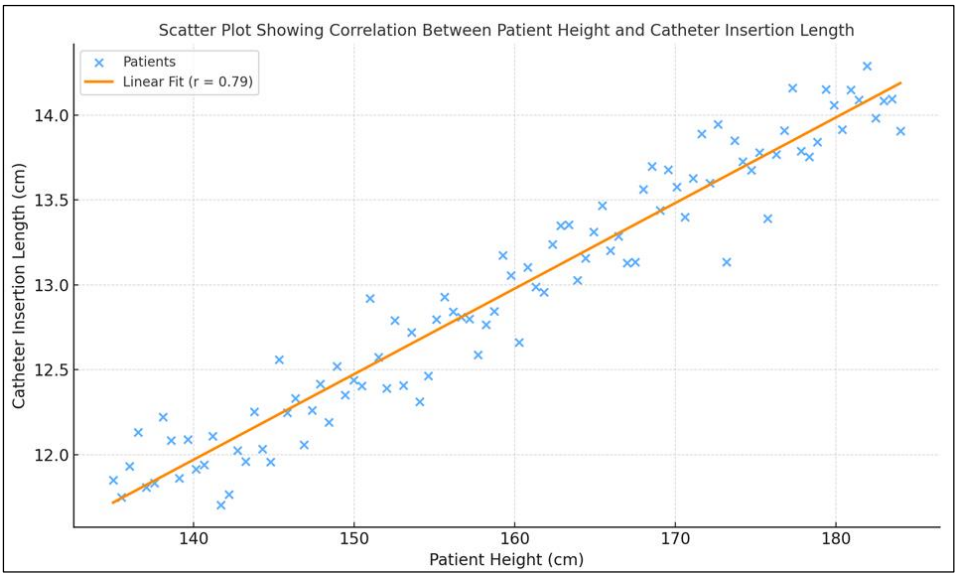

Figure 4: Association between patient anthropometry and required catheter insertion length

Table 1: Demographic and procedural characteristics of the study population

Parameter	Mean ± SD	Range	Comments
Age (years)	49.16 ± 16.19	18 – 87	Moderate variability
Height (cm)	163.78 ± 10.99	135 – 184	Moderate variability
BMI (kg/m²)	22.4 ± 2.8	18 – 29	Estimated
Insertion Length (cm)	12.47 ± 0.71	10.0 – 14.0	Measured from Point A to Point C
TEE Tip Distance (cm)	0.52 ± 0.07	0.45 – 0.59	From SVC–RA junction
Tip Optimal on TEE	91.7%	–	88 of 96 tips within range
Tip Acceptable on CXR	100%	–	All within 1 cm of carina

Values are presented as mean ± standard deviation (SD), range, or percentage, as appropriate. Insertion length was measured from the skin puncture site to the Angle of Louis using surface landmarks.

Table 2: Summary of insertion depth and TEE-confirmed tip position with 95% confidence intervals

Variable	Mean ± SD	95% Confidence Interval	Interpretation
Insertion Length (cm)	12.47 ± 0.71	12.32 – 12.61	Average distance from skin puncture site to SVC–RA junction based on surface landmarks
TEE Tip Distance (cm)	0.52 ± 0.07	0.45 – 0.59	Tip position relative to SVC–RA junction, confirming central placement within target zone.

Data represent the mean values and variability for key procedural outcomes

4. Discussion

Correct placement of central venous catheter (CVC) tips is essential to reduce complications and ensure effective functionality. In 1989, the U.S. Food and Drug Administration cautioned against intracardiac advancement of catheters, citing risks such as arrhythmias and cardiac tamponade, thereby underscoring the importance of avoiding entry into cardiac chambers.[11] Subsequent research highlighted additional concerns, particularly regarding catheter angulation. It was noted that when the angle exceeds 40°, the risk of vessel wall erosion increases.[12] Anatomical differences between the right and left brachiocephalic veins significantly influence catheter trajectory. The left brachiocephalic vein enters the superior vena cava (SVC) at a more acute angle, making it more susceptible to misdirection and deeper placement below the carina. On the other hand, right-sided catheterization tends to follow a more direct path, which lowers the likelihood of misplacement. Research has shown that catheter angles exceeding 40° occurred in only 2.4% of right-sided insertions, while 63% were observed on the left.[13] These findings support the use of the right supraclavicular route for its more predictable and safer trajectory into the SVC.

By utilizing transesophageal echocardiography (TEE), clinicians can obtain real-time images of the catheter tips without radiation, enabling prompt detection of issues like misplacement, looping, or vessel wall contact.[7] In this study, all right supraclavicular catheter placements aligned with the long axis of the SVC, and none exhibited angulation beyond 40°, indicating appropriate placement. These CVCs were used for purposes such as fluid administration, inotropic support, and hemodynamic monitoring, necessitating positioning near the SVC–right atrium (RA) junction. This location ensures unobstructed flow and minimizes the risk of complications such as thrombus formation, unintended entry into tributaries like the azygos or contralateral brachiocephalic vein, or tip migration. Positioning in the lower SVC, just external to the pericardial reflection, also helps reduce the risk of cardiac tamponade.

Placement of the catheter tip in the upper portion of the SVC, however, may be suboptimal due to movement caused by neck positioning or respiratory changes. Catheter tips located more than 4 cm above the SVC–RA junction are associated with increased rates of dysfunction and thrombosis.[12] In one study, 41.7% of catheters placed in the proximal third of the SVC developed thrombotic complications, compared with only 2.6% when placed in the distal third.[1] Moreover, higher catheter tip positions have been linked to an increased risk of bloodstream infections, while deeper placements may reduce colonization rates.[13] Therefore, the middle SVC, external to the pericardial reflection, is considered an optimal site for balancing clinical efficacy and safety.[9]

In contrast to Peres ' formula (Height/10 – 2 cm), which assumes uniform thoracic proportions,[5,14] our landmark-guided approach yielded a mean insertion length of 12.47 cm, indicating it may be more accurate and individualized, especially in Indian patients with diverse body habitus. TEE proved to be an effective imaging tool for confirming catheter tip location, offering high-resolution visualization without radiation exposure. It is versatile for use in both surgical and intensive care settings.[15,16] In our study, TEE confirmed appropriate tip positioning in 91.7% of cases. This aligns with the findings of Corradi et al.,[17] who demonstrated that TEE identified 92% of catheter malpositions, in contrast to only 32% detected by chest radiography reinforcing the superiority of echocardiographic guidance.

While chest X-ray is a widely used method for confirming catheter tip placement after the procedure, it does have certain limitations. These include delays in image availability, radiation exposure, and inconsistency in interpretation among observers. Catheter tip location can also shift due to changes in head position, with reported migrations ranging from 1.5 cm to 3 cm.[18] Variability in interpretation between clinicians further complicates radiographic evaluation.[19] Nonetheless, in the present study, all catheter placements were confirmed as correct via chest radiography using the carina as the anatomical reference, consistent with the findings of Vinay M et al.[14]

Kim et al. have also supported the use of surface anatomical landmarks to estimate appropriate catheter depth.[20] Despite some methodological differences, our results reinforce the effectiveness of such landmarks, particularly when supplemented with intraoperative confirmation via TEE and post-procedural verification using chest radiographs.

No major complications were encountered during the study. Six participants were excluded due to unsuccessful vascular access or failure to advance the guidewire. One catheter was excluded because it was inadvertently inserted into the right internal jugular vein. A notable strength of this study is its focus on a practical and reproducible technique for estimating insertion depth based on external anatomical landmarks. This method avoids the need for complex formulas or preoperative imaging and can be reliably applied across a broad range of patient populations and clinical settings.

This study also had several limitations. Although the landmark-guided supraclavicular approach proved effective, the use of real-time ultrasound was limited due to spatial constraints, making it technically difficult in this setting. The study was also restricted to right-sided catheterizations, which limits generalizability to left-sided approaches where anatomical differences may influence outcomes. While transesophageal echocardiography (TEE) allowed precise confirmation of tip location, its routine use is constrained by cost, availability, and the need for expertise, making it less feasible in non-operative settings.

Additionally, postoperative chest radiographs may have been affected by technical variability, and potential catheter migration due to body positioning was not accounted for.[21] The absence of a control group using other established methods (e.g., ultrasound- or ECG-guided insertion) restricted comparative evaluation. Future studies should explore the applicability of this method across diverse clinical contexts and patient populations, including bedside scenarios and left-sided access.

5. Conclusion

Surface landmark-based technique serves as a dependable approach for determining optimal catheter insertion depth during supraclavicular subclavian central venous access. Accurate placement of the catheter tip at the superior vena cava–right atrium junction achieved in 91.7% of cases, confirmed by transesophageal echocardiography, and in 100% of cases by postoperative chest radiography. These findings support the practicality and reliability of the technique, especially in clinical scenarios without advanced imaging modalities such as ultrasound.

6. Source of Funding

None.

7. Conflict of Interest

None.

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