

Mechanical Complications of Subclavian Central Venous Catheterization: A Prospective Longitudinal Study from a Tertiary Care Teaching Hospital in South India

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Abstract

Background: Central venous catheter (CVC) insertion is an indispensable procedure in emergency and surgical practice for hemodynamic monitoring, administration of vasoactive medications, parenteral nutrition, and management of difficult venous access. Despite its widespread use, mechanical complications remain an important cause of procedure-related morbidity. The incidence reported in the literature ranges from 5% to 19%, with complications influenced by patient characteristics, operator experience, insertion technique, and number of cannulation attempts.¹⁻⁵

Objectives: To determine the prevalence of mechanical complications following subclavian central venous catheter insertion and identify factors associated with

these complications among patients undergoing catheterization in a tertiary care teaching hospital.

Methods: A prospective longitudinal study was conducted among 201 consecutive patients aged >13 years undergoing subclavian CVC insertion in the Department of General Surgery and allied specialties at Government Medical College, Kozhikode. Patients with pre-existing procedure-related complications, chest wall deformities, bleeding disorders, or previous surgery at the intended insertion site were excluded. Participants were followed for 24 hours after catheter insertion for development of mechanical complications. Data were analyzed using SPSS version 19.0. Associations were assessed using the Chi-square test, with $p < 0.05$ considered statistically significant.

Results: Mechanical complications occurred in 26 of 201 patients (12.9%). Failure to place the catheter was the commonest complication (8.5%), followed by arterial puncture (6.0%), pneumothorax (2.0%), and hematoma (1.0%). Multiple complications occurred in 3.9% of patients. Multiple percutaneous punctures were significantly associated with overall mechanical complications ($\chi^2=12.25$, $p<0.001$). Overweight patients were significantly more likely to require multiple punctures ($\chi^2=6.13$, $p=0.04$). Female sex and the presence of comorbidities were significantly associated with hematoma formation ($p=0.04$ and $p=0.02$, respectively).

Conclusion: Approximately one in eight patients experienced a mechanical complication following subclavian CVC insertion. Repeated cannulation attempts represented the most important modifiable risk factor. Strategies including ultrasound guidance, structured procedural training, and limiting repeated puncture attempts may reduce procedure-related complications.

Keywords: Central venous catheter, Mechanical complications, Subclavian vein, Arterial puncture, Pneumothorax, Hematoma

Introduction

Central venous catheterization (CVC) is one of the most frequently performed invasive procedures in modern clinical practice. It provides reliable central venous access for administration of vasoactive medications, hyperosmolar solutions, total parenteral nutrition, chemotherapy, hemodialysis, and invasive hemodynamic monitoring. The internal jugular, subclavian, and femoral veins are the preferred access sites, with the choice determined by clinical indication, operator

expertise, patient anatomy, and anticipated duration of catheterization.¹

Although indispensable in critical care and surgical practice, CVC insertion is associated with several complications that may increase patient morbidity, prolong hospitalization, and escalate healthcare costs. These complications are broadly categorized into mechanical, infectious, and thrombotic events. Mechanical complications occur during or immediately after catheter insertion and include arterial puncture, hematoma, pneumothorax, hemothorax, catheter malposition, cardiac tamponade, air embolism, thoracic duct injury, arrhythmias, nerve injury, and catheter placement failure.^{2,3} Published studies have reported an overall incidence of mechanical complications ranging between 5% and 19%, depending on patient characteristics, insertion site, operator experience, and procedural technique.²⁻⁵

The anatomical site of catheter insertion substantially influences complication rates. Subclavian venous access offers advantages including lower rates of catheter-related bloodstream infection and thrombosis compared with femoral and internal jugular access. However, it carries a relatively greater risk of pneumothorax because of the close proximity of the pleural dome. Conversely, arterial puncture occurs more frequently during internal jugular and femoral vein cannulation.⁴ Consequently, careful patient selection and meticulous procedural technique remain essential for minimizing adverse events.

Several patient- and procedure-related factors influence the occurrence of mechanical complications. Previous investigations have consistently demonstrated that repeated cannulation attempts substantially increase complication rates. Mansfield et al. reported that

complication rates increased dramatically after multiple needle passes, highlighting the importance of achieving venous access with minimal puncture attempts.³ Similarly, ultrasound-guided catheterization has been shown to improve first-pass success while reducing arterial puncture and other insertion-related complications compared with landmark-guided techniques.^{5,6}

Operator experience is another important determinant of procedural success. In many teaching hospitals, junior residents perform central venous catheterization under supervision, often without structured simulation-based training. Previous studies suggest that clinicians require approximately 10–20 supervised procedures before achieving procedural competence, emphasizing the importance of standardized training and supervision in reducing complications.^{2,5}

Data regarding mechanical complications of CVC insertion from Indian tertiary care teaching hospitals remain limited, particularly for subclavian catheterization performed in routine surgical practice. Identifying locally relevant risk factors may help optimize procedural safety, improve training protocols, and guide quality improvement initiatives.

Therefore, the present study aimed to determine the prevalence of mechanical complications associated with subclavian central venous catheter insertion and identify patient- and procedure-related factors associated with these complications in a tertiary care teaching hospital in South India.

Materials and Methods

Study Design and Setting

This prospective longitudinal observational study was conducted in the Department of General Surgery and allied specialties at Government Medical College,

Kozhikode, Kerala, India, over a one-year period. Patients undergoing subclavian central venous catheter insertion in the casualty, wards, and intensive care units were consecutively recruited.

Study Population

The study included patients aged more than 13 years undergoing subclavian CVC insertion after obtaining informed written consent.

Inclusion Criteria

- Age >13 years.
- Both sexes.
- Patients undergoing subclavian central venous catheterization during the study period who provided written informed consent.

Exclusion Criteria

Patients were excluded if they:

- Had pre-existing complications similar to those being evaluated.
- Had structural chest wall deformities.
- Had bleeding disorders.
- Had undergone previous surgery at the intended catheter insertion site.

Sample Size and Sampling

A minimum sample size of 200 participants was estimated using the formula:

$$n = 4PQ/d^2$$

where P represented the lowest prevalence reported in previous literature and d was taken as 20% of the estimated prevalence. Consecutive sampling was employed until the desired sample size was achieved. A total of 201 participants were included in the final analysis.

Study Procedure

Central venous catheterization was performed by junior surgical residents under the supervision of senior

surgeons or medical officers using standard aseptic precautions. Following successful venous cannulation through the subclavian route, guidewire-assisted catheter placement was completed using the Seldinger technique. Catheter position was confirmed clinically, following which the catheter was secured. Patients underwent immediate post-procedural chest radiography and were monitored clinically for 24 hours to identify procedure-related complications.

Outcome Measures

The primary outcome was the occurrence of any mechanical complication related to catheter insertion. Mechanical complications assessed included:

- Failure to place the catheter
- Arterial puncture
- Pneumothorax
- Hematoma
- Hemothorax
- Cardiac tamponade
- Arrhythmia
- Air or guidewire embolism
- Thoracic duct injury
- Phrenic nerve injury

Secondary outcomes included identification of patient- and procedure-related factors associated with the occurrence of mechanical complications.

Variables Studied

Baseline variables included:

- Age
- Sex
- Body mass index (BMI)
- Comorbidities
- Indication for catheterization
- Side of catheter insertion
- Number of percutaneous puncture attempts

These variables were analyzed for their association with overall mechanical complications and individual complications.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 19.0. Continuous variables are presented as mean $\pm$ standard deviation, whereas categorical variables are expressed as frequencies and percentages. Associations between categorical variables were evaluated using the Chi-square test. A two-sided p-value <0.05 was considered statistically significant.

Ethical Considerations

Written informed consent was obtained from all participants before enrollment. The study was conducted in accordance with institutional ethical standards and the principles of the Declaration of Helsinki.

Results

A total of 201 patients who underwent subclavian central venous catheterization were included in the analysis. The mean age of the study population was 57.1 ± 11.5 years. Most participants were males (65.7%), had a normal body mass index (57.7%), and had no documented comorbidities (79.1%). Lack of peripheral venous access was the commonest indication for catheterization (57.2%). Right-sided catheterization was performed in 81.6% of procedures, while 56.7% of patients required multiple percutaneous puncture attempts during catheter insertion.

Table 1: Baseline characteristics of study participants (N = 201)

Variable	n (%)
Age (years)	
<30	4 (2.0)
31–40	16 (8.0)
41–50	34 (16.9)

51–60	60 (29.9)
61–70	70 (34.8)
>70	17 (8.5)
Gender	
Male	132 (65.7)
Female	69 (34.3)
BMI	
Underweight	33 (16.4)
Normal	116 (57.7)
Overweight	52 (25.9)
Comorbidity	
None	159 (79.1)
CAD	23 (11.4)
COPD	19 (9.5)
Indication	
Lack of peripheral access	115 (57.2)
Total parenteral nutrition	43 (21.4)
Elective surgery	43 (21.4)
Side of catheterization	
Right	164 (81.6)
Left	37 (18.4)
Percutaneous punctures	
Single	87 (43.3)
Multiple	114 (56.7)

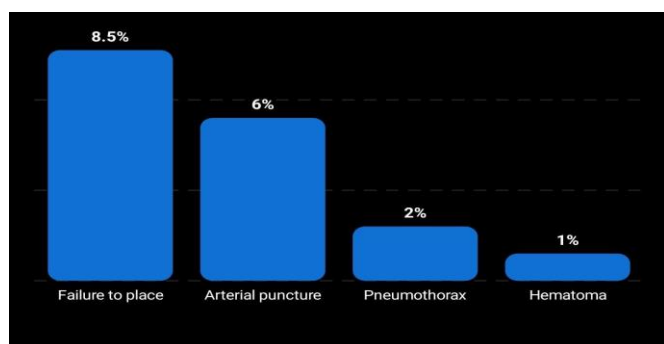


Figure 1. Distribution of mechanical complications

Overall, 26 patients (12.9%) experienced at least one mechanical complication following catheter insertion. Failure to place the catheter was the commonest complication (8.5%), followed by arterial puncture (6.0%), pneumothorax (2.0%), and hematoma (1.0%). No cases of hemothorax, arrhythmia, cardiac tamponade, thoracic duct injury, phrenic nerve injury, or guidewire embolism were encountered during the study period. Multiple complications occurred in eight patients (3.9%), most commonly the combination of arterial puncture and failure to place the catheter. No procedure-related mortality was observed.

Table 2: Frequency of mechanical complications following catheterization

Mechanical complication	n	%
Overall mechanical complication	26	12.9
Failure to place catheter	17	8.5
Arterial puncture	12	6.0
Pneumothorax	4	2.0
Hematoma	2	1.0
Multiple complications	8	3.9
Procedure-related mortality	0	0

Factors associated with mechanical complications

Patients who required multiple percutaneous punctures had a significantly higher rate of overall mechanical complications compared with those undergoing a single puncture (20.2% vs. 3.4%; $\chi^2 = 12.25$, $p < 0.001$). Overweight participants (BMI >25 kg/m²) were significantly more likely to require multiple puncture attempts than patients with normal or low BMI ($\chi^2 = 6.13$, $p = 0.04$). Left-sided catheterization was also significantly associated with an increased likelihood of multiple puncture attempts ($\chi^2 = 4.88$, $p = 0.02$).

Neither the side of catheterization nor BMI demonstrated a statistically significant association with overall

mechanical complications, arterial puncture, or pneumothorax. Likewise, overall complication rates did not differ significantly according to gender or the presence of comorbidities. However, hematoma formation occurred significantly more often among females ($p = 0.04$) and among patients with CAD or COPD ($p = 0.02$).

Table 3: Factors associated with overall mechanical complications

Variable	χ^2	p value	Significant
BMI vs multiple punctures	6.13	0.04	Yes
Multiple punctures vs overall complications	12.25	<0.001	Yes
Side of insertion vs multiple punctures	4.88	0.02	Yes
Gender vs overall complications	0.23	0.63	No
BMI vs overall complications	2.54	0.28	No
Comorbidity vs overall complications	1.76	0.18	No

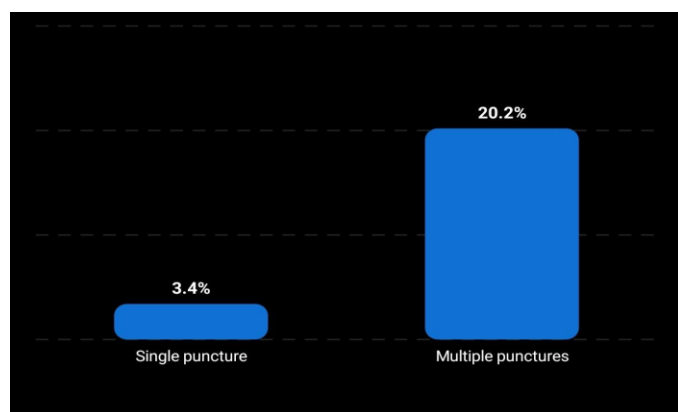


Figure 2. Mechanical complication rate according to number of puncture attempts

Table 4: Significant associations with individual mechanical complications

Outcome	Associated factor	χ^2	p value
Hematoma	Female gender	3.86	0.04
Hematoma	CAD/COPD	7.73	0.02
Multiple punctures	BMI >25 kg/m ²	6.13	0.04
Overall complications	Multiple punctures	12.25	<0.001

The overall prevalence of mechanical complications following subclavian central venous catheterization was 12.9%, with failure to place the catheter representing the most frequent adverse event. Repeated puncture attempts emerged as the strongest predictor of mechanical complications, while overweight patients were more likely to require multiple attempts. Female sex and underlying comorbidities were associated with hematoma formation, whereas no significant associations were observed between catheter side and overall complication rates or between BMI and overall mechanical complications. These findings identify modifiable procedural factors that may improve the safety of central venous catheterization.

Discussion

The present prospective longitudinal study evaluated the occurrence of mechanical complications following subclavian central venous catheter (CVC) insertion in a tertiary care teaching hospital and identified factors associated with these adverse events. Among 201 patients undergoing catheterization, the overall incidence of mechanical complications was 12.9%, with failure to place the catheter (8.5%) being the most common complication, followed by arterial puncture (6.0%), pneumothorax (2.0%), and hematoma (1.0%). The most

important finding of this study was the strong association between multiple percutaneous puncture attempts and the occurrence of mechanical complications, emphasizing the importance of achieving successful venous access on the first attempt whenever possible.

The overall complication rate observed in the present study is consistent with previously published reports, which have documented mechanical complication rates ranging from 5% to 19% following central venous catheterization.^{2,3,10} Differences in complication rates among studies may be attributed to variations in patient characteristics, operator experience, catheter insertion site, procedural technique, and the increasing adoption of ultrasound-guided catheterization. Although the present study evaluated only subclavian vein catheterization, the observed complication rate remains within the expected range reported in international literature, suggesting that the findings are comparable with contemporary evidence.

Failure to place the catheter was the most frequent complication encountered in this study. Although many previous studies have primarily focused on complications such as pneumothorax and arterial puncture, unsuccessful catheter placement remains an important procedural outcome because repeated cannulation attempts not only prolong the procedure but also substantially increase the likelihood of vascular injury and other adverse events. This finding highlights the need for improved procedural planning, careful anatomical landmark identification, and early consideration of alternative access sites when initial attempts are unsuccessful.

Arterial puncture was observed in 6% of patients, making it the second most common mechanical

complication. Similar incidences have been reported in landmark-guided catheterization studies, where inadvertent arterial puncture remains one of the commonest immediate complications of central venous access.^{2,3} The present study found no statistically significant association between arterial puncture and catheter insertion side, BMI, gender, or comorbidities, suggesting that procedural factors such as needle trajectory and operator experience may have a greater influence than patient-related characteristics.

Pneumothorax occurred in 2% of participants, a frequency comparable to previous reports describing incidences ranging from 1% to 6%.^{7,8} Although subclavian venous access has traditionally been associated with an increased risk of pleural injury because of its anatomical proximity to the lung apex, the present study did not demonstrate a significant association between pneumothorax and either catheter insertion side or the number of puncture attempts. The relatively low incidence observed may reflect careful procedural supervision and prompt post-procedural radiographic evaluation.

One of the most clinically relevant findings of this study was the significant relationship between multiple percutaneous punctures and overall mechanical complications. Patients requiring more than one puncture had nearly a six-fold higher frequency of complications than those in whom catheterization was successful on the first attempt. This observation closely mirrors the findings of Mansfield et al., who demonstrated a marked increase in complication rates after repeated needle passes, and reinforces recommendations advocating early assistance or ultrasound guidance when venous access cannot be achieved promptly.³ The findings also support current

procedural guidelines that emphasize minimizing repeated cannulation attempts to improve patient safety.

The study also demonstrated that overweight patients were significantly more likely to require multiple puncture attempts. Excess adipose tissue may obscure anatomical landmarks, making landmark-guided catheterization technically more challenging. Although BMI itself was not independently associated with overall mechanical complications, its indirect effect through increased puncture attempts may contribute to procedural difficulty. Similar observations have been reported by previous investigators, although the relationship between obesity and CVC complications remains inconsistent across studies.

Overall complication rates did not differ significantly according to gender. However, female patients demonstrated a significantly higher incidence of hematoma formation. Likewise, patients with coronary artery disease or chronic obstructive pulmonary disease were also more likely to develop hematoma following catheterization. The mechanism underlying these observations remains uncertain but may relate to vascular fragility, concurrent antiplatelet therapy, or technical challenges encountered during catheter insertion in patients with underlying cardiorespiratory disease. Since only two cases of hematoma were observed, these findings should be interpreted cautiously and require confirmation in larger prospective studies.

The side of catheter insertion did not significantly influence the occurrence of overall complications, arterial puncture, pneumothorax, or hematoma. Nevertheless, left-sided catheterization was associated with a greater requirement for multiple puncture attempts. This finding may reflect anatomical differences between the right and left subclavian veins or operator

preference for right-sided catheterization. However, because only a relatively small proportion of patients underwent left-sided catheterization, further studies with balanced comparison groups are necessary before definitive conclusions can be drawn.

No procedure-related mortality or severe complications such as cardiac tamponade, air embolism, hemothorax, thoracic duct injury, phrenic nerve injury, or guidewire embolism were encountered. Although these complications are well documented in the literature, they remain uncommon during routine central venous catheterization, particularly when procedures are performed under supervision and appropriate post-procedural monitoring is undertaken.

Strengths

The strengths of this study include its prospective longitudinal design, standardized post-procedural follow-up, inclusion of consecutive patients, and comprehensive assessment of both overall and individual mechanical complications. The study also evaluated several patient- and procedure-related factors, enabling identification of modifiable determinants of mechanical complications in routine surgical practice.

Limitations

This study has several limitations. It was conducted at a single tertiary care teaching hospital, which may limit the generalizability of the findings. Only subclavian vein catheterizations were evaluated; therefore, the results cannot be extrapolated to internal jugular or femoral venous access. Operator experience was not quantified, and the use of ultrasound guidance was not assessed, both of which may substantially influence complication rates. In addition, the relatively small number of individual complications limited subgroup analyses and

prevented multivariable regression modeling to identify independent predictors of complications.

Clinical Implications

The findings of this study have important implications for clinical practice. Emphasis should be placed on maximizing first-pass success through structured procedural training, supervision of junior operators, and routine use of ultrasound guidance where feasible. Early involvement of experienced clinicians after unsuccessful initial attempts may substantially reduce procedure-related complications. Particular attention should also be given to overweight patients, in whom repeated puncture attempts are more likely. These quality improvement measures have the potential to reduce avoidable morbidity associated with central venous catheterization while improving procedural efficiency.

Conclusion

This prospective longitudinal study demonstrated that 12.9% of patients undergoing subclavian central venous catheterization experienced at least one mechanical complication, a rate comparable with previously reported literature. Failure to place the catheter was the most frequent complication, followed by arterial puncture, pneumothorax, and hematoma. The requirement for multiple percutaneous puncture attempts emerged as the strongest predictor of overall mechanical complications, while overweight patients were more likely to require repeated attempts. Female sex and the presence of comorbidities were associated with hematoma formation, although these findings should be interpreted cautiously because of the small number of events.

The findings emphasize the importance of maximizing first-pass success through meticulous procedural technique, adequate operator training, and early assistance from experienced clinicians when

catheterization proves difficult. Wider adoption of ultrasound-guided catheterization, structured simulation-based training, and standardized institutional protocols may further reduce procedure-related morbidity and improve patient safety.

Future multicentric studies involving larger sample sizes and multiple venous access sites are warranted to identify independent predictors of mechanical complications and evaluate interventions aimed at improving procedural outcomes.

Declarations

Ethics Approval and Consent to Participate

The study was conducted after obtaining informed written consent from all participants in accordance with institutional ethical standards of Government Medical College, Kozhikode Ethics Committee.

Availability of Data

The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

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