



ORIGINAL ARTICLE

Comparison of Accuracy in Central Venous Catheter Tip Placement in Right Sided Internal Jugular Vein Using Clinical and Endocavitary ECG Method in Elective Surgeries in a Tertiary Care Center

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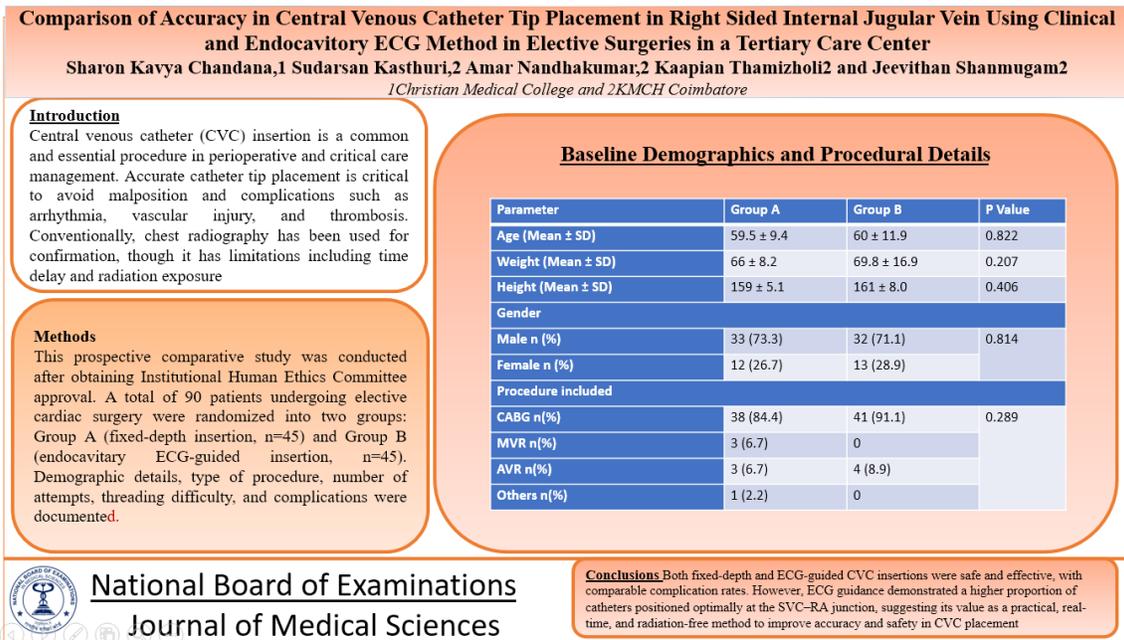
Abstract

Introduction: Central venous catheter (CVC) insertion is a common and essential procedure in perioperative and critical care management. Accurate catheter tip placement is critical to avoid malposition and complications such as arrhythmia, vascular injury, and thrombosis. Conventionally, chest radiography has been used for confirmation, though it has limitations including time delay and radiation exposure. **Materials and Methods:** This prospective comparative study was conducted after obtaining Institutional Human Ethics Committee approval. A total of 90 patients undergoing elective cardiac surgery were randomized into two groups: Group A (fixed-depth insertion, n=45) and Group B (endocavitary ECG-guided insertion, n=45). Demographic details, type of procedure, number of attempts, threading difficulty, and complications were documented. **Results:** The baseline demographics, including age (59.5 ± 9.4 years in Group A vs. 60 ± 11.9 years in Group B, $p=0.822$), weight (66 ± 8.2 vs. 69.8 ± 16.9 , $p=0.207$), and height (159 ± 5.1 vs. 161 ± 8.0 , $p=0.406$), were comparable between groups. Most patients underwent CABG (84.4% vs. 91.1%). First-attempt success rates were similar (73.3% vs. 66.7%, $p=0.49$). Difficult threading occurred in 20% of Group A and 28.9% of Group B. **Conclusion:** Both fixed-depth and ECG-guided CVC insertions were safe and effective, with comparable complication rates. However, ECG guidance demonstrated a higher proportion of catheters positioned optimally at the SVC–RA junction, suggesting its value as a practical, real-time, and radiation-free method to improve accuracy and safety in CVC placement.

Keywords: central venous catheter, endocavitary ECG, tip position, chest radiography, cardiac surgery

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Graphical Abstract



Introduction

Central venous catheter (CVC) insertion is one of the most common invasive procedures performed, not only in operation theatres and intensive care units but also extended to bedside placements in chemotherapy and medical wards. Though central venous catheterization offers multifarious benefits, the procedure is associated with adverse events that may be hazardous to patients [1,2].

Meticulous care and adjuncts such as ultrasound and fluoroscopy substantially improve the success of central venous catheter placement. Nevertheless, a considerable number of catheter-related complications still occur in day-to-day practice [3–7].

The common adverse events associated with CVC insertion in the neck and thorax have been extensively reported in the literature and include

infection, hematoma, and pneumothorax. Other recognized complications of CVC placement include hemothorax, chylothorax, extravasation of infusate, unrecognized arterial placement, cardiac tamponade, and mediastinal hemorrhage (8). A less commonly described but important complication is malpositioning of the catheter tip in a vessel other than the superior vena cava (SVC), reported in approximately 7% of thoracic CVC placements, and capable of leading to serious sequelae. Malposition enhances the risks of catheter wedging, erosion or perforation of vessel walls, local venous thrombosis, and catheter dysfunction [1,10,11].

Over-insertion of the catheter tip can result in life-threatening cardiac tamponade or precipitate arrhythmias, whereas inadequate depth of insertion may lead to thrombus formation and increased rates of infection. More than

100 cases of cardiac perforation due to a malpositioned CVC tip have been reported in the literature, highlighting the critical importance of accurate tip positioning [11–13].

Despite advancements in imaging techniques and procedural protocols, malposition and related complications of central venous catheter placement remain clinically significant and under-reported in routine practice. Accurate positioning of the catheter tip is crucial for patient safety, effective therapy, and reduction of morbidity and mortality associated with CVC use. This study was therefore undertaken to assess the demographic and procedural factors, technical difficulties, complications, and radiological outcomes associated with CVC insertion, with the objective of identifying predictors of safe and successful placement and minimizing malposition-related risks.

Materials and Methods

This was a prospective cross sectional comparative study conducted at a tertiary care centre. The study was carried out between August 2018 and November 2018. Ninety patients requiring central venous catheter placement for elective surgeries were included. They were randomly allocated into two equal groups of 45 each (Group A and Group B) using computer-generated block randomization sequences. All patients requiring central venous catheter placement for elective surgical procedures were eligible. Patients with arrhythmias, pacemaker

rhythms, deranged coagulation profiles, local infection at the insertion site, anatomical chest or neck deformities, or those aged below 18 years were excluded.

Prior to enrolment, a patient information sheet describing the study protocol, benefits, and possible risks was provided, and written informed consent was obtained. Ethical clearance was secured from the Institutional Human Ethics Committee (IHEC) before initiating the study.

In Group A, the depth of catheter insertion was determined by the anesthetist's judgment following institutional guidelines. For right internal jugular vein cannulations, the catheter fixation depth was typically 12–13 cm for males and 11–12 cm for females, a depth validated in Indian populations to minimize malpositions, particularly inadvertent intra-atrial placements [14,15].

In Group B, catheter depth was guided using endocavitary electrocardiography (ECG). This technique utilized a specialized adaptor (e.g., Braun) connected between the guidewire and ECG monitor, allowing the operator to switch between surface and intracavitary ECG. Lead II was mainly used for visualization of P-wave changes. The method relied on distinct ECG patterns as the catheter advanced:

- A normal upright P-wave indicated placement in the upper SVC.

- A P-wave of half the surface amplitude indicated position in the lower SVC.
- A maximal upright P-wave suggested the catheter tip at the cavo-atrial junction.
- Biphasic or negative P-wave deflections signified advancement into the right atrium [16,17].

Thus, intracavitary ECG provided a real-time physiological marker of tip position, improving precision over conventional depth-based methods.

Outcome assessment was performed using postoperative chest radiographs in the intensive care unit or post-anesthesia care unit. These X-rays confirmed the catheter tip position and identified any misplacements. In addition, complications such as carotid puncture or hematoma were documented.

Sample size calculation was based on retrospective data from 438 eligible cases over a six-month period. With a 95% confidence interval, 5% margin of error, and response distribution of 5%, the sample size was estimated as 90. Block randomization with a block size of six ensured balanced distribution between the study arms.

Statistical analysis: Data were coded and entered in Microsoft Excel, and statistical analysis was performed using SPSS software (version 27). Continuous variables such as age, height, and weight

were expressed as mean \pm standard deviation (SD) and compared between groups using the Student's t-test. Categorical variables such as gender, number of attempts, complications, and radiographic outcomes were expressed as percentages and compared using the Chi-square test or Fisher's exact test where appropriate. A p-value <0.05 was considered statistically significant.

Results

The mean age of patients was 59.5 ± 9.4 years in Group A and 60 ± 11.9 years in Group B ($p = 0.822$), while the mean weight was 66 ± 8.2 kg in Group A and 69.8 ± 16.9 kg in Group B ($p = 0.207$). The mean height was also comparable between the two groups (159 ± 5.1 cm vs. 161 ± 8.0 cm, $p = 0.406$). Male patients predominated in both groups, with 73.3% in Group A and 71.1% in Group B, while females constituted 26.7% and 28.9% respectively ($p = 0.814$). In terms of procedures, CABG was the most common, performed in 84.4% of patients in Group A and 91.1% in Group B, while other procedures such as MVR (6.7% vs. 0%), AVR (6.7% vs. 8.9%), and miscellaneous surgeries (2.2% vs. 0%) formed the minority. No significant differences were observed between the groups in baseline or procedural characteristics, indicating comparability of study populations (Table 1).

Table 1. Baseline Demographics and Procedural Details

Parameter	Group A	Group B	P Value
Age (Mean \pm SD)	59.5 \pm 9.4	60 \pm 11.9	0.822
Weight (Mean \pm SD)	66 \pm 8.2	69.8 \pm 16.9	0.207
Height (Mean \pm SD)	159 \pm 5.1	161 \pm 8.0	0.406
Gender			
Male n (%)	33 (73.3)	32 (71.1)	0.814
Female n (%)	12 (26.7)	13 (28.9)	
Procedure included			
CABG n(%)	38 (84.4)	41 (91.1)	0.289
MVR n(%)	3 (6.7)	0	
AVR n(%)	3 (6.7)	4 (8.9)	
Others n(%)	1 (2.2)	0	

The first-attempt catheterization was successful in 73.3% of Group A and 66.7% of Group B, while 26.7% and 33.3% respectively required a second attempt ($p = 0.49$). Difficulty in threading was reported in 20% of cases in Group A and 28.9% in Group B ($p = 0.327$). Complications were infrequent overall, with carotid puncture seen in one case (2.2%) in Group A and none in

Group B, while hematoma occurred in 6.7% of Group A and 4.4% of Group B ($p = 0.438$). Importantly, pneumothorax did not occur in either group. These findings highlight that the technical aspects of cannulation and complications were comparable across both groups, with low complication rates overall (Table 2).

Table 2. Technical Aspects and Complications

Parameter	Sub Classification	Group A N (%)	Group B N (%)	P Value
Attempts	First	33 (73.3)	30 (66.7)	0.49
	Second	12 (26.7)	15 (33.3)	
Difficulty threading	No	36 (80.0)	32 (71.1)	0.327
	Yes	9 (20.0)	13 (28.9)	
Complications Encountered	Carotid Puncture	1(2.22)	0	0.438
	Hematoma	3(6.66)	2(4.44)	

Radiological evaluation of catheter tip placement showed that in Group A, 31.1% were 2.1–3.5 cm below the carina, 40% were 0.1–2.0 cm below, 22.2% were at the carina, and 6.7% were above the carina; while in Group B, 40.9% were 2.1–3.5 cm below, 43.2% were 0.1–2.0 cm below, 15.9% were at the carina, and none were above ($p = 0.31$). Regarding the final location of catheter tips on chest X-rays, 11.1% in Group A and 8.8% in Group B were in

the upper SVC, 73% and 84% respectively were at the SVC-RA junction, and 15% versus 6.6% extended into the right atrium ($p = 0.19$). These results show that although not statistically significant, ECG guidance resulted in a higher proportion of tips at the optimal SVC-RA junction and fewer malpositions into the right atrium compared to the clinical method (Table 3).

Table 3: Radiological Outcomes

Parameter	Sub Classification	Group A N (%)	Group B N (%)	P Value
Distance of tip from Carina	2.1–3.5 cm below carina	14 (31.1)	18 (40.9)	0.31
	0.1–2.0 cm below carina	18 (40.0)	19 (43.2)	
	At the level of carina	10 (22.2)	7 (15.9)	
	0.1–2.0 cm above carina	3 (6.7)	0 (0.0)	
Location of catheter tip in both groups on chest x-rays	Upper SVC tip	5 (11.1)	4 (8.8)	0.19
	SVC-RA junction tip	33 (73)	38 (84)	
	RA Tip	7 (15)	3 (6.6)	

Discussion

Central venous catheter (CVC) insertion is a ubiquitous invasive procedure, often lifesaving in diverse clinical scenarios. Despite its wide use, the procedure is still associated with potentially serious complications, some of which may be life-threatening. Real-time ultrasound guidance has revolutionized central venous access, making the technique safer than traditional landmark-based approaches, as demonstrated in numerous studies [14,18]. The addition of fluoroscopy has further increased success rates in selected settings. Nevertheless, complications remain inevitable even in expert hands, highlighting the need for adjunctive strategies to improve safety.

There is no clear consensus on the ideal CVC tip position; however, it is generally agreed that the optimal site is at the cavo-atrial junction (CAJ), the region between the superior vena cava (SVC) and right atrium [15]. Traditionally, chest radiography has been the most widely employed method to confirm CVC tip placement and rule out malposition or complications such as pneumothorax [19]. However, post-procedural chest X-ray is not a real-time modality and often diagnoses malposition after catheter insertion is complete, thereby failing to prevent adverse events. Moreover, chest X-rays are subject to drawbacks, including time delay, radiation exposure, variable image quality, and difficulties in interpretation due to patient positioning, rotation, or poor exposure.

In routine practice, clinicians often adopt empirical methods to determine insertion depth, such as using fixed formulae, approximations based on patient height, or institutional standards of 13 cm in males and 12 cm in females [20,21]. Although convenient, these methods are prone to inaccuracies, as factors such as patient height, puncture site variation, and neck thickness significantly affect precision. This underlines the need for a real-time, reliable method for confirming catheter tip position.

Among bedside techniques, endocavitary ECG has emerged as a promising approach. This technique enables real-time visualization of P-wave morphology to indicate proximity to the right atrium, thereby allowing adjustment of insertion depth before fixation [16]. Studies have demonstrated its effectiveness in minimizing malposition, reducing complications, and improving procedural success rates [22,23].

In the present study, demographic characteristics such as age, height, and weight were comparable between the two groups, with no statistically significant differences ($p > 0.05$). The mean age was 59.5 ± 9.4 years in Group A and 60 ± 11.9 years in Group B, while mean heights were 159.1 ± 5.1 cm and 161 ± 8.0 cm, respectively. This comparability in baseline characteristics ensured that group differences in outcomes were unlikely to be attributable to demographic confounders. Similarly, the gender

distribution and type of surgical procedures (predominantly CABG in both groups) were balanced, indicating that the groups were homogeneous at baseline.

Technical aspects, such as the number of attempts and difficulty in threading, showed no significant differences between groups. Complications were minimal, with only a few cases of carotid puncture and hematoma, again with no statistically significant differences. Importantly, radiological confirmation of catheter tip location demonstrated that Group B (endocavitary ECG-guided placement) achieved a higher proportion of tips positioned at the SVC–RA junction compared to Group A, which relied on fixed-depth institutional protocols. Although not statistically significant in this study, this trend reflects findings from previous reports that have highlighted the superior accuracy of ECG-guided placement in achieving optimal catheter positioning [17].

Conclusion

The present study demonstrated that demographic and procedural characteristics were comparable between the groups, ensuring homogeneity. Technical difficulties and complications were minimal and not significantly different between the groups. Importantly, radiological evaluation indicated that the use of endocavitary ECG guidance resulted in a higher proportion of catheter tips positioned at the superior vena cava–right atrial

junction, which is considered the optimal site, compared to the conventional fixed-depth method.

Although the differences did not reach statistical significance, the findings align with existing evidence that ECG guidance offers a real-time, cost-effective, and reliable method for accurate tip localization. This approach may reduce malposition-related complications and the need for repositioning. Thus, integrating endocavitary ECG into routine practice has the potential to improve safety and efficacy in central venous catheter placement, particularly in resource-limited settings where fluoroscopy is not feasible.

Statements and Declarations

Conflicts of interest

The authors declare that they do not have conflict of interest.

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References

1. Parienti JJ, Mongardon N, Mégarbane B, Mira JP, Kalfon P, Gros A, Marqué S, Thuong M, Pottier V, Ramakers M, Savary B, Seguin A, Valette X, Terzi N, Sauneuf B, Cattoir V, Mermel LA, du Cheyron D; 3 SITES Study Group. Intravascular Complications of Central Venous Catheterization by Insertion Site. *N Engl J Med.* 2015 Sep

- 24;373(13):1220-9. doi: 10.1056/NEJMoa1500964.
2. Kusminsky RE. Complications of central venous catheterization. *J Am Coll Surg.* 2007;204(4):681-96. doi: 10.1016/j.jamcollsurg.2007.01.039.
 3. Karakitsos D, Labropoulos N, De Groot E, Patrianakos AP, Kouraklis G, Poularas J, Samonis G, Tsoutsos DA, Konstadoulakis MM, Karabinis A. Real-time ultrasound-guided catheterisation of the internal jugular vein: a prospective comparison with the landmark technique in critical care patients. *Crit Care.* 2006;10(6):R162. doi: 10.1186/cc5101.
 4. Vezzani A, Brusasco C, Palermo S, Launo C, Mergoni M, Corradi F. Ultrasound localization of central vein catheter and detection of postprocedural pneumothorax: an alternative to chest radiography. *Crit Care Med.* 2010;38(2):533-8. doi: 10.1097/CCM.0b013e3181c0328f.
 5. Wigmore TJ, Smythe JF, Hacking MB, Raobaikady R, MacCallum NS. Effect of the implementation of NICE guidelines for ultrasound guidance on the complication rates associated with central venous catheter placement in patients presenting for routine surgery in a tertiary referral centre. *Br J Anaesth.* 2007 Nov;99(5):662-5. doi: 10.1093/bja/aem262.
 6. Connolly B, Mawson JB, MacDonald CE, Chait P, Mikailian H. Fluoroscopic landmark for SVC-RA junction for central venous catheter placement in children. *Pediatr Radiol.* 2000 Oct;30(10):692-5. doi: 10.1007/s002470000297.
 7. Tseng M, Sadler D, Wong J, Teague KR, Schemmer DC, Saliken JC, So B, Gray RR. Radiologic placement of central venous catheters: rates of success and immediate complications in 3412 cases. *Can Assoc Radiol J.* 2001 Dec;52(6):379-84.
 8. Gibson F, Bodenham A. Misplaced central venous catheters: applied anatomy and practical management. *Br J Anaesth.* 2013 Mar;110(3):333-46. doi: 10.1093/bja/aes497.
 9. Eisen LA, Narasimhan M, Berger JS, Mayo PH, Rosen MJ, Schneider RF. Mechanical complications of central venous catheters. *J Intensive Care Med.* 2006;21(1):40-6. doi: 10.1177/0885066605280884.
 10. Schummer W, Schummer C, Rose N, Niesen WD, Sakka SG. Mechanical complications and malpositions of central venous cannulations by experienced operators. A prospective study of 1794 catheterizations in critically ill patients. *Intensive Care Med.* 2007;33(6):1055-9. doi: 10.1007/s00134-007-0560-z.

11. Defalque RJ, Campbell C. Cardiac tamponade from central venous catheters. *Anesthesiology*. 1979 Mar;50(3):249-52. doi: 10.1097/0000542-197903000-00021.
12. Safety Committee of Japanese Society of Anesthesiologists. Practical guide for safe central venous catheterization and management 2017. *J Anesth*. 2020 Apr;34(2):167-186. doi: 10.1007/s00540-019-02702-9.
13. McGee WT, Ackerman BL, Rouben LR, Prasad VM, Bandi V, Mallory DL. Accurate placement of central venous catheters: a prospective, randomized, multicenter trial. *Crit Care Med*. 1993 Aug;21(8):1118-23. doi: 10.1097/00003246-199308000-00008.
14. Russell WC, Parker JL. Thirteen centimetre central venous catheters, lucky for all? *Anaesthesia*. 2003 Apr;58(4):388. doi: 10.1046/j.1365-2044.2003.030957.x.
15. Kujur R, Rao MS, Mrinal M. How correct is the correct length for central venous catheter insertion. *Indian J Crit Care Med*.;13(3):159-62. doi: 10.4103/0972-5229.58543.
16. Joshi AM, Bhosale GP, Parikh GP, Shah VR. Optimal positioning of right-sided internal jugular venous catheters: comparison of intra-atrial electrocardiography versus Peres' formula. *Indian J Crit Care Med*. 2008 Jan;12(1):10-4. doi: 10.4103/0972-5229.40943.
17. Coe AJ. AAGBI Safe vascular access guidelines I. *Anaesthesia*. 2016;71(8):985. doi: 10.1111/anae.13553.
18. Peres PW. Positioning central venous catheters--a prospective survey. *Anaesth Intensive Care*. 1990 Nov;18(4):536-9. doi: 10.1177/0310057X9001800422.
19. Beheshti MV. A concise history of central venous access. *Tech Vasc Interv Radiol*. 2011;14(4):184-5. doi: 10.1053/j.tvir.2011.05.002.
20. Smith RN, Nolan JP. Central venous catheters. *BMJ*. 2013;347:6570. doi:10.1136/bmj.f6570.
21. Fiona Ives. *Central Venous Catheters*. 1st ed. Wiley-Blackwell; 2009. 57–57p.
22. Frykholm P, Pikwer A, Hammarskjöld F, Larsson AT, Lindgren S, Lindwall R, Taxbro K, Oberg F, Acosta S, Akeson J. Clinical guidelines on central venous catheterisation. *Swedish Society of Anaesthesiology and Intensive Care Medicine. Acta Anaesthesiol Scand*. 2014 May;58(5):508-24. doi: 10.1111/aas.12295.
23. Jeon Y, Ryu HG, Yoon SZ, Kim JH, Bahk JH. Transesophageal echocardiographic evaluation of ECG-guided central venous catheter placement. *Can J Anaesth*. 2006 Oct;53(10):978-83. doi: 10.1007/BF03022525.