Egyptian Journal of Anaesthesia

Vol. 41, 2025
ISSN: 1110-1849 (print))
ISSN: 1687-1804 (online)
DOI: 10.21608/EGJA.2025.364822.1022

ORIGINAL ARTICLE

A Randomized Controlled Trial Comparing Electrocardiography Guided Technique and Anatomical Based Technique for Ideal Positioning of Dialysis Catheter Tip in Pediatric Patients

Saad Ahmed Moharam[1], Sara Mabrouk Elghoul[2], Amgad Elshikh[1], Mohammed Said ElSharkawy[1], Mostafa Mohamed Shaheen[1]

[1]Department of Surgical Intensive Care and Pain Medicine, [2]Department of Pediatrics, Faculty of Medicine, Tanta University, Egypt.

Correspondence to *Saad Ahmed Moharam, MD, Anesthesiology, Department of Surgical Intensive Care and Pain Medicine, Faculty of Medicine, Tanta University, Tanta, Egypt.*
E-mail: Saad.moharam@med.tanta.edu.eg

Background A dialysis catheter is the first choice of vascular access in urgent hemodialysis. Nevertheless, accurate estimation of the catheter length as well as precise tip placement remain crucial to prevent adverse consequences. This work aimed to compare the efficacy of ECG-guided and anatomical landmark techniques in detecting the best dialysis catheter tip's position.

Materials and Methods This prospective randomized controlled study involved 150 children and adolescents aged between five and eighteen years, both sexes, requiring catheter placement for acute as well as chronic renal failure indications. All participants went through an equal categorization into two groups: Group A (control) involved participants who had the dialysis catheter placed utilizing the anatomical landmark approach, and the ECG-guided technique in Group B.

Results Age, sex, weight, height, insertion time, and catheter failure were insignificantly different among both groups. Mispositioned catheter tip, over-insertion, and arrhythmia exhibited insignificant values within group B as opposed to group A. Pneumothorax did not occur in any patient of the ECG group or control group.

Conclusions In pediatrics, the ECG-guided approach exhibited superior precision as well as effectiveness while inserting the catheter tip as opposed to the anatomical landmark one concerning ideal placement, insertion depth as well as fewer negative consequences.

Keywords Dialysis Catheter Tip, Electrocardiography Guided Technique, Landmark, Pediatric.

Egyptian Journal of Anaesthesia 2025,

INTRODUCTION

Chronic kidney disease (CKD) represents an increasingly important issue in public health worldwide [1]. The end-stage renal disease (ESRD) incidence has tripled in pediatrics over the last twenty years [2].

Hemodialysis (HD) remains the most often used renal replacement method while treating pediatrics with ESRD [3]. Children could exhibit substantial disruptions regarding their electrolyte balance as well as toxic substances excreted by the kidneys, thus leading to the acute renal failure occurrence that requires immediate HD [4].

The precise placement of the catheter tip of central venous access (CVA) is crucial in all cases, with special emphasis on children. The high position of the catheter tip in the superior vena cava (SVC) (i.e., middle third or higher) could increase malfunction chances, fibroblastic sleeve, as well as venous thrombosis. Conversely, the low position of the catheter tip in the lower part of the right atrium (RA) or the right ventricle could increase arrhythmia risk [5].

Central venous dialysis catheters represent the primary choice for vascular access among pediatrics especially for cases requiring an immediate HD, serving as an intermediary for those anticipated to have a scheduled kidney transplant [6].

Numerous methods based on patient characteristics such as height [7] and age [8], anatomical landmarks [9] and ECG guidance [10] have been suggested to decide the correct depth of catheter placement.

This work was aimed at comparing the efficacy of ECG-guided and anatomical landmark techniques' in detecting the ideal dialysis catheter tip's position.

MATERIAL AND METHODS

Our single-institution prospective randomized controlled study involved 150 children and adolescents aged between five and eighteen years, both sexes, who require dialysis catheter insertion for any indication of acute or chronic renal failure.

The study was done from May 2023 to December 2023 following the Ethical Committee, Our University Hospitals' approval (approval code: 36264PR196/5/23) along with registration of clinicaltrials.gov (ID: NCT05935475). All the participants' relatives were asked to fill in informed consent.

We excluded individuals having coagulopathic disorders, infections, as well as cardiac arrhythmia or pacemakers.

Participants went through a random allocation utilizing an internet-based computer program (http://www.randomizer.org) into two groups who had the dialysis catheter placed utilizing the anatomical landmark approach in Group A (control), and the ECG-guided technique in Group B.

All participants went through a comprehensive medical history, involving the dialysis' causes, clinical assessment, as well as laboratory testing [complete blood count, bleeding as well as clotting time, serum potassium, creatinine, along with blood urea level].

One anesthesiologist conducted the procedure in both groups with strict adherence to sterile conditions. Everyone underwent a right internal jugular vein cannulation (IJV). The subjects were positioned in the Trendelenburg position, then the dialysis catheter (AMECATH, AMECO medical industries, 10th of Ramadan City, Cairo, Egypt) was inserted utilizing the catheter-over-guidewire approach (also known as the Seldinger technique), with the use of ultrasonography (Philips CX50, extreme edition, Amsterdam, the Netherlands) machine to scan the neck via a superficial linear probe (7-13 MHz) [11].

ECG-guided technique

Following the dialysis catheter's insertion into the right IJV, the guidewire was subsequently removed till its tip was precisely located at the SVC entry in RA. This procedure was performed utilizing the ECG guidance: the *P* wave is seen as a biphasic wave within the RA. Subsequently, the tip then gradually removed at intervals of 0.5cm till the *P*-wave exhibited a normal pattern [12] (Figure 1).

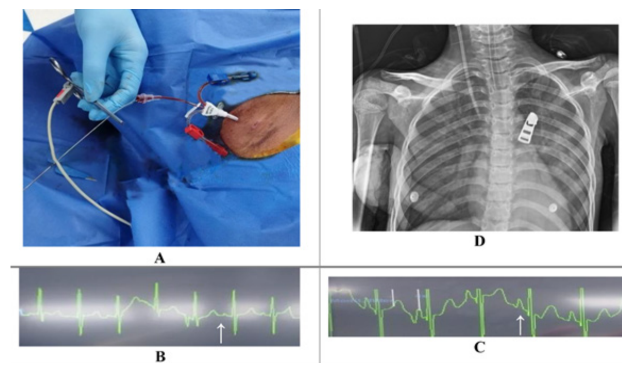

Figure 1: ECG-guided technique for positioning of dialysis catheter tip C showing P wave changes in amplitude or morphology that indicate advanced tip position of catheter that require withdrawal of the catheter tip till normal pattern of P wave as in B.

Anatomical landmark technique

Method for determining the insertion depth of dialysis catheter. Two points are marked on the patient's skin during the IJV catheterization. Point A is marked at the sternal head of the right clavicle, most prominent point. Point B is marked at the midpoint of the perpendicular line from Point A to the line connecting both nipples. Point I is the insertion point of the needle. Distance from Point I to Point A and from Point A to Point B is measured. The depth of dialysis catheter is determined by adding the two measurements and subtracting 0.5 cm from this [13] (Figure 2).

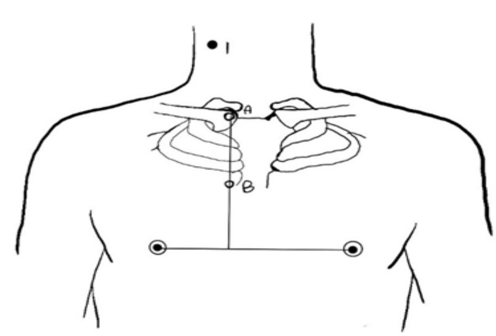

Figure 2: Anatomical landmark technique Point A is marked at the sternal head of the right clavicle, most prominent point. Point B is marked at the midpoint of the perpendicular line from Point A to the line connecting both nipples. Point I is the insertion point of the needle.

Before placement, measuring the catheter depth was accomplished from the placement point to the catheter tip point (representing the vertical line midway from the sternocleidomastoid clavicular head to the inter nipple line).

Then, the catheter was sutured to skin as well as covered utilizing a clear dressing. Following the catheter's placement, the subject went through monitoring. The duration for inserting the catheter, as well as any adverse consequences following the procedure were recorded.

If hemodynamic instability occurred, ultrasound chest was performed to exclude pneumothorax. All participants went through an anterior-posterior CXR while they were supine. The whole SVC was identified on CXR as the region extending from the lower border of the first right costal cartilage near the sternum and ending at the conventional radiographic SVC-RA junction [14]. Chest *X*-Rays were performed within both groups to determine the appropriate catheter's insertion length, CXR frequency for repositioning (Figures 1,3).

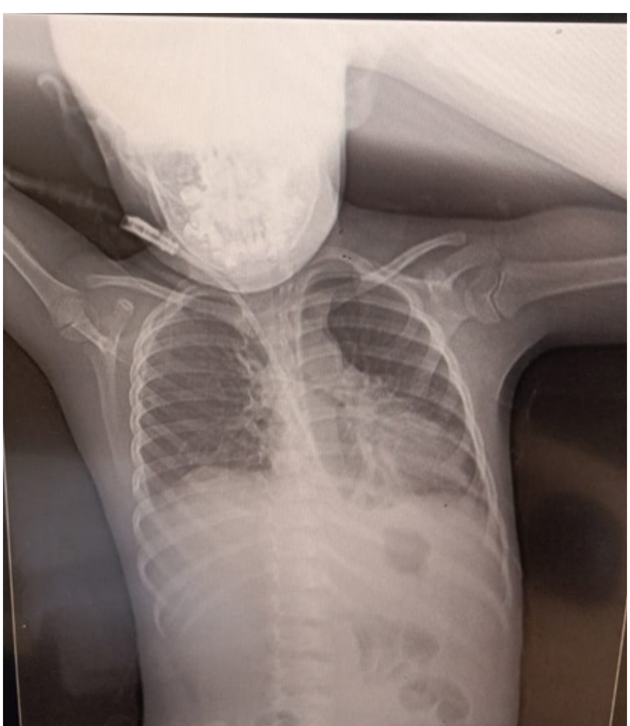

Figure 3: Dialysis catheter malposition using the anatomical landmark technique.

Malposition is defined as a deviation from the ideal catheter tip placement in the mid-to-upper SVC. The tip of the catheter should be placed in the middle SVC, outside the lower SVC's pericardial reflection. This corresponds to the level of the carina, 2cm above the junction of the SVC and the right atrium. Over-insertion refers to the condition where the dialysis catheter tip is inserted too far into the vein or extends more than 2cm above the junction of the SVC and the right atrium.

Catheter failure refers to a situation where the dialysis catheter does not function as intended, leading to an inability to provide effective dialysis.

The primary outcome was the incidence of a malpositioned dialysis catheter tip. The secondary outcomes were the occurrence of over-insertion, postprocedural CXR, catheter failure, and arrhythmia on insertion.

Sample Size Calculation

The sample size calculation was conducted using G*Power 3.1.9.2 (Universität Kiel, Germany). It was based on the incidence of malpositioned dialysis catheter tips, observed as 20% with the anatomical landmark approach and 0% with the ECG-guided technique, according to an unpublished pilot study of 10 patients from our target population. With an alpha error of 0.05, a power of 99%, and an allocation ratio of 1:1, the sample size was adjusted to include an additional seven cases to account for potential dropouts. Consequently, a total of 75 patients were allocated.

Statistical analysis

Data went through a statistical analysis utilizing SPSS v27 (IBM©, Armonk, NY, USA). The Shapiro-Wilks test as well as histograms were utilized for assessing the normality of the data distribution. Quantitative parametric data were displayed as mean as well as SD then went through analysis utilizing unpaired student *t*-test. Qualitative variables were displayed as frequency as well as percentage then went through analysis utilizing the Chi-square test or Fisher's exact test when appropriate. A two-tail *P* value of less than 0.05 was deemed to exhibit statistical significance.

RESULTS

Regarding our research, 173 cases underwent an assessment for eligibility, around fourteen individuals did not match the eligibility criteria along with nine others disagreed to take part in our research. The included cases underwent an equal and random allocation into two groups (seventy-five cases within each). All participants went through follow-up as well as a statistical analysis (Figure 4).

Age, sex, weight and height exhibited insignificant variation between both groups (Table 1).

Central venous catheter tip positioning was malpositioned in 9(12%) patients in group A and 1(1.33%) in group B. The incidence of malpositioned dialysis catheter tips was significantly lower in values within group B as opposed to group A (*P*=0.017) with 9(1.17:69.29) RR (95% CI). Insertion time exhibited insignificant variation among the two groups. Pneumothorax did not occur in any patient of both groups. Catheter failure was insignificantly different between the two groups. Arrhythmia occurred in 22(29.33%) in group A and 3(4%) in group B. Arrhythmia was significantly lower within group B as opposed to group A (*P*<0.001) with 7.33(2.29:23.46) RR (95% CI) (Table 2).

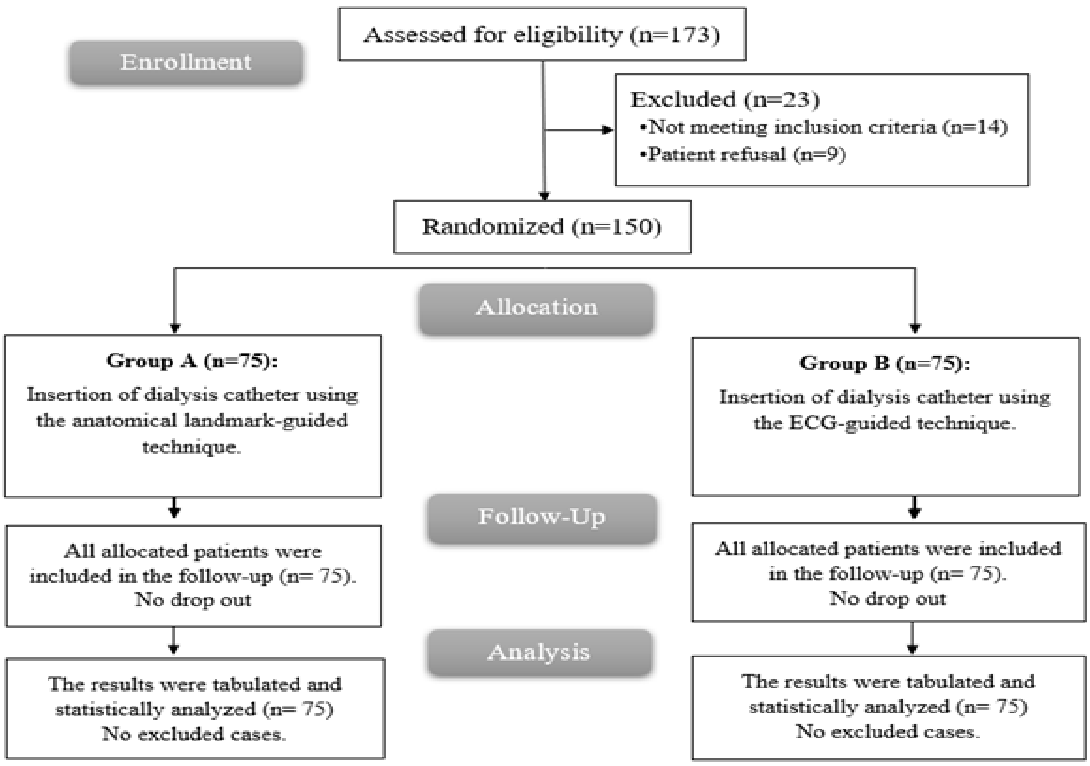

Figure 4: CONSORT flowchart of the enrolled patients

Table 1: Demographic data of all groups:

		Group A (*n*=75)	Group B (*n*=75)	*P* value
Age (years)		10.8±3.49	11.79±3.57	0.089
Sex	Male	41(54.67%)	35(46.67%)	0.327
	Female	34(45.33%)	40(53.33%)	
Weight (kg)		44.52±14.02	48.07±14.42	0.129
Height (cm)		145.47±22.59	151.97±22.77	0.081

Data exhibited as mean±SD or frequency (%).

Table 2: Dialysis catheter tip positioning, insertion time, postprocedural CXR, catheter failure, and arrhythmia of all groups:

		Group A (*n*=75)	Group B (*n*=75)	*P* value
Central venous catheter tip positioning	Mispositioned	9(12%)	1(1.33%)	0.017*
	Normal	66(88%)	74(98.67%)	
Insertion time (min)		13.31±2.21	12.89±1.59	0.191
Postprocedural CXR	Pneumothorax	0(0%)	0(0%)	---
Catheter failure		0(0%)	0(0%)	---
Arrhythmia		22(29.33%)	3(4%)	<0.001*

Data exhibited as mean±SD or frequency (%); *: Significant as *P* value ≤0.05; CXR: Chest *X*-Ray.

DISCUSSION

The novelty of this study lies in its direct comparison of ECG-guided and anatomical landmark techniques for dialysis catheter placement specifically within a pediatric population. While ECG guidance has been extensively studied in adults, pediatric-specific data is limited. This study contributes valuable insights into the effectiveness and safety of ECG-guided catheter placement for children and adolescents, targeting its advantages in precision, reduced risk of malposition, and fewer adverse effects such as arrhythmias. Additionally, by evaluating the ECG-guided approach's impact on minimizing radiation exposure from chest *X*-Rays, this research addresses an important concern in pediatric care, as children are particularly sensitive to cumulative radiation effects.

It is crucial to position the central venous catheter tip within the SVC–RA junction, thus preventing associated consequences, involving vascular perforations, hydrothorax, and pneumothorax [15].

Typically, conventional chest *X*-Rays are utilized for ensuring the precise catheter tip placement [16].

ECG-guided approach enables the clinician to immediately adjust the dialysis catheter tip's location through analyzing the P-wave morphology, which is in contrast to CXR, requiring serial imaging, thus taking longer time along with several radiation doses and CXR is not always available [17]. Therefore, ECG-guided dialysis catheter placement exhibits numerous advantages over the anatomical landmark approach, mostly due to its superior precision in placing the catheter tip. Additionally, it provides benefits in terms of time efficiency, cost-effectiveness, safety, as well as preventing repetitive radiation doses [18].

In our study, insertion time, and catheter failure were insignificantly different between landmark group and ECG group. Malpositioned CVC tip, over insertion, and arrhythmia exhibited significant less values within ECG group as opposed to landmark groups. Pneumothorax did not occur in any patient of ECG group or landmark group.

The reduced incidence of arrhythmias in ECG Group could be attributed to the higher precision and control inherent in the ECG-guided approach [19]. Although both techniques involve guidewire insertion near or within the right atrium, the ECG guidance allows for real-time monitoring of the P-wave morphology, helping the operator detect and confirm the correct positioning before the catheter tip reaches deeper within the atrium. This minimizes the risk of inadvertently advancing the catheter too far into the heart, where it is more likely to trigger arrhythmias [20].

Similar to our findings, Krishnan *et al*., [20] found that insertion time was insignificantly different between landmark and ECG group. Malposition CVC tip, over insertion, and arrhythmia exhibited significantly lower values in ECG group as opposed to controls. Pneumothorax did not occur in any patient of ECG group or landmark group.

Moreover, Barnwal *et al*., [9] concluded that the ECG-guided approach exhibited a superior precision for placing the CVC tip. The landmark group developed more complications.

Regarding our research, the P-wave amplitude exhibited a rising pattern when the CVC tip moved forward toward the RA. Additionally, the P-wave morphology restored its normal state when pulling the tip retrogradely into the SVC. Our findings supported Lee *et al*., [21] addressing that the P-wave morphology restored its normal state at approximately four cm above the SVC-RA junction.

Smith *et al*., [22] stated that there were anterograde direction moved catheter, the P-wave morphology inverted, exhibiting a negative configuration. Nevertheless, research have addressed, the carina level is often located at one cm above the pericardial reflection within the thorax centre. As a result, the likelihood of image distortion as well as errors remains low, making it a reliable landmark while positioning the CVC tip [23-25].

The observed range of CVC tip malpositioning, as documented by various publications, falls between 1.8% to 9.3% [26]. Several research projects utilizing ECG guidance to precisely position the CVC tip [23,27,28].

Smith *et al*., [22] addressed, P-wave amplitude exhibited a statistically significant variation while measuring its height at the SVC-RA junction, as opposed to measurements at three as well as five cm within the RA. Therefore, our work contributes to the evident data that supports inserting the CVC tip could be more precise utilizing ECG guidance.

Our research addressed, postprocedural CXR exhibited a precise CVC tips' insertion rate of 98.57% within the ECG-guided group as opposed to 82.86% within the landmark one. Various research supported our results, but they addressed varying success rates [14,20,21,26,27].

Our research also addressed that a considerable decrease within the CVC depth while placing the tips into the SVC utilizing ECG-guided approach as opposed to the landmark one that aligned with Krishnan *et al*.'s findings [20].

The limitations of the technique include that the ECG-guided approach remains challenging when utilized for cases with absent or unrecordable P-wave, involving arterial fibrillation, atrial flutter, or pacemaker-driven rhythm). Additionally, P-wave variations could occur because of pericardial reflection as well as catheter tips' absence at the SVC-RA junction. CVC tips were only confirmed utilizing radiographic assessment.

Limitations in this study were the relatively small sample size along with a single-centered study. All participants went through a relatively limited follow-up timeframe. Unfortunately, we did not use or directly compare our results to these established formulas, which may have provided a more standardized basis for comparison. Further studies to compare other techniques are recommended.

CONCLUSIONS

In pediatrics, the ECG-guided approach exhibited superior precision while inserting the dialysis catheter tip as opposed to the anatomical landmark one concerning the ideal placement, insertion depth, and fewer negative consequences.

ETHICS APPROVAL AND CONSENT FOR PARTICIPANTS

The study was done from May 2023 to December 2023 following the Ethical Committee, Our University Hospitals' approval (approval code: NCT05935475) along with registration of clinicaltrials.gov (ID: 36264PR196/5/23). All the participants' relatives were asked to fill in informed consent.

Authors' contributions

Study concept and design: S. A. M., S.M.E. and A. E.; analysis and interpretation of data: M.M.S. and M. S. E.; drafting of the manuscript: M. A.; critical revision of the manuscript for important intellectual content: S. A. M., S.M.E., M.M.S. and M. S. E.

CONFLICT OF INTERESTS

There are no conflicts of interest.

REFERENCES

1. Bello AK, Okpechi IG, Osman MA, Cho Y, Htay H, Jha V, *et al*. (2022). Epidemiology of haemodialysis outcomes. Nat Rev Nephrol. 18:378-95.
2. Akinkugbe O, Marchetto L, Martin I, Chia SH. (2024). Systematic review and meta-analysis of the incidence of chronic kidney disease after pediatric critical illness. Crit Care Explor. 6:e1129.
3. Chanchlani R, Young C, Farooq A, Sanger S, Sethi S, Chakraborty R, *et al*. (2021). Evolution and change in paradigm of hemodialysis in children: a systematic review. Pediatr Nephrol. 36:1255-71.
4. Kellum JA, Romagnani P, Ashuntantang G, Ronco C, Zarbock A, Anders H-J. (2021). Acute kidney injury. Nat Rev Dis Primers. 7:7-52.
5. El Ghobashy M, Khan BN, Ahmed S, Mostafa G, Bazaraa H. (2022). Image guided techniques for central venous access in critically ill pediatric patients. Med J Cairo Univ. 90:2131-41.
6. Sohail MA, Vachharajani TJ, Anvari E. (2021). Central venous catheters for hemodialysis-the myth and the evidence. Kidney Int Rep. 6:2958-68.
7. Lee J, Park JH, Oh S, Lee JM. (2024). Optimal insertion depth of central venous catheter through the right internal jugular vein, verified by transesophageal echocardiography: A prospective observational study. Int J Med Sci. 21:431-8.
8. Yamamoto T, Schindler E. (2019). A new way to determine correct depth of central venous catheter insertion using a real-time ultrasound-guided insertion technique in pediatric patients. Paediatr Anaesth. 29:368-76.
9. Barnwal NK, Dave ST, Dias R. (2016). A comparative study of two techniques (electrocardiogram- and landmark-guided) for correct depth of the central venous catheter placement in paediatric patients undergoing elective cardiovascular surgery. Indian J Anaesth. 60:470-5.
10. Shah H, Dave N, Karnik P. (2020). Accuracy of electrocardiography guidance for depth of insertion of central venous catheters in children: A prospective observational study. Medical Journal of Dr DY Patil University. 13:244-7.
11. Rossetti F, Pittiruti M, Lamperti M, Graziano U, Celentano D, Capozzoli G. (2015). The intracavitary ECG method for positioning the tip of central venous access devices in pediatric patients: results of an Italian multicenter study. J Vasc Access. 16:137-43.
12. Krishnan AK, Menon P, Gireesh Kumar KP, Sreekrishnan TP, Garg M, Kumar SV. (2018). Electrocardiogram-guided technique: An alternative method for confirming central venous catheter tip placement. J Emerg Trauma Shock. 11:276-1.
13. Na HS, Kim JT, Kim HS, Bahk JH, Kim CS, Kim SD. (2009). Practical anatomic landmarks for determining the insertion depth of central venous catheter in paediatric patients. Br J Anaesth. 102:820-3.
14. Gebhard RE, Szmuk P, Pivalizza EG, Melnikov V, Vogt C, Warters RD. (2007). The accuracy of electrocardiogram-controlled central line placement. Anesth Analg. 104:65-70.
15. Walsh EC, Fitzsimons MG. (2023). Preventing mechanical complications associated with central venous catheter placement. BJA Educ. 23:229-37.
16. Zhang M, Liu HL, Li WH, Li MZ. (2023). The value of transthoracic echocardiography and chest *X*-Ray in locating the tip of central venous catheter in dialysis patients: a comparative study with computed tomography imaging. Ren Fail. 45:2290179.
17. Zhao C, Zhu Y, Yin X, Zhang C, He Y, Gao J. (2022). ECG method for positioning the tip of peripherally inserted central catheters in patients with atrial fibrillation. Ann Noninvasive Electrocardiol. 27:e12931.
18. D'Andrea V, Pezza L, Prontera G, Ancora G, Pittiruti M, Vento G, *et al*. (2023). The intracavitary ECG method for tip location of

ultrasound-guided centrally inserted central catheter in neonates. J Vasc Access. 24:1134-9.

19. Garg M, Meena R, Joshi A, Saiyed A, Garg A. (2023). Comparison of landmark versus ECG-guided technique for correct insertion of central venous catheter in paediatric patients undergoing cardiothoracic surgery. Arch Anesthesiol Crit Care. 9:232-7.
20. Krishnan AK, Menon P, Gireesh Kumar KP, Sreekrishnan TP, Garg M, Kumar SV. (2018). Electrocardiogram-guided Technique: An Alternative Method for Confirming Central Venous Catheter Tip Placement. J Emerg Trauma Shock. 11:276-81.
21. Lee JH, Bahk JH, Ryu HG, Jung CW, Jeon Y. (2009). Comparison of the bedside central venous catheter placement techniques: landmark vs electrocardiogram guidance. Br J Anaesth. 102:662-6.
22. Smith B, Neuharth RM, Hendrix MA, McDonnall D, Michaels AD. (2010). Intravenous electrocardiographic guidance for placement of peripherally inserted central catheters. J Electrocardiol. 43:274-8.
23. Jeon Y, Ryu HG, Yoon SZ, Kim JH, Bahk JH. (2006). Transesophageal echocardiographic evaluation of ECG-guided central venous catheter placement. Can J Anaesth. 53:978-83.
24. Stonelake PA, Bodenham AR. (2006). The carina as a radiological landmark for central venous catheter tip position. Br J Anaesth. 96:335-40.
25. Ryu HG, Bahk JH, Kim JT, Lee JH. (2007). Bedside prediction of the central venous catheter insertion depth. Br J Anaesth. 98:225-7.
26. Sharma D, Singh VP, Malhotra MK, Gupta K. (2013). Optimum depth of central venous catheter - Comparision by pere's, landmark and endocavitory (atrial) ECG technique: A prospective study. Anesth Essays Res. 7:216-20.
27. Chu KS, Hsu JH, Wang SS, Tang CS, Cheng KI, Wang CK, *et al*. (2004). Accurate central venous port-A catheter placement: intravenous electrocardiography and surface landmark techniques compared by using transesophageal echocardiography. Anesth Analg. 98:910-4.
28. Ender J, Erdoes G, Krohmer E, Olthoff D, Mukherjee C. (2009). Transesophageal echocardiography for verification of the position of the electrocardiographically-placed central venous catheter. J Cardiothorac Vasc Anesth. 23:457-61.