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A comparison between two radiological criteria for verifying tip location of central venous catheters

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Abstract

Introduction: Current guidelines recommend intraprocedural methods—such as Intra-Cavitary ECG (IC-ECG) and echocardiography—for verifying the location of the tip of central venous catheters. Nonetheless, there are clinical conditions which may require to verify tip location by less accurate methods such as Chest X-Ray (CXR). We have compared the feasibility and accuracy of two radiological methods for tip location—the Sweet Spot Criterion (SSC) and the Carina Criterion (CC)—using IC-ECG as reference.

Methods: In this retrospective multicenter study, we reviewed the radiology databases of three hospitals, examining all CXRs performed on patients after insertion of Peripherally Inserted Central Catheters (PICCs), as long as the tip location had been successfully performed during the procedure by IC-ECG. Tip location was verified using SSC and CC, comparing the two methods in terms of feasibility and accuracy.

Results: We reviewed the CXR of 1116 PICCs successfully inserted by IC-ECG. CC was not feasible in 0.5% (impossible visualization of the carina) and difficult in 1.5%; in 97.7% of cases, the position of the tip was adequate (1–5 cm below the carina), in 0.6% too high (<1 cm), in 1.2% too low (6–9 cm). On the other hand, because of unclear visualization of radiological landmarks, SSC was not feasible in 0.9% and difficult in 10.5%; though, according to SSC the tip location was always acceptable (in 94.2% the tip was in the middle of the spot, in 2.5% close to the superior border, and in 2.3% close to the inferior border); no tip was visualized outside of the spot.

Conclusion: CC and SSC were similar in terms of feasibility (99.5% vs 99.1%) and accuracy (98.1% vs 100%), though CC was subjectively perceived to be easier and more rapid to perform.

Keywords

Tip location, central venous access device, PICC, intracavitary ECG, chest-X ray

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Introduction

Correct tip location of central vascular access devices (CVADs) is of paramount importance to avoid position-related complications.[1–3] Trans-esophageal-echocardiography (TEE) is the most accurate method for verifying that the tip of the CVAD is at the cava-atrial junction (CAJ), but it is expensive, invasive, and logistically inappropriate for everyday clinical practice. Alternative options to TEE are intraprocedural methods such as Intra-Cavitary ECG (IC-ECG),[4] transthoracic echocardiography (TTE)[5,6] and fluoroscopy. Fluoroscopy is not considered a first option for tip location, since it is more expensive, less accurate and more invasive if compared to IC-ECG and TTE.[7,8]

Chest-X-ray (CXR) is currently not recommended for tip location by international guidelines[7] since it has the same disadvantages of fluoroscopy (low accuracy, invasiveness, high cost) and the additional disadvantage of

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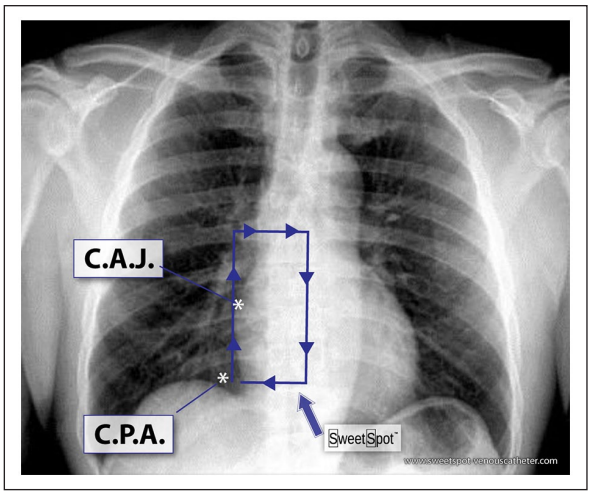

Figure 1. How to draw the Sweet Spot™.
(1) On a frontal CXR, identify the CAJ and the right CPA. (2) Start at a point as close as possible to the CPA that permits a vertical line to be drawn along the right edge of the cardiac silhouette. (3) Go twice the distance of the CPA to the CAJ. (4) Next, continue a horizontal line to your right equaling one-half the length of the previous vertical line. (5) Lastly, turn inferiorly and complete the rectangle.

being performed after the procedure. Furthermore, the CXR-based verification of tip location is based on the interpretation of radiological landmarks, which may be uncertain or imprecise. Also, the criteria for using such landmarks are often poorly defined, subjective and/or non-repeatable.

One of the most used criteria, the so-called Carina Criterion (CC), is based on identification of the carina, which roughly corresponds to the mid-portion of the superior vena cava (SVC); considering that the whole length of the SVC in the adult patient is approximately 6–7 cm, the lower third of the SVC starts 1 cm below the level of the carina, with the CAJ approximately located 3 cm below the carina. This criterion is quite easy, widely used, and repeatable,[9–11] though it cannot be extended to the pediatric or neonatal population.

In 2012, a new radiological criterion has been developed by Ken Symington, with the purpose of minimizing the subjective interpretation of the location of the carina and of the distance between carina and tip of the catheter, the so-called Sweet Spot™ criteria (SSC).[12] This method consists in drawing a rectangle superimposed on a frontal CXR; if the tip of the catheter is visualized inside this rectangle, it is correctly positioned. This rectangle is drawn after identifying the CAJ and the cardio-phrenic angle (CPA). The initial outward bulge of the lower right cardiomediastinal margin is due to the transition from the smaller, more tubular superior vena cava to the more capacious and rotund right atrium. Then, a vertical line is drawn, along the right edge of the cardiac silhouette: the line drawn must be twice as long as the distance from CPA to CAJ. Subsequently, from the CPA, a horizontal line is drawn to the right, equal to half the length of the vertical line. Last, the drawing is completed by tracing the other two lines that will form a rectangle, where the height will be double the width (Figure 1). The SSC therefore has no fixed length or width, but it is tailored to the individual patient's CXR. Depending on anatomy, it can be quite wide and exceed 8×4 cm.

In this study, we compared these two radiological criteria (CC vs. SSC) in terms of feasibility, accuracy, and simplicity/rapidity of use. As reference standard for accuracy, we have been using IC-ECG, since several clinical studies comparing TEE versus IC-ECG versus CXR have shown that IC-ECG—when applicable and feasible—is as accurate as TEE, while CXR is far less accurate.[13–15]

Methods

We retrospectively reviewed the radiology databases of three hospitals, examining all CXRs performed on adult patients (>18 years old) after PICC insertion, (a) if the tip location had been successfully verified by IC-ECG during the procedure and (b) if CXR had been performed less than 48 h after insertion. Tip location was evaluated using SSC and CC on all CXRs. All radiographs were examined by clinicians appropriately trained in the use of both SSC and CC.

The study was approved by the institutional review board. The need for informed consent was waived due to the study's retrospective design and the use of anonymous clinical data.

The goal of this study was the comparison between the CC and the SSC in terms of feasibility, accuracy, and simplicity. Feasibility was defined as the identification of the radiological landmarks belonging to each criterion. Accuracy was defined as the appropriate position of the tip, taking the position defined by IC- ECG as reference. Simplicity/rapidity of the method was defined as ease and speed in the application of each radiological criteria, as perceived by the operator.

As regards IC-ECG, it was assumed that in all cases the tip of the PICC had been left in a position corresponding to the maximum peak of the P wave. IC-ECG method was performed either by standard ECG monitors or by dedicated ECG monitors, with different types of connection between the catheter and the monitor, but always using the "saline" method and not the "guidewire" method.[16]

As regards CC, the position of the catheter tip was assessed on the post-procedural CXR assuming that in the adult patient the CAJ should be approximately 3 cm below the carina; positions between 1 and 5 cm below the carina were accepted as correct, and the method scored as accurate. Feasibility of the CC was evaluated as % of CXRs where the carina was possible to identify. The simplicity of the method—in terms of time required for the identification of the radiological landmarks and definition of tip location—was expressed as a subjective, qualitative judgment of the clinician (yes = definition of tip location within 2 min; no = definition of tip location requiring more than 2 min).

Table 1. Clinical data.

Number of patients included in the study	1116
Age (years) mean ±SD	63.2 ± 16.6
Males/Females	480/636
Type of patients	
Hospitalized patients	547 (49%)
Outpatients	569 (51%)
Catheter type	
Silicone PICC	368 (33%)
Polyurethane PICC	748 (67%)
Insertion vein	
Basilic vein	795
Brachial vein	296
Cephalic vein	25
CXR	
Supine position	848 (76%)
Standing position	268 (24%)

The clinician was also asked to note if the identification of the radiological landmarks had been easy or difficult.

As regards the SSC, a rectangle was drawn on each CXR, following the instructions described in the Sweet Spot™ website. Positions of the tip of the catheter inside the "spot" were considered accurate; positions of the tip of the catheter on the edge of the "spot" (within 1 cm from the edge) were considered acceptable; tips of the catheter located outside of the "spot" were not considered acceptable in terms of accuracy. Feasibility of SSC was evaluated as % of CXRs where the SSC landmarks were possible to identify. The simplicity of the method—in terms of time required for the identification of the radiological landmarks and definition of tip location—was expressed as a subjective, qualitative judgment of the clinician (yes = definition of tip location within 2 min; no = definition of tip location requiring more than 2 min). The clinician was also asked to note if the identification of the radiological landmarks had been easy or difficult.

Data collection

We recorded all relevant clinical information, including age and gender of the patient, type of patient (outpatient or inpatient), type of catheter used, site and side of catheter insertion, and whether the CXR had been taken performed in supine or standing position.

All data were included in an Excel (Microsoft Inc., Redmond, WA) spreadsheet for record and analysis. Continuous data were expressed as mean (SD). Categorical data were reported as absolute numbers and percentages (%).

Results

We reviewed 1116 PICCs successfully placed with intraprocedural tip location by IC-ECG (maximal height of P wave = tip at the cavo-atrial junction), both in hospitalized patients (49%) and in outpatients (51%). Both silicone PICCs (33%) and power injectable PICCs in polyurethane (67%) were used. In most patients (76%), CXR had been performed in supine position (Table 1).

All 1116 CXRs were examined. According to CC, tip position was appropriate (1–5 cm below the carina) in 97.7% of cases: 956 tips (85.7%) were placed at 1–3 cm below the carina and 134 tips (12%) at 4–5 cm. In 1.8% of cases, there was a discrepancy between IC-ECG and CC, since at CC the tip was estimated to be "too high" (<1 cm) or "too low" (6–9 cm). CC was not feasible in 0.5% (impossible identification of the carina) and difficult in 1.5% (difficult visualization of the carina). When feasible, tip location by CC was performed rapidly in 98.05% of cases (Table 2). Because of unclear visualization of radiological landmarks, SSC was not feasible in 0.9% (10 cases) and difficult in 10.5% (81 cases); in 99.1%, the tip was within the spot (94.2% in the middle, 2.5% close to the superior border, 2.3% close to the inferior border); no tip was visualized outside of the spot (Table 2). We found that all tips placed at 6 cm below the carina (and thus inacceptable according to the CC method) were located at the inferior edge of the sweet spot (according to the SSC method).

Interestingly, all the CXRs with impossible or difficult identification of the radiological landmark (for both criteria) occurred in hospitalized and bedridden patients who had the radiographs taken in the supine position.

CC and SSC were similar in terms of feasibility (99.5% vs 99.1%). Considering only cases where each method was feasible, accuracy was not significantly different between CC (98.1%) and SSC (100%). However, in the clinician's perception, CC was faster to perform (98%) if compared to SSC (89.5%); also, CC was apparently easier than SSC, with less difficulty in visualizing the radiological landmarks (1.5% vs 10.5%).

Discussion

It has long been known that the correct position of the tip at the CAJ or the lower third of the SVC is crucial to reduce some complications, such as device malfunction,[1] catheter-related thrombosis,[2] arrhythmias and even tricuspid valve damage.[3,17] Proximal positions of the tip (i.e. catheter too short) are associated with malfunction and thrombosis, mostly secondary to the vascular damage caused by the tip against the wall of the SVC.[11,18]

More than 20 years ago, describing three possible zones of tip location, Fletcher and Bodenham suggested that the safest zone (called "zone A") is the area including the lower third of SVC and the upper part of right atrium, that is, the area soon above and soon below the CAJ[19] . Considering CXR, which has been the most common used method for tip location of CVADs for decades, this zone A corresponds to the projection of the tip in an area located

Table 2. Comparison between the two criteria of tip location at chest-X-ray.

	Carina Criteria *n* = 1116	Sweet Spot™ Criteria *n* = 1116
Difficult identification of landmarks	15 (1.5%)	81 (10.5%)
Impossible identification of landmarks	5 (0.5%)	10 (0.9%)
Feasibility	99.5%	99.1%
Appropriate tip position according to each method	1–5 cm below the carina	inside the spot
Tip in appropriate position	1090 (97.7%)	1106 (99.1%)
Tip in inappropriate position	21 (1.8%)	0
Carina Criteria		
Tip < 1 cm below the carina (too short)	7 (0.6%)	
Tip at 1–3 cm below the carina	956 (85.7%)	-
Tip at 4–5 cm below the carina	134 (12%)	
Tip at 6–9 cm below the carina (too long)	14 (1.2%)	
Sweet Spot™ Criteria		
Tip in the middle of the sweet spot		1052 (94.2%)
Tip close to the superior edge	-	28 (2.5%)
Tip close to the inferior edge		26 (2.3%)
Tip outside the spot		0
Accuracy vs IC-ECG method (excluding cases with impossible identification of landmarks)	98.1%	100%
Rapidity (less than 2 minutes) (excluding cases with impossible identification of landmarks)	98%	89.5%

from 1 to 5 cm below the carina. Though, this is a criterion based on the statistical correlation between the location of the CAJ and the location of the carina, the distance between the two structures being approximately 3 cm in adult patients. On the contrary, TEE and IC-ECG localize very precisely the CAJ, not based on a statistical correlation, but identifying CAJ—patient by patient—either by the visualization of the crista terminalis (TEE) or of the peak of the P wave (IC-ECG).

In the XX century, many studies have demonstrated the accuracy of IC-ECG for tip location of CVADs, using post-procedural CXR as comparison.[20,21] All these studies demonstrated that the IC-ECG method was safe, easy to perform, inexpensive, and also relatively accurate if using CXR-based tip location as standard reference.

At the beginning of the XXI century, the IC-ECG was most appropriately validated as accurate by using TEE as standard reference. At least three clinical studies[13–15] have shown that IC-ECG is more accurate than CXR for CAJ identification. In these three studies, IC-ECG was found to be as accurate as TEE, but preferable because less invasive, less expensive, and more routinely applicable for CVADs insertion. Further studies showed the accuracy and feasibility of IC-ECG as a tip location method not only for PICCs[22,23] but also for different types of CVADs (ports, PICCs, tunneled-cuffed catheters, etc.).[24–26] Recently, a modified IC-ECG has been developed for tip location in patients with atrial fibrillation,[27] thus expanding the applicability of the method. Recently, TTE has also been proven to be as accurate as CXR for tip location (though less accurate than TEE and IC-ECG), especially using techniques of enhanced visualization such as the "bubble test."[5,6,8]

Therefore, current guidelines[7,8,28] recommend intraprocedural tip location by IC-ECG and/or TTE, rather than post-procedural tip location by CXR. The role of radiology for tip location of CVAD is inevitably becoming more marginal, especially for PICCs. Nonetheless, in some clinical situations it may be useful to check tip location by CXR, for example when more accurate and less invasive methods (such as IC-ECG or TTE) are not applicable or feasible.

In this regard, CC is widely used because of its simplicity. Though, if compared to IC-ECG or TEE, CC is not accurate in 100% of cases, since it is based on the assumption that the distance between two anatomical structures (CAJ and carina) is the same in all patients; furthermore, the CC method is less accurate in children and largely inaccurate in neonates; also, sometimes the radiological landmark represented by the carina may not be easy to identify.

Therefore, Symington has proposed a different radiological criterion (SSC) with the purpose of removing the subjective and sometimes erroneous interpretations of the carina profile. While less popular than CC, SSC is very interesting because it takes into consideration a wide area (the "sweet spot") rather than a specific point, thus taking into account the inevitable movement of the tip during breathing or during changes of body position. In addition, this method is relatively independent from patient factors

such as age and size. However, the SSC method might be difficult or impossible to perform in case of significant CXR distortion/rotation (severe scoliosis, lordosis, pectus excavatum) or in restrictive pulmonary diseases with low lung volumes.

To our knowledge, this is the first study that compare these two radiological criteria to identify tip location of CVADs.

A recent randomized clinical trial investigated the accuracy of tip location using two different methods, one based on CXR and the other based on surface landmarks, comparing them to TEE. In this trial, CXR, using the CC, was less accurate than surface landmarks (85.7% vs 96.4%, $p=0.047$).[29] In fact, the CC was associated with a higher incidence of tip located 2 cm above the CAJ; the tip was more accurately positioned in the distal SVC, close to the CAJ, using surface landmarks (14.3% vs 3.6%, $p=0.047$). This is clinically relevant, since a position of the tip above the carina is not acceptable, because of the risk of damage to the wall of the SVC.[11]

In our study, both methods (CC and SSC) had a high feasibility (>99%), and their accuracy was not significantly different. The 100% accuracy of SSC is related to the advantage of accepting as correct any location of the tip in a wide area, while CC considers appropriate a short range of positions (between 1 and 5 cm below the CAJ, the so-called "zone A"). Though, from the subjective point of view of the operator, the SSC was associated with a more frequent "difficulty" in identifying the radiological landmarks (10.5%) if compared to CC (1.5%). In addition, CC had the advantage of being very fast to perform (in 98%).

Limitations

This study has some limitations. First, this is a retrospective observational study, so that giving the nature of the study design, it was assumed that in all cases using the IC-ECG method, the tip was correctly placed at the CAJ (peak of P wave) and left in that position. Second, the three clinicians who examined the CXRs were specifically and appropriately trained in the interpretation of both CC and SSC; as the SSC is somehow complex to use, its feasibility may be reduced in the hands of untrained operators.

Conclusion

We found that the two criteria for CXR-based tip location do not differ in terms of feasibility and accuracy, but our data suggest that the SSC method was more likely to be associated with difficult identification of the radiological landmarks and prolonged time before defining the location of the tip. Though post-procedural tip location by CXR is infrequently indicated in clinical practice, if required, both criteria (CC and SSC) can be used.

Author contribution

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by MP, AB and GOM. The draft of the manuscript was written by SDA and MP. All authors read and approved the final manuscript.

Declaration of conflicting interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: The authors declare no conflict of interest. Currently A. Bilancia is employee of Becton Dickinson and G. Ortiz Miluy discloses employment with Izasa Medical, but they had no relationship with their companies at the time of planning and developing the study.

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References

1. Petersen J, Delaney JH, Brakstad MT, et al. Silicone venous access devices positioned with their tips high in the superior vena cava are more likely to malfunction. *Am J Surg* 1999; 178: 38–41.
2. Ballard DH, Samra NS, Gifford KM, et al. Distance of the internal central venous catheter tip from the right atrium is positively correlated with central venous thrombosis. *Emerg Radiol* 2016; 23: 269–273.
3. Pittiruti M and Lamperti M. Late cardiac tamponade in adults secondary to tip position in the right atrium: an urban legend? A systematic review of the literature. *J Cardiothorac Vasc Anesth* 2015; 29: 491–495.
4. Pittiruti M, Pelagatti F and Pinelli F. Intracavitary electrocardiography for tip location during central venous catheterization: A narrative review of 70 years of clinical studies. *J Vasc Access* 2021; 22: 778–785.
5. Greca AL, Iacobone E, Elisei D, et al. ECHOTIP: A structured protocol for ultrasound-based tip navigation and tip location during placement of central venous access devices in adult patients. *J Vasc Access*. Epub ahead of print 8 September 2021. DOI: 10.1177/1129729821104432
6. Iacobone E, Elisei D, Gattari D, et al. Transthoracic echocardiography as bedside technique to verify tip location of central venous catheters in patients with atrial arrhythmia. *J Vasc Access* 2020; 21: 861–867.
7. 2021 Infusion Therapy Standards of Practice Updates. *J Infus Nurs* 2021; 44: 189–190.
8. Lamperti M, Biasucci DG, Disma N, et al. European Society of Anaesthesiology guidelines on peri-operative use of ultrasound-guided for vascular access (PERSEUS vascular access). *Eur J Anaesthesiol* 2020; 37: 344–376.

9. Schuster M, Nave H, Piepenbrock S, et al. The carina as a landmark in central venous catheter placement. *Br J Anaesth* 2000; 85: 192–194.
10. Zhang X, Jia D, Ke N, et al. Excellent inter-observer agreement between radiologist and nurse: tracheal carina-based identification of peripherally inserted central catheter tip position. *J Vasc Access* 2018; 19: 28–33.
11. Stonelake PA and Bodenham AR. The carina as a radiological landmark for central venous catheter tip position. *Br J Anaesth* 2006; 96: 335–340.
12. Sweet Spot, http://www.sweetspot-venouscatheter.com (accessed 9 August 2022).
13. Chu KS, Hsu JH, Wang SS, et al. Accurate central venous port-A catheter placement: intravenous electrocardiography and surface landmark techniques compared by using transesophageal echocardiography. *Anesth Analg* 2004; 98: 910–914.
14. Jeon Y, Ryu HG, Yoon SZ, et al. Transesophageal echocardiographic evaluation of ECG-guided central venous catheter placement. *Can J Anaesth* 2006; 53: 978–983.
15. Ender J, Erdoes G, Krohmer E, et al. Transesophageal echocardiography for verification of the position of the electrocardiographically-placed central venous catheter. *J Cardiothorac Vasc Anesth* 2009; 23: 457–461.
16. Pittiruti M, La Greca A and Scoppettuolo G. The electrocardiographic method for positioning the tip of central venous catheters. *J Vasc Access* 2011; 12: 280–291.
17. Collier PE, Blocker SH, Graff DM, et al. Cardiac tamponade from central venous catheters. *Am J Surg* 1998; 176: 212–214.
18. Gravenstein N and Blackshear RH. In vitro evaluation of relative perforating potential of central venous catheters: comparison of materials, selected models, number of lumens, and angles of incidence to simulated membrane. *J Clin Monit* 1991; 7: 1–6.
19. Fletcher SJ and Bodenham AR. Safe placement of central venous catheters: where should the tip of the catheter lie? *Br J Anaesth* 2000; 85: 188–191.
20. Francis KR, Picard DL, Fajardo MA, et al. Avoiding complications and decreasing costs of central venous catheter placement utilizing electrocardiographic guidance. *Surg Gynecol Obstet* 1992; 175: 208–211.
21. Garutti I, Olmedilla L, Pérez-Peña JM, et al. [Intracavitary electrocardiography. A useful method for checking the correct localization of central venous catheters]. *Rev Esp Anestesiol Reanim* 1993; 40: 90–93.
22. Pittiruti M, Scoppettuolo G, La Greca A, et al. The EKG method for positioning the tips of PICCs: results from two preliminary studies. *J Assoc Vasc Access* 2008; 13(4): 179–186.
23. Moureau NL, Dennis GL, Ames E, et al. Electrocardiogram (EKG) guided peripherally inserted central catheter placement and tip position: results of a trial to replace radiological confirmation. *J Assoc Vasc Access* 2010; 15(1): 8–14.
24. Pittiruti M, Bertollo D, Briglia E, et al. The intracavitary ECG method for positioning the tip of central venous catheters: results of an Italian multicenter study. *J Vasc Access* 2012; 13: 357–365.
25. Capozzoli G, Accinelli G, Fabbro L, et al. Intra-cavitary ECG is an effective method for correct positioning the tip of tunneled Groshong catheters. *J Vasc Access* 2012; 13: 393–396.
26. Baldinelli F, Capozzoli G, Pedrazzoli R, et al. Evaluation of the correct position of peripherally inserted central catheters: anatomical landmark vs. Electrocardiographic technique. *J Vasc Access* 2015; 16: 394–398.
27. Calabrese M, Montini L, Arlotta G, et al. A modified intracavitary electrocardiographic method for detecting the location of the tip of central venous catheters in atrial fibrillation patients. *J Vasc Access* 2019; 20: 516–523.
28. Pittiruti M, Hamilton H, Biffi R, et al. ESPEN guidelines on parenteral nutrition: central venous catheters (access, care, diagnosis and therapy of complications). *Clin Nutr* 2009; 28: 365–377.
29. Kim SK, Ahn JH, Lee YK, et al. Accuracy of catheter positioning during left subclavian venous access: a randomized comparison between radiological and topographical landmarks. *J Clin Med* 2022; 11: 3692.