Determination of the optimal length of insertion for central venous catheterization via axillary vein cannulation using preoperative chest X-ray- A prospective feasibility study

Srikanth Naik, Ameya Pappu, Sarathkumar M.S, Rashmi Ramachandran, M.K. Arora[1], Anjan Trikha, Preet M. Singh[2], Rahul Kumar Anand, Chandan J. Das[3], Vimi Rewari

Departments of Anaesthesiology, Pain Medicine and Critical Care and [3]Radiology, All India Institute of Medical Sciences, [1]Department of Anaesthesia, Institute of Liver and Biliary Sciences, New Delhi, India, [2]Department of Anesthesiology, Washington University School of Medicine, St. Louis, USA

Abstract

Background and Aims: Ensuring safe central venous catheter tip placement is important. Multiple techniques are available to estimate the length of catheter insertion for subclavian and internal jugular approaches. However, the methods to determine the length of insertion for the axillary route have not been validated. The purpose of this feasibility study was to evaluate a simple method for the calculation of catheter length to be inserted and assess whether it accurately predicts the correct tip placement.
Material and Methods: A total of 102 patients requiring preoperative central venous cannulation were evaluated, out of which 60 had successful axillary vein (AxV) cannulation. The length of insertion was calculated using the formula: $(2/3^* A + B) + Y$ (A: Clavicular length on chest radiograph [CXR], B: Vertical distance between the sternal head and carina on CXR, Y: Perpendicular distance from the skin to the AxV on ultrasound). A postoperative CXR was used to assess the accurate tip placement (2 cm above the carina to 0.5 cm below it). The primary outcome of the study was the rate of successful placement of the central venous catheter (CVC) in terms of the correct position of the tip of the catheter when the length of the catheter inserted was predicted by the formula described previously.
Results: Optimal placement was observed in 83.33% of the cases. A higher rate of accuracy was seen in the females (P value = 0.03) and shorter patients (P value = 0.01). A Bland–Altman plot depicted a high degree of agreement.
Conclusion: Use of the formula using a CXR and ultrasound allowed P successful placement of the CVC tip at the desired location in 83.33% of the cases.

Keywords: Axillary vein, central venous catheterization, ultrasonography

Introduction

Central venous catheterization is a frequently performed procedure in hospitals worldwide. The misplacement of the catheter tip, however, remains a persistent problem. Safe catheter tip position has been a matter of considerable debate.[1] The ideal position of the catheter is in a large central vein outside the pericardial reflection and parallel to its long axis, such that it does not impinge on the vessel/heart wall.[2] It is imperative that the tip be proximal to the boundaries of the pericardial sac to prevent cardiac tamponade.[3] On the other hand, if the catheters are placed too proximally, there is an

Address for correspondence: Dr. Ameya Pappu,
Department of Anaesthesiology, Pain Medicine and Critical Care, All India Institute of Medical Sciences, New Delhi, India.
E-mail: ameyapappu@gmail.com

Access this article online	
Quick Response Code:	Website: https://journals.lww.com/joacp
	DOI: 10.4103/joacp.joacp_223_21

How to cite this article: Naik S, Pappu A, Sarathkumar MS, Ramachandran R, Arora MK, Trikha A, *et al*. Determination of the optimal length of insertion for central venous catheterization via axillary vein cannulation using preoperative chest X-ray- A prospective feasibility study. J Anaesthesiol Clin Pharmacol 2023;39:215-9.

Submitted: 07-May-2021 **Revised:** 08-Jul-2021
Accepted: 19-Jul-2021 **Published:** 31-May-2023

elevated risk of thrombosis.[4] A correct length to be inserted, thus, needs to be pre-determined before inserting the catheter.

A multitude of techniques is used to estimate the length of insertion to maximize chances of accurate tip placement ranging from simple formulas to right atrial electrocardiography.[5-9] Many of these have been explored and validated for the central venous cannulation via the internal jugular and subclavian vein. Such methods to predetermine the depth of catheter insertion to facilitate the correct tip position via the axillary vein (AxV) have not yet been validated.

The purpose of this study was to evaluate a simple method for the calculation of catheter length to be inserted and assess whether it accurately predicts the correct tip placement.

Material and Methods

After obtaining the Institutional Ethics Committee approval (Reference No. IECPG/366/29.06.2016, RT-25/27.07.2016), this feasibility study was conducted on 60 adult patients requiring the right AxV cannulation for elective surgery in the main operation theater complex at the All India Institute of Medical Sciences, New Delhi between November 2016 and March 2018. All the patients requiring preoperative central venous cannulation were screened for possible inclusion in the study by going through the operative lists 1 day prior to the surgery. The patients screened were included in the study if they were willing to participate in the study and provided written consent thereof. We excluded patients having contraindications to the right AxV cannulation including local site infection, previous cannulation on the same side, and obvious deformity involving the site or presence of arteriovenous fistula on the ipsilateral limb. The patients with the previous surgery of the right upper limb, body mass index >30 kg/m^2, previous surgical interventions at the cannulation site, and coagulopathy were also excluded. All the patients included in the study underwent a preoperative posteroanterior view chest radiography (CXR). The catheter length to be placed via the right AxV was calculated using the method described below. The right clavicular length—defined as the length from the acromioclavicular joint to the sternoclavicular joint, 'A,' was calculated using the scale on the radiograph. The vertical distance between the sternal head of the clavicle and the carina was designated as 'B.' Considering that the usual insertion site is at the junction of the medial 2/3rd and lateral 1/3rd of the clavicle, the calculated length of insertion, 'X,' was obtained by adding 2/3rd of 'A' to 'B' [Figure 1a].

In the operating room, intravenous access was established and standard monitors were attached with the heart rate, blood pressure, and oxygen saturation monitored throughout the duration of anesthesia and surgery. The anesthesia technique was left to the discretion of the attending anesthesiologist. All central lines were inserted after hemodynamic stability was achieved post-induction of anesthesia and intubation of the trachea.

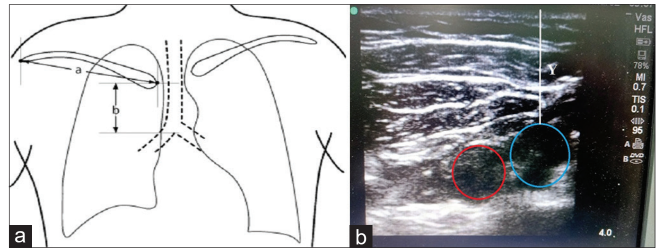

Figure 1: (a) Calculated measurement $x = 2/3a + b$. (b) Skin to AxV distance on ultrasound

Central venous catheter insertion technique via the right AxV

All central venous catheterizations were performed by the anesthesiology faculty/residents having an experience of at least 20 central venous cannulations using ultrasound guidance. The patients were placed in a 15° Trendelenburg position with the arms abducted. A pre-procedural ultrasound exam was performed to confirm AxV patency and rule out any thrombus. The skin overlying the right axillary and internal jugular vein (IJV) areas was prepared using a solution of 2% chlorhexidine. The area of puncture was isolated using surgical drapes with simultaneous access to both the right AxV and right IJV. The vein was imaged using a linear probe with 13-6 MHz frequency (FUJIFILM SonoSite Edge). The transducer surface was coated with a sterile gel and covered with a sterile cover. The right AxV cannulation was performed using a modified Seldinger technique with a BBraun Certofix® Trio 7 Fr triple lumen polyurethane catheter (distal = 16 G, middle = 18 G, proximal = 18 G). The vein was visualized at the junction of medial 2/3rd and lateral 1/3rd of the clavicle in the infraclavicular region. The proceduralist could modify the insertion site to a location providing the best ultrasound view. The transducer was placed perpendicular to the clavicle at this point and the vein and artery were imaged in cross-section in a short-axis view. The distance between the skin to AxV was measured and this distance was designated as 'Y,' which was added to the calculated measurement 'X' [Figure 1b]. The optimal length of the catheter insertion 'L' was calculated as:

Optimal length (L) = Calculated Measurement (X) + Depth of vein from skin (Y)

A 16 G, 6.5 cm introducer needle with a 5 mL syringe attached was advanced under real-time ultrasound guidance using an 'out of plane' approach. Once the intravenous position of the needle was confirmed by aspiration of blood as well as by ultrasonographic confirmation, the guidewire was advanced through the alternate port of the needle. The ipsilateral internal jugular vein was compressed by an assistant during the insertion of the guidewire. No specific maneuvers were used to prevent the catheter entry into the contralateral subclavian vein.

The catheter was fixed as per the optimal length (L), rounded off to the nearest 0.5 cm. Additionally, the number of attempts required to cannulate the vein and complications, if any, were also noted.

Postoperatively, another CXR was done and the distance between the CVC tip and carina was noted (the difference between the optimal length and actual length placed). The catheter tips placed in an area extending between 2 cm above the carina to 0.5 cm below the carina were accepted as optimally placed. The placement within this zone defined successful prediction of the insertion length by the formula.

Statistical analysis

The statistical analysis was carried out using STATA 12.0 (Stata Corp LP college station, Tx77845, USA).

The categorical variables were presented as number (%) and continuous variables as mean ± standard deviation (SD).

The primary outcome of the study was the rate of successful placement of CVC in terms of the correct position of the tip of the catheter when the length of the catheter inserted was predicted by the formula described previously.

To derive the relation between patient parameters such as gender, weight, BMI, gender, and the optimal catheter length, the *t*-test with independent variables was used. The study was conceived as a feasibility study and a sample size of 60 patients was decided upon in consultation with the department of biostatistics. This was based on the average number of central venous cannulations being performed in the operation theaters and the duration of the residency program as this study was conceived as a post-graduate thesis. We continued recruitment in the study till 60 successful catheterizations via the right AxV could be performed.

Results

One hundred and two patients were screened for inclusion, out of which 72 patients satisfied the inclusion criteria. A successful AxV cannulation was defined as the entry of the central venous catheter into the venous system via the AxV. The right AxV cannulation was unsuccessful in seven patients and alternate routes were used for central venous access. Five catheters were found to be malpositioned in the postoperative CXR, entering either the ipsilateral IJV or coiling back into the AxV. The catheter entry into the contralateral subclavian vein was not noted. The above 12 patients were excluded from the final analysis. The AxV was successfully cannulated in 60 patients (83.33% success rate) with 7 patients requiring a second attempt. The flow of the patients recruited in the study and the outcome of the successful/unsuccessful placement of the central venous catheter is given in Figure 2.

The patient characteristics are presented in Table 1. The measurements and calculations derived from the preoperative CXR are shown in Table 2. This includes the measured clavicular length (A) and the vertical distance on the CXR between the sternal head of the clavicle and the carina (B). The skin to the vein distance measured using ultrasound (Y) and the calculated length of the insertion (X + Y) are depicted in Table 3.

The optimal placement was seen in 50 out of the 60 patients (83.33%), defined as the placement of the tip of the catheter in a zone lying between 2 cm above the carina to 0.5 cm below it.

For analysis, the patients were categorized into two groups: Group A: Correctly placed catheter tips and Group B: Incorrectly placed catheter tips. A higher success rate was noted in the female patients (93.3 vs. 73.3%, *P* value = 0.03). The catheter tip placement using the formula was also more accurate in shorter patients. The mean height of the patients in whom the catheter was successfully placed was lower (160.4 vs. 167.2 cm, *P* value = 0.01). No statistically significant difference was noted with regards to age, weight,

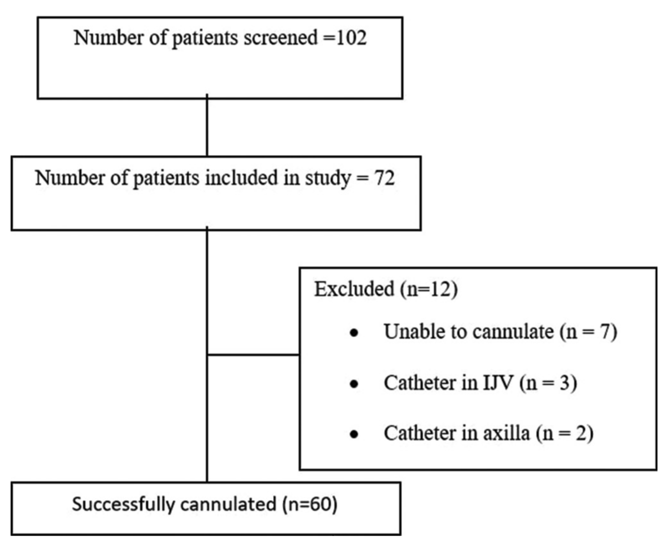

Figure 2: Flow of patients

and body mass index in terms of successful placement, though the patients with non-optimal placement weighed more (the difference in the mean was 5.52 kg) as compared to the patients with the optimal position, P value = 0.07. The magnitude of error (cm) in all the patients with suboptimal catheter tip placement is shown in Table 4.

A Bland–Altman plot [Figure 3] was used to graphically represent the calculated measurement and the length of the catheter fixed. In this graph, the average of the calculated and catheter fixed was plotted against the X-axis and the difference between both the measurements were plotted against the Y-axis. Only 10% of the values (6 values) were outside the limits of agreement. A total of 45 values lie on the line of equality depicting a high degree of agreement.

Table 1: Patient demographic parameters

Parameter	Mean	SD	Minimum	Maximum
Age (years)	40.3	14.1	18	70
Height (cm)	161.5	8.0	148	178
Weight (kg)	55.5	8.8	39	78
BMI (kg/m^2)	21.2	2.57	16.6	27.9

SD: standard deviation

Table 2: Preoperative calculation and measurements

Parameter	Mean	SD	Minimum	Maximum
Clavicular length (A) (cm)	14.6	1.42	15.0	18.5
2/3rd of 'A' (cm)	9.74	0.94	7	12.3
Vertical distance on CXR (B) (cm)	5.29	1.08	5.25	8
Calculated measurement (X) (cm)	15.03	1.62	12	19.6

cm: centimeters, SD: standard deviation

Table 3: Calculated catheter measurements

Parameters	Mean	SD	Minimum	Maximum
Calculated measurement [X] (cm)	15.03	1.62	12	19.6
Skin to vein distance [Y] (cm)	1.72	0.49	1	2.9
Calculated measurement [X+Y] (cm)	16.69	1.59		
Catheter fixed at [L] (cm)	16.72	2.17		

cm: centimeters; SD: standard deviation

Table 4: The difference between the calculated and actual measurements in the patients with catheter in non-optimal position

S. No.	Calculated Measurement (cm)	Catheter Fixed (cm)	Δt (cm)
P 1	18.0	18.0	-3.0
P 6	17.4	17.5	+2.5
P 9	17.2	17.0	-3.0
P 10	19.3	19.0	-1.5
P 15	15.7	16.0	-2.5
P 16	20.6	20.0	+2.5
P 17	22.1	20.0	+5.0
P 18	16.8	17.0	-2.0
P 24	17.6	18.0	-1.0
P 41	17.4	17.5	-1.0

cm: centimeters

Discussion

The placement of the tip of the CVC in the extra-pericardial part of the superior vena cava is usually targeted to prevent mechanical complications by the catheter tip which include arrhythmias and tamponade.[1,2] While the carina is a useful surrogate marker to identify the correct placement on a CXR, even this does not accurately rule out tip placement below the pericardial reflection.[10]

The axillary approach to the central venous access is being increasingly adopted, especially with the availability of real-time ultrasound guidance. Besides increased patient comfort, it also keeps the catheter away from the oropharyngeal/tracheostomy secretions and may also be used as an alternate site when the traditional sites are inaccessible. In addition, it eliminates the risk of a non-compressible arterial bleed and damage to the lung as it lies outside the ribcage.[11] However, the question of the length of CVC insertion remains to be solved.

A multitude of approaches has been evaluated to solve this problem when using 'traditional' sites of CVC placement. They include simplistic predefined lengths based on gender, the Peres' formula based on height, and calculations derived from CXR measurements.[6,8,12,13] In addition, modalities like electrocardiograms and transesophageal echocardiography have been evaluated to confirm proper placement.[6,9]

Approaches using echocardiography and electrocardiography are equipment- and operator-dependent with a considerable learning curve. Furthermore, the postero-anterior CXR remains the

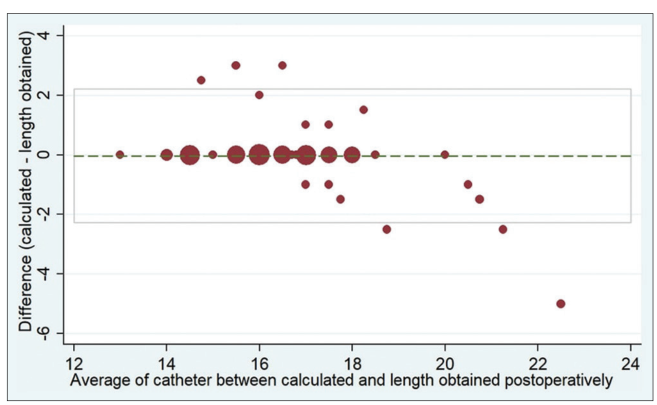

Figure 3: Bland–Altman plot

mainstay for the confirmation of accurate central venous catheter placement. The formula-based approaches, while extensively evaluated for the IJV and subclavian routes have not yet been evaluated for the AxV approach. Our approach to calculate the length of insertion used distances that are simple to measure and do not require additional equipment or technical know-how.

In our feasibility study, our calculated length of insertion was successful in ensuring the correct catheter tip placement in the target zone in 50 of 60 patients (83.33%). The calculation of the length of insertion using the scale on the CXR allowed us to accurately estimate the length needed. The catheters with mispositioned tips were excluded from the final analysis to prevent skewing of the result. Ryu *et al*.[7] used a similar technique for calculating the depth of insertion when using the right internal jugular and right subclavian routes. They used the length between the needle insertion point and the clavicular notch added to the length between the clavicular notch and the carina measured using a CXR. They concluded that the technique was reliable at ensuring an accurate placement of the CVC tip near the carina.

The ultrasound is invaluable in locating the deeply placed AxV. The visualization away from the clavicle allows the use of both long and short-axis views. We first located the AxV at the junction of the medial 2/3rd and lateral 1/3rd of the clavicle. We used this medial 2/3rd distance to calculate the length of insertion. However, we allowed the proceduralist to perform venipuncture where he/she was able to obtain the best image to maximize comfort and prevent undue difficulty in cannulation. This may have impacted our results. We also used the perpendicular distance from the skin to the wall of the AxV on the ultrasound screen and added it to the final length. As the catheter traveled obliquely, this distance was likely underestimated. However, as this distance is quite small (1.72 ± 0.49), it is unlikely to have had a major impact on our results.

The formula we have used to calculate the length of insertion is based on the distances calculated using a posteroanterior CXR. While its simplicity enables easy calculation, the method suffers a disadvantage due to the occurrence of parallax, which may contribute to the error seen in some cases.[14] The aforementioned shortcoming notwithstanding, a CXR-based formula is able to accurately predict the length of insertion, which is consistent with the results noted in the other studies for alternate sites of insertion.[15,16] Also, a CXR is an investigation that most physicians, regardless of the specialty are comfortable with, and does not require specialized equipment or additional training to interpret—which increases the feasibility of our technique in most healthcare settings. Another disadvantage of our method is the requirement of a pre-procedural and post-procedural CXR—which may limit its use in emergent situations.

Conclusion

We conclude that the use of the formula using a CXR and ultrasound allows successful placement of the CVC tip at the desired location in 83.33% of cases.

Financial support and sponsorship

Institutional.

Conflicts of interest

There are no conflicts of interest.

References

1. Fletcher SJ, Bodenham AR. Editorial II. Safe placement of central venous catheters: Where should the tip of the catheter lie? Br J Anaesth 2000;85:188-91.
2. Gibson F, Bodenham A. Misplaced central venous catheters: Applied anatomy and practical management. Br J Anaesth 2013;110:333-46.
3. Collier PE, Goodman GB. Cardiac tamponade caused by central venous catheter perforation of the heart: A preventable complication. J Am Coli Surg 1995;181:459-63.
4. Timsit JF, Farkas JC, Boyer JM, Martin JB, Misset B, Renaud B, *et al*. Central vein catheter-related thrombosis in intensive care patients: Incidence, risk factors, and relationship with catheter-related sepsis. Chest 1998;114:207-13.
5. Schuster M, Nave H, Piepenbrock S, Pabst R, Panning B. The carina as a landmark in central venous catheter placement. Br J Anaesth 2000;85:192-4.
6. Sharma D, Singh VP, Malhotra MK, Gupta K. Optimum depth of central venous catheter-Comparison by pere's, landmark and endocavitory (atrial) ECG technique: A prospective study. Anesth Essays Res 2013;7:216-20.
7. Ryu H, Bahk J, Kim J, Lee J. Bedside prediction of the central venous catheter insertion depth. Br J Anaesth 2007;98:225-227.
8. Czepizak C, O'Callaghan J, Venus B. Evaluation of formulas for optimal positioning of central venous catheters. Chest 1995;107:1662-4.
9. Jeon Y, Ryu H, Yoon S, Kim J, Bahk J. Transesophageal echocardiographic evaluation of ECG-guided central venous catheter placement. Can J Anaesth 2006;53:978-83.
10. Dulce M, Steffen I, Preuss A, Renz D, Hamm B, Elgeti T. Topographic analysis and evaluation of anatomical landmarks for placement of central venous catheters based on conventional chest X-ray and computed tomography. Br J Anaesth 2014;112:265-71.
11. Bodenham A, Lamperti M. Ultrasound guided infraclavicular axillary vein cannulation, coming of age. Br J Anaesth 2016;116:325-7.
12. Jayaraman J, Shah V. Bedside prediction of the central venous catheter insertion depth – Comparison of different techniques. J Anaesthesiol Clin Pharmacol 2019;35:197-201.
13. Peres PW. Positioning central venous catheters – A prospective survey. Anaesth Intensive Care 1990;18:536-9.
14. Venugopal AN, Koshy RC, Koshy SM. Role of chest X-ray in citing central venous catheter tip: A few case reports with a brief review of the literature. J Anaesthesiol Clin Pharmacol 2013;29:397-400.
15. Chaskar V, Karnik PP, Dave NM, Garasia M. Comparative study of three methods for depth of central venous catheter placement in children: An observational pilot study. Turk J Anaesthesiol Reanim 2018;46:116-20.
16. Lee J, Bahk J, Ryu H, Jung C, Jeon Y. Comparison of the bedside central venous catheter placement techniques: Landmark vs electrocardiogram guidance. Br J Anaesth 2009;102:662-6.