RESEARCH PAPER

Appropriate Length and Position of the Central Venous Catheter Insertion via Right Internal Jugular Vein in Children

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Design: Observational study.

Setting: Tertiary University Hospital.

Participants/patients: Patients, aged 6 days to 19 years, who underwent contrast enhancement computerized tomography imaging of the thorax (CT-thorax).

Main outcome measures: We measured three lengths consisting of length A in axial plane at the level of the lower border of the 6th C-spine from the skin to RIJV at its mid lumen, length B and C in sagittal plane from the RIJV at the level of the lower of the 6th C-spine to the superior vena cava (SVC) at carina and from carina to SVC-right atrium junction, respectively. Lengths A plus B represented the length of CVC where the tip was expected in the SVC at carina (CVC_{carina}). Lengths A plus B and C represented the length of CVC when the tip was expected in the SVC at SVC-right atrium junction (CVC_{SVC-RA}).

Results: One hundred and sixty-five cases with mean age of 8.1 ± 4.7 years were reviewed. The CVC_{SVC-RA} and CVC carina were significantly correlated with age and body surface area (BSA). Using multiple regression analysis, CVC_{SVC-RA} (cm) was equal to 6.4 + 2.8[BSA (m^2)] + 0.022[age (month)] and CVCcasina (cm) equal to 4.9 +2.7[BSA (m^2)] +0.013[age (month)] (Adjusted R-squared 0.7275, 0.7140).

Conclusions: We recommended the appropriate CVC length via RIJV approach should be between these two calculated lengths and the CVC length in each age according to the BSA.

Keywords: *Central venous catheter, Children, Right internal jugular vein.*

Central venous catheters (CVC) are commonly indicated in patients in pediatric intensive care units for medications, volume replacement, parenteral nutrition, obtaining blood sampling, hemodialysis vascular access, or central venous pressure (CVP) monitoring. Regardless of the indications, the position of the CVC tip is important to avoid potential serious complications, including pneumothorax, hemothorax, pericardial effusion leading to cardiac tamponade, cardiac perforation, or arrhythmias due to irritation to the endocardium [1,2]. Some guidelines recommended that the CVC tip should be positioned in the superior vena cava (SVC) above the level of the pericardial reflection to be certain that it is outside the pericardium [3-6]. Studies proposed that the carina was a reliable and simple radiographic marker for the position of the CVC tip, based on the examination of either embalmed or fresh cadavers [4-8]. Some recommended that the CVC tip should be placed just above the superior vena cava and right atrium (SVC-RA) junction to avoid malposition and CVC tip perforation [9-11]. The length of CVC insertion from skin to SVC at the level of the carina or to SVC at SVC-RA junction, using right internal jugular vein (RIJV) approach may be varied according to age, bodyweight, and height, especially in children. The aims of this study were to evaluate the length from the skin at the puncture site of RIJV to the SVC at the level of the carina and the length from the skin at the puncture site of RIJV to the SVC at the level of SVC-RA junction. We also devised a formula for ideal catheter insertion length from RIJV approach in children.

Accompanying Editorial: Pages 734-5

METHODS

Contrast enhancement computerized tomography imagings of the thorax (CT-thorax) performed in patients aged 6 days to 19 years between July 2008 and July 2011 were retrospectively reviewed. Patients with congenital heart diseases, cardiovascular abnormalities, neck or mediastinal masses, SVC obstruction, abnormality of cervical spine, and gross deformity of chest wall were excluded. In addition, those studies with inadequate quality, including poor contrast opacification of the RIJV, and studies which did not cover the lower border of the 6th cervical spine level representing cricoid cartilage, the same level of skin using for landmark of RIJV approach were also excluded.

Demographic data including age, sex, weight, height, and BSA were obtained. All CT-thorax cases were loaded into the Picture Archiving and Communications System (PACS), using a DICOM Conformance (Synapse version 3.2.0, FUJIFILM Medical Systems USA's Synapse PACS System, USA). This study was approved by the Institute Ethics Committee.

Measurements

Measurement of three lengths in CT-thorax included length A, measured in axial plane at the level of the lower border of the 6^{th} C-spine from the skin to RIJV at its mid lumenl ength B, measured in sagittal plane from RIJV at the level of the lower border of the 6^{th} C-spine to SVC at the level of carina; and length C, measured in the sagittal plane from SVC at the level of carina to SVC at the level of SVC-RA junction. Lengths A plus B represented the length of the CVC insertion when expected the CVC tip in SVC at the level of carina (CVC_{carina}). Lengths A plus B and C represented the length of the CVC insertion when expected the CVC tip in SVC at the level of SVC-RA junction (CVC_{SVC-RA}). All measurements were performed in mediastinal window with the window level ranges 40-80 HU, window width ranges 300-400 HU and magnified to 250-300%. Inter-observer agreement for first 10% of cases was measured by experienced cardiovascular radiologist, radiology resident, and pediatric resident. The remaining cases were reviewed for inter-observer agreement by radiology and pediatric residents. Twenty cases (12%) were repeatedly measured by the pediatric residents blinded to the first measurement for intra-observer agreement.

Statistical analysis: Continuous variables including age, height, weight, body surface area (BSA), and distances were described as mean and standard deviation (SD). Categorical variables were described as percentage. All statistical analyses were performed using retrospective descriptive study and linear regression analysis. STATA version 10 (STATA Corp, College Drive, Texas, USA) statistical software was used to analyze data. Paired T-test and Bland-Altman method were used for assessing agreement between inter-observer and intra-observer measurements. A P value <0.05 was considered to be statistically significant.

Using sample size estimation for correlation coefficients, if we expected to have power (1-beta) of 0.99, probability of type I error (alpha) of 0.05, and correlation coefficient rho of 0.5, we needed the sample size of 55 in the validation study.

RESULTS

Of 250 cases, 85 cases were excluded whereas 165 cases with mean age of 8.1 ± 4.70 years, height of 121.4 ± 29.0 cm, weight of 26.7 ± 16.0, and BSA of 0.9±0.4 m^2 were included in this study.

The length of CVC_{SVC-RA} varied in each age group. This length significantly correlated with patients' height (r = 0.87, P<0.001), weight (r = 0.74, P<0.001), and BSA (r = 0.83, P <0.001). Using multiple regression analysis, after adjusting for other variables, patients' age and BSA were significantly correlated with length of CVC. The formula that predicted this length of the CVC insertion was calculated as the following.

Length of CVC_{SVC-RA} (cm) = 6.4 + 2.8[BSA (m^2)] + 0.022[age (month)]; (Adjusted R^2=0.7275)

The length of CVC_{Carina} varied in each age group. This length significantly correlated with patients' height(r = 0.85, P<0.001), weight (r = 0.76, <0.001), and BSA (r = 0.83, P<0.001). Using multiple regression analysis, after adjusting for other variables, patients' age and BSA were significantly correlated with length of CVC. The formula that predicted this length of the CVC insertion was calculated as the following:

Length of CVC_{carina} (cm) = 4.9 + 2.7[BSA (m^2)] + 0.013[age (month)]; (Adjusted R^2 = 0.7140)

There were no statistical significant differences of inter-observer agreement for first 10% of cases (n=15) in measuring these lengths and for the remaining cases (n = 150). There were no statistical significant differences of

TABLE I LENGTH (IN CM) OF CENTRAL VENOUS CATHETER INSERTION IN THE SUPERIOR VENA CAVA (SVC) AT VARIOUS SITES AND LENGTH OF SVC AT THE LEVEL OF CARINA TO SVC AND RIGHT ATRIUM JUNCTION (N=165).

Age (y)	*No. (%)*	CVC_{carina}	CVC_{SVC-RA}	*Length* $_{carina-junction}$
6 d-1	8 (4.8)	5.6 ± 1.2	6.9 ± 1.0	1.3 ± 0.4
>1-3	23 (14.0)	6.8 ± 0.9	8.7 ± 1.5	1.9 ± 0.7
>3 -6	31 (18.8)	7.4 ± 0.8	9.6 ± 1.1	2.1 ± 0.7
>6-9	29 (17.6)	8.1 ± 1.5	10.5 ± 1.6	2.4 ± 0.6
>9-11	21 (12. 7)	8.9 ± 0.7	11.8 ± 0.9	2.9 ± 0.7
>11-13	22 (13.3)	9.8 ± 1.2	12.9 ± 1.9	3.2 ± 1.0
≥13	31 (18.8)	11.4 ± 1.3	14.6 ± 1.8	3.2 ± 0.9

CVC_{SVC-RA} = Length of the central venous catheter (CVC) insertion when expected the tip of the CVC in the superior vena cava (SVC) at the level of SVC and right atrium junction; CVC_{carina}= Length of the central venous catheter (CVC) insertion when expected the tip of the CVC in the superior vena cava (SVC) at the level of carina; $Length_{carina-junction}$ = Length from superior vena cava (SVC) at the level of carina to SVC at the level of SVC and right atrium junction.

intra-observer for the lengths of CVC_{carina} and CVC_{SVC-RA}. Bland-Altman plot demonstrated acceptable agreement in measurement of the lengths of CVC_{carina} and CVC_{SVC-RA} by two observers with bias (mean difference) and precision (±1SD) of these two lengths by two independent observers equal to 0.02 ± 1.21 and -0.05 ± 1.59, respectively. Most of the differences between two observers' measurements were in the limit of agreement lines (±1.96 SD).

DISCUSSION

In this study, length of CVC_{carina} and length of CVC_{SVC-RA} were accurately measured by CT-thorax imaging. These two lengths could be calculated from our recommended formula. Although the superior part of the pericardial reflection which transverses SVC could not be identified, neither on plain chest *X*-ray nor CT-thorax imaging, but it is approximately 0.8 cm below the SVC at the level of the carina in adult population [4]. Study from pediatric populations demonstrated that the carina was 0.5 ± 0.04 cm above the pericardial reflection as it transverses the SVC [5]. However, study from neonates demonstrated that the pericardial reflection may transverse the SVC at a distance of 5 mm below the carina or even 4 mm above the carina [12]. Nevertheless, the carina is still an easily sighted and clear radiological landmark in children similar to that in adults to confirm that the CVC tip is outside the pericardial reflection [4, 5]. Some authors recommended the CVC tip to be in the lower SVC regardless of the concern that the CVC tip might be below the pericardial reflection to make the CVC tip be more parallel to the vessel wall [13]. If the CVC tip was positioned more in the proximal SVC, it had a higher rate of malposition or migration to other vessels consisting of azygos, internal mammary, left innominate, subclavian, and internal jugular veins. This position could not represent a proper central vein and carried risks of thrombus, infection, and extravasation [14]. Positioning the CVC tip in the distal SVC at the level below the carina, but above the SVC-RA junction could reduce these risks and also extend the time use of the CVC [14-16]. Our data demonstrated that the length between SVC at the level of the carina and SVC at the SVC-RA junction also increased according to increased BSA and age. Therefore, we recommended that the CVC tip to be positioned more toward the SVC at the level of carina in younger age and more toward the SVC-RA junction in older age.

On comparing the length of CVC insertion recommended by Andropoulos, *et al*. [10] and our recommendation according to BSA and age, our recommendation was less than the previous study, especially younger age. This was because they measured the length when the CVC tip was in the SVC at the level of SVC-RA junction [10]. For simplification and recall purposes, we recommended CVC length starting at the age of 1 year to be equal to 6.5 cm, then, increasing by 0.5 cm every 1 year of age up to the age of 12 years (12.0 cm) (***Table* II**). Importantly, the recommended lengths of CVC in each age group are based on the assumption that the weight and height are normal (50^{th} percentile). Therefore, it is not recommended for use if a child is malnourished or obese.

This study had some limitations. Firstly, we assumed the puncture site at the level of the lower body of the 6^{th} C-spine to be the surface anatomical landmark. This may not hold true in all cases, since the puncture site may be varied. The angle of measure of this length was perpendicular, whereas in the real situation, approximately 15-30 degrees are to be expected. As a result, this assumption may cause shorter length from this

TABLE II SUGGESTED LENGTH FOR CENTRAL VENOUS CATHETER INSERTION BY RIGHT INTERNAL JUGULAR VEIN APPROACH IN EACH AGE (Y)

Age (y)	*Wt P50th*	*Ht P50th*	*CVC carina (cm)*	*CVC SVC-RA (cm)*	*Recommended length (cm)*	*Andropoulos's Formula(cm)*
1	10	75	6.3	8.0	6.5	6.5
2	12	89	6.7	8.4	7.0	7.9
3	14	95	7.0	8.9	7.5	8.5
4	16	100	7.3	9.3	8.0	9.0
5	18	107	7.6	9.7	8.5	8.7
6	20	115	7.9	10.1	9.0	9.5
7	23	122	8.3	10.6	9.5	10.2
8	26	128	8.6	11.1	10.0	10.8
9	29	133	8.9	11.5	10.5	11.3
10	33	138	9.2	11.9	11.0	11.8
11	37	144	9.9	12.7	11.5	12.4
12	42	151	10.4	13.3	12.0	13.1
13	46	157	10.8	13.8	13.0	13.7
14	49	160	11.1	14.3	14.0	14.0
15	52	162	11.4	14.7	14.0	14.2
16	54	163	11.6	15.0	14.0	14.3
17	55	163	11.8	15.3	14.0	14.3

CVC_{SVC-RA} = Length of the central venous catheter (CVC) insertion when expected the tip of the CVC in the superior vena cava (SVC) at the level of SVC and right atrium junction; # CVC_{carina} = Length of the central venous catheter (CVC) insertion when expected the tip of the CVC in the superior vena cava (SVC) at the level of carina; Ht = height, Wt = weight, $P50^{th}$ = fifty percentile; Andropoulos's formula (cm): (Height/10) –1 (Ht ≤100 cm), (Height/10) –2 (Ht >100 cm) [10].

WHAT IS ALREADY KNOWN?

- In children, the ideal position and recommended length of central venous catheter via the right internal jugular vein remains controversial.

WHAT THIS STUDY ADDS?

- We suggest the appropriate length of the central venous catheter via the right internal jugular vein in each age group from 1 year to 17 years.

measurement when compared to the real situation. However, this length (length A) was quite short when compared to the others (lengths B and C), thereby limiting the degree of error in itself. Secondly, the number of patients in each age group was not high and may not represent all variables of weight, height, and BSA. Thirdly, none of these had the CVC in the imaging. However, this might not be so important, since we just wanted to know the length if we expected the CVC tip to be in the SVC at the level of carina and SVC-RA junction. The strength of this study was that all lengths were accurately measured in CT-thorax which satisfactorily demonstrated the SVC at the level of the carina and SVC-RA junction.

In conclusion, the length of CVC insertion by RIJV approach in pediatric populations could be calculated from BSA and age. This study has put forward the length for each age group in year. Nevertheless, validation in clinical practice is warranted to confirm our suggestion.

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