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# Simple formulas to determine optimal subclavian central venous catheter tip placement in infants and children

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ABSTRACT

*Background/Purpose:* Optimal central venous catheter (CVC) tip location is necessary to decrease the incidence of complications related to their use. We sought to create a practical method to reliably predict the length of catheter to insert into the subclavian vein during CVC placement in children.
*Methods:* We performed a retrospective review of 727 chest radiographs of children who underwent either left or right subclavian CVC placement. We measured the distance from the subclavian entry site to the to the right atrium/superior vena cava (RA/SVC) junction, following the catheter's course. We analyzed the relationship between that length and patient characteristics, including: age, gender, height, weight and body surface area (BSA).
*Results:* Two derived formulas using the BSA best correlated with the optimal subclavian CVC length. For the left subclavian vein approach, the optimal catheter length was 6.5*BSA + 7 cm, and for the right subclavian vein approach it was 5*BSA + 6. The use of these formulas correlated in CVC tip placement in a clinically proper location in 92.9% of smaller children and in 95.7% of larger children.
*Conclusion:* The optimal length of central venous catheter to insert into the subclavian vein may be determined through the use of a simple formula using the BSA.



Central venous access in children is obtained for a variety of reasons including, but not limited to: infusion of parenteral nutrition, chemotherapy, and vasoactive medications, hemodynamic monitoring, and to ensure vascular access. To obtain central venous access, especially for long term need, the subclavian vein is commonly used. With the standard Seldinger technique [1], once the subclavian vein has been accessed with a guide wire, the length of catheter tubing to insert into the vein in order to position the catheter tip at the junction of the right atrium and superior vena cava (RA/SVC junction) must be determined. Positioning the catheter tip at the RA/SVC junction decreases the rate of complications such as superior vena cava thrombosis, dysrhythmias and the rare cases of great vein and cardiac puncture resulting in tamponade [2,3]. Additionally, the intra-operative insertion of an incorrect length of catheter may lead to removal and replacement or revision of the catheter, increasing the possibility of intra-operative or postoperative complications, prolonging the operative time, and increasing equipment expenses. The technique used to determine the proper catheter length must be simple to use and easy to remember.

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## 1. Methods

We performed a retrospective review of 727 consecutive children, who underwent central venous catheter placement, by either the left (514) or right (213) subclavian vein approach, between January 1, 2005 and June 6, 2008, using a departmental billing database. Fourteen different pediatric general surgeons, all experienced in subclavian central venous line placement, placed approximately 50 catheters each. Given the retrospective nature of this study, it was not possible to determine how many times the line had to be repositioned or replaced in the operating room. In all cases, central venous access was gained in the right or left subclavian vein using an infraclavicular approach. The subclavian vein was accessed percutaneously using a finder needle and then dilated over a guidewire using the Seldinger technique. There was no attempt at standardization of the procedure and the appropriate length of catheter was chosen on an individual basis by each surgeon. Each patient had an upright, anterior-posterior chest radiograph taken immediately following the procedure in the post-anesthesia care unit.

Patient demographics including age, gender, height and weight were collected. Body surface area (BSA) was determined and displayed automatically in the electronic medical record using the Mosteller method [4]:

$$\mathrm{BSA}\left(\mathrm{m}^2\right) = \frac{\sqrt{[\mathrm{Height\ (cm)} \times \mathrm{Weight\ (kg)}]}}{60}$$

To determine the proper CVC length, we retrospectively reviewed the post-procedure chest radiographs. Using the free-hand ruler function on an electronic film viewing system (Synapse Fujifilm, Tokyo, Japan), we measured the length of catheter, following the course of the catheter, from the subclavian vein entry site, determined by the location of the change in direction of the catheter tubing from superiorly to transversely, to the RA/SVC junction (determined by a rounded broadening of the right mediastinal margin). To obtain this measurement we followed the course of the catheter tubing, but it was independent of the location of the actual tip of the catheter. In order to take into account variations in the location of the RA/SVC junction based upon the radiographic technique, the radiographic measurement was adjusted for the degree of inspiration on the film according to the formula: adjusted length (cm) = measured length (cm) + (9 minus the rib number noted at the top of right diaphragm). For example, if the distance from the subclavian vein entry site to the RA/SVC junction was measured as 11 cm and the apex of the right diaphragm was at the 7$^{th}$ rib, the adjusted length would be 11 + (9-7) = 11 + 2 = 13 cm.

In order to determine the range of clinically acceptable distance away from the RA/SVC junction that would be considered proper CVC tip placement, we reviewed 200 randomly chosen radiographs blinded to the patients' BSA and optimal line length. The most superior position above and the most inferior position below the RA/SVC junction on the radiograph that would be considered clinically acceptable CVC tip placement were determined. This range was defined anatomically as lying within the mid-superior vena cava to the upper right atrium. The distance between these two points was measured using the ruler function on an electronic film viewing system (Synapse Fujifilm, Tokyo, Japan). The measured length was then divided by 2, resulting in the maximally acceptable distance away from the RA/SVC junction for CVC tip placement. These values (i.e. maximally acceptable distances) were then evaluated across the range of BSA's. The percentage of patients whose CVC tip placement would have been within an acceptable distance from the RA/SVC junction through the use of the derived predictive formulas was determined for smaller children (BSA of less than 0.50- approximately less than 10 kg in weight) and for larger children (BSA > 0.50).

### 1.1. Statistical analysis

The adjusted optimal CVC length was then analyzed to determine the best fitting relationship by considering gender, age, height, weight, and BSA as separate predictor variables. Several linear and nonlinear regression models were explored using $R^2$ as the criterion for best fit. Multivariate analysis was also performed to assess whether there were gender differences and to identify if a combination of predictor variables improved estimation of true catheter length. The absolute difference between observed and predicted length and average percent error were used to summarize the precision of the prediction model. For predicted CVC length, a 95% prediction interval was constructed to provide a range of measurements around the optimal length for both left and right sides. Statistical analysis was performed using the SPSS software package (version 16.0, SPSS Inc., Chicago, IL). Two-tailed values of $P < .05$ were used to indicate statistical significance. This study was approved by the Boston Children's Hospital Committee for Clinical Investigation (IRB) ID number: M07-07-0284.

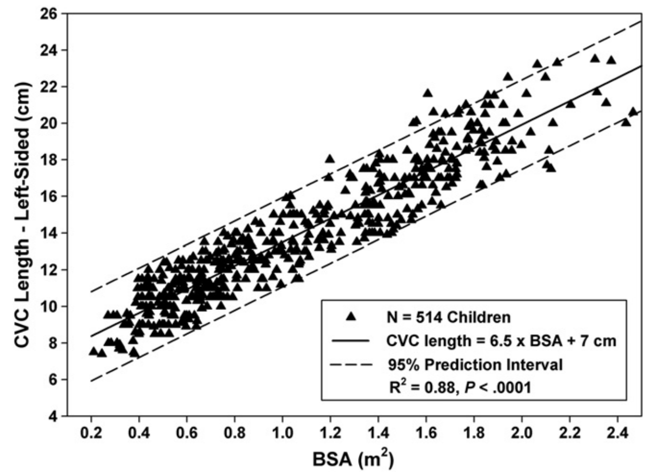


**Fig. 1.** The distance from the left subclavian vein central venous catheter insertion site to the right atrial, superior vena caval junction in 514 children graphed by body surface area. CVC = central venous catheter, BSA = body surface area, m2 = meter squared, cm = centimeter.

## 2. Results

Our study population ranged from 0.21 to 21.9 years of age with a mean age of 8.7 ± 6 years (Table 1). Weight ranged from 3.2 to 126.9 kilograms with a mean of 33.6 ± 23.7 kg, height from 37 to 194 cm with a mean of 124.1 ± 36.1 and BSA from 0.21 to 2.46 $m^2$ with a mean value of 1.05 ± 0.51 $m^2$. There were 397 boys and 330 girls, 514 of whom underwent left subclavian CVC insertion and 213 right subclavian CVC insertion. There were no significant differences in optimal CVC length identified between males and females (p > .20).

BSA was a highly significant predictor of optimal CVC length for both left and right-sided catheters (P < 0.001) using linear regression (R2 = 0.89, R2 = 0.88, Figs. 1 and 2). As expected, multivariate analysis revealed that optimal CVC lengths were significantly longer for left-sided catheters than right ($P < .0001$). Several nonlinear models including quadratic, cubic, and power functions were compared and resulting $R^2$ values that were not higher than a simple linear equation. Gender, weight, and height provided no significant improvement in the accuracy of estimating the actual CVC length (all $P > .05$). The linear prediction equations for determining the optimal CVC length are:

$$\text{Optimal length of left subclavian CVC} = (6.5 \times \text{BSA}) + 7\text{cm}$$
$$\text{Optimal length of right subclavian CVC} = (5 \times \text{BSA}) + 6\text{cm}$$

The data are plotted in a scatter diagram for left and right groups as shown (Figs. 1 and 2).

Using 200 randomly selected study radiographs, we determined the range of clinically acceptable distance from the RA/SVC junction for the CVC tip. This distance varied from 1.1 to 4.3 cm and correlated directly with the BSA (ρ = 0.81), which varied from 0.21 to 2.44 (Fig. 3).

Using these derived prediction formulas to determine optimal CVC length resulted in CVC tip placement within the clinically acceptable maximal distance away from the RA/SVC junction in 92.9% of children with a BSA less than 0.5 and in 95.7% of children with a BSA greater than 0.5.

**Table 1**
Study patient characteristics of 727 patients who underwent central venous catheter placement by either the left or right subclavian vein approach.

| | Age (years) | Weight (kg) | Height (cm) | BSA (m2) |
|---|---|---|---|---|
| Range | 0.21 to 21.9 | 3.2 to 126.9 | 37 to 194 | 0.21 to 2.46 |
| Mean | 8.7 | 33.6 | 124.1 | 1.05 |
| STD | 6.0 | 23.7 | 36.1 | 0.51 |

kg = kilograms, cm = centimeters, BSA = Body Surface Area, m2 = meter squared, STD = standard deviation.