

Departments of Anesthesiology, Cardiothoracic Surgery and Radiology, Seoul National University Hospital, Seoul National University College of Medicine, Seoul, Korea

SUMMARY
To reduce the possibility of cardiac tamponade, a rare but lethal complication of central venous catheters, the tip of the central venous catheter should be located above the cephalic limit of the pericardial reflection, not only above the superior vena cava-right atrium junction. This study was performed to measure the superior vena cava lengths above and below the pericardial reflection in cardiac surgical patients. Cardiac surgical patients (n=61; 27 male), whose age [mean±SD (range)] was 47±15 (15-75) years, were studied. The intrapericardial and extrapericardial lengths, and the length of the mediastinal part were measured separately. The whole vertical lengths of the superior vena cava on either side were calculated respectively by adding the intra- and extrapericardial and mediastinal duplication lengths. The lateral extrapericardial was 29.1±6.5 (Mean±SD) (9-49) mm (range), and lateral extrapericardial length was 32.6±6.9 (20-53) mm. The medial extrapericardial length was 23.3±5.0 (11-39) mm, medical duplicated length was 7.2±3.3 (4-20) mm, and medial intrapericardial was 28.3±7.0 (20-52) mm. The averaged superior vena cava length of both sides was 60.3±9.0 (44.5-90) mm. Almost half of the superior vena cava was found to be within the pericardium and half out. This information may be helpful in deciding how far a central venous catheter should be withdrawn beyond the superior vena cava-right atrial junction during right atrial electrocardiographic guided insertion, and in the prediction of optimal central venous catheter insertion depth.

Key Words: VEINS: superior vena cava, length. COMPLICATIONS: central venous catheterization, cardiac tamponade

The United States Food and Drug Administration guidelines state that central venous catheter (CVC) tips should not be placed in, or allowed to migrate into the heart1. However, to avoid the rare but lethal complication of cardiac tamponade, the CVC tip should be located above the cephalic limit of the pericardial reflection2,4, not merely above the superior vena cava (SVC)-right atrial (RA) junction. Without information about the SVC length, it may not be possible to determine how far the CVC should be withdrawn after it is located at the level of the SVC-RA junction (e.g. during a right atrial electrocardiographic guided insertion technique), or to identify a potentially dangerous positioning of a CVC tip on the chest X-ray.

The SVC length below the cephalic limit of the pericardial reflection has previously been assumed to be 20 mm2, or reported to be about 3.0 cm in a study of 34 cadavers of very old people4. However, cadaveric studies measuring anatomic structures may be limited by the post mortem factors causing distortion of anatomical structures and the emptied vessels. Thus, measurements of the SVC lengths below and above the cephalic limit of pericardial reflection in live, blood-filled vessels were warranted.

The purpose of this study was to measure the intrapericardial (IP) and extrapericardial (EP) lengths on...
the blood-filled SVC during cardiac surgery, and to seek for any anatomical landmarks for the prediction of the cephalic limit of pericardial reflection or SVC lengths on the chest X-ray.

METHODS

After receiving Hospital Review Board approval and obtaining informed consent, 61 elective cardiac surgical patients (27 males and 34 females) were enrolled in the study. Twenty-six of the patients underwent aortic valve replacement; six mitral valve replacement; 22, coronary artery bypass surgery, and four, off-pump coronary artery bypass surgery. Patients who required a re-operation were not included. After routine sternotomy, a self-retaining retractor was placed. The pericardial sac was opened. The IP part of SVC was exposed as usual. The EP part of SVC was exposed after removing the loose connective tissue medially and laterally.

The cephalic limit of pericardial reflection on the medial side was taken as the angular transitional junction between the left brachiocephalic vein and the SVC. The cephalic limit of pericardial reflection on the lateral side was regarded to be at the same level as the medial. The vertical lengths on each side of SVC were measured as follows: black suture silk of about 10 cm long was pinched with two forceps. The between-forceps length was adjusted to be exactly the same as the part of SVC length that we were trying to measure, while keeping the silk tight. Afterwards, we measured the distance between the two forceps with a pre-sterilized ruler. The IP and EP lengths on both sides, and the length of the medial duplicated part (MD) were measured separately (Figure 1). The whole vertical lengths of the SVC on either side were calculated by simply adding the IP and EP lengths, and the MD length in the case of the medial SVC length. The distances were measured by two cardiac surgeons, and with less than 3% inter-observer difference. The arithmetic mean of the individual measurements was used for data analyses.

To find potential anatomical landmarks for the cephalic limit of pericardial reflection or SVC lengths that are easily identifiable at bedside or on chest X-ray, the jugular notch of the clavicle to tracheal carina (notch-carina length) and the jugular notch to tracheobronchial angle distances (notch-angle length) were measured vertically on the preoperative routine posterior-anterior (PA) chest X-ray. The distances were measured with electronic calipers on the 12-times enlarged images of the digital PACS (Picture Archiving Communication System) as follows. Because intrathoracic structures appear magnified on PA views, a correction was made to calculate the notch-carina and notch-angle lengths for each patient: actual distance = projected distance on the plain film × [distance between X-ray tube and object is equal to distance between X-ray tube and film]. Distance between X-ray tube and object = the distance between X-ray tube and film (72 inch × 25.40 mm = 1828.8 mm) minus the distance between the carina and the anterior chest wall, which was measured on the lateral chest X-ray. To improve accuracy and reliability, three measurements of the distances were performed with electronic calipers to the nearest 0.1 mm. The arithmetic mean was calculated by using the measurements within 5% variances and used for the study.

The relationships of the height, weight, body mass index or age with the SVC length or IP, MD and EP lengths were analyzed by the Pearson's partial correlation analysis. On the assumption that any disease with the proximal aortic enlargement might lengthen the SVC length, SVC lengths depending on the pre-
sence or absence of aortic valvular disease were compared with unpaired t-test. Pearson's correlation analysis was used to assess the relationship between the notch-carina and notch-angle lengths and the IP, MD, EP and whole SVC lengths. Values are presented as mean±SD (range). P values <0.01 were considered significant.

RESULTS

Patients' age was 47±15 (15-75) years, height 161.8±8.6 (140.0-186.0) cm, and weight 60.8±9.5 (46.0-83.0) kg. Neither the SVC length nor any portion of the SVC correlated with the weight, body mass index or age of the patients. The only exception was the height, which had some correlation with medial EP length (r=0.343, P=0.007).

The EP, MD and IP lengths of both sides of the SVC are shown in Table 1. The averaged SVC length of the both sides was 60.3±9.0 (44.5-90) mm. The SVC length of 13 patients with aortic valvular disease (62.7±8.9 mm) did not appear to be longer than that of 48 patients without aortic valvular disease (59.6±9.0 mm).

The notch-carina length was correlated with the pulmonary diseases increases with age, the SVC length may be lengthened in the extremely aged population of the cadaver study.

The cephalic limit of pericardial reflection was known to surround the SVC as far as insertion of the azygos vein\textsuperscript{9}, or lie at the same level as the angle made by the right main bronchus and the trachea\textsuperscript{10,11}. The tracheal carina was found to be always located above the cephalic limit of pericardial reflection on cadaver dissection\textsuperscript{12}. The internal jugular vein or the innominate vein is located just behind the jugular notch of the clavicle\textsuperscript{12,13}, which is easily palpable 0.25 to 1 cm lateral to the sternal end\textsuperscript{14}. Therefore, this jugular notch may be used as a surface landmark for central venous access. In this study, it was attempted to correlate the notch-carina and notch-angle lengths with the IP, MD, EP and whole SVC lengths. Because the distance between X-ray tube and film is variable and relatively short, the parallax effect varies and is more augmented in the periphery during portable chest X-ray examination. Thus preoperative routine chest X-ray was used for measurements of the notch-carina and notch-angle lengths. Although correlation was not high, the notch-carina and notch-angle lengths that were correlated with the whole SVC length may have a role as potential factors for the prediction of optimal CVC insertion depth. However, it should be noted that correlation alone is not an appropriate method to assess predictive value.

The MD part of the SVC, where a duplication of the pericardial sac fortifies the vessel wall on the medial side, was previously reported to be 24 mm (range 16-40 mm)\textsuperscript{6}, but was only 7.2 mm long (range 4-20 mm) in this study. Contrary to the suggestion of a previous report\textsuperscript{6}, it does not seem to be probable that the thickened MD part may have a protective role against the tip-induced perforation for the right-sided subclavian or antecubital CVC, which may be prone to abutting on the medial wall. In many anatomy textbooks, the SVC is stated to be about 7 cm in length\textsuperscript{6}, but the actual SVC length in the current study was around 6 cm. We speculate that age, ethnic difference or cardiac disease-associated anatomical changes might explain the differences in the whole SVC or MD lengths.

Almost nowhere in the central veins, even above the heart, would be completely safe from the CVC-induced complications. Thus individual clinical factors must dictate the choice of access point and the site of CVC tip placement\textsuperscript{6}. SVC wall puncture below the cephalic limit of pericardial reflection by CVC tip is rare, but is a recognised cause of cardiac tamponade\textsuperscript{2,14,15}. Therefore, positioning of CVC tip above

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\textbf{Table 1} & \\
\hline
\textbf{Lengths of the superior vena cava on the lateral and medial sides} & \\
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\textbf{Extrapercardial length (mm)} & Lateral side \quad Medial side \\
29.1±6.5 (9-49) & 23.3±5.0 (11-39) \\
\hline
\textbf{Medial duplicated part (mm)} & \\
7.2±3.3 (4-20) & \\
\hline
\textbf{Intrapercardial length (mm)} & \\
32.6±6.9 (20-53) & 28.3±7.0 (20-52) \\
\hline
\textbf{Total length (mm)} & \\
61.7±9.6 (45-80) & 60.3±9.0 (44-94) \\
\hline
\textbf{Data are mean±SD (range). n=61.} & \\
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\end{tabular}
\end{table}

mean and lateral SVC lengths [r=0.361, P=0.006; r=0.437, P=0.001]. The notch-angle length was correlated with the lateral SVC length [r=0.389, P=0.003].

DISCUSSION

The IP part of the SVC [mean (SE)] has been reported to be 3.0 (0.2) cm (range 1.0-5.0 cm) from the measurements of 34 cadavers aged 78 (1.7) years\textsuperscript{6}. Since Schuster and colleagues measured the IP length after they had excised the heart by cutting the IP part of the SVC, the complicated measuring process may have introduced some inaccuracy. The flattening of the diaphragm in the patients with pulmonary emphysema pulls the heart downwards and thereby possibly increases the distance between the puncture site and the RA\textsuperscript{4}. Since the incidence of chronic obstructive

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the cephalic limit of pericardial reflection should reduce the incidence of this lethal complication. 

Although the EP and IP lengths and the whole SVC length were highly variable, half of the SVC was found to be within the pericardium and the other half out of the pericardium. The information from this study, in which the IP and EP lengths of the SVC were accurately measured on the blood-filled vessels in vivo, may be helpful in deciding how far the CVC should be withdrawn beyond the SVC-RA junction, and in the prediction of optimal CVC insertion depth.

REFERENCES