J Anesth (2015) 29:724–727
DOI 10.1007/s00540-015-2012-1

ORIGINAL ARTICLE

Estimation of catheter insertion depth during ultrasound-guided subclavian venous catheterization

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Received: 9 February 2015 / Accepted: 30 March 2015 / Published online: 16 April 2015

Abstract
Background Several methods have been used to predict the optimal depth of central venous catheter (CVC) tip position when using the anatomical landmark technique. In the present study, we devised a simple formula to predict CVC depth using ultrasound images and chest X-ray (CXR) in patients undergoing ultrasound-guided subclavian venous catheterization.
Methods Central venous catheterization via the subclavian vein was performed under ultrasound guidance. We measured five parameters to determine the distance between the needle insertion point and the CVC tip: insertion point to vein puncture point (A), insertion point to a skin point indicating a vertical position above the vein puncture point (B), insertion point to the clavicular notch (C), clavicular notch to the carina (D), and catheter tip to carina (E). Catheter insertion depth was then determined as follows: calculated catheter insertion depth $= A - B + C + D$; actual catheter insertion depth $= (A - B + C + D) + E$.
Results The calculated CVC insertion depth (mean ± SD) was 15.4 ± 1.5 cm from the needle insertion point to the carina [95 % confidence interval (CI) 15.0–15.9 cm]. Actual depth was 15.4 ± 1.5 cm (95 % CI 15.0–15.9 cm). No significant difference was observed between the calculated CVC insertion depth and the actual distance from the needle insertion point to the carina ($p = 0.940$).
Conclusions The appropriate length of a CVC inserted through the subclavian vein can be estimated by a formula using ultrasound images and CXR.

Keywords Central venous catheterization · Subclavian vein · Ultrasonography

Introduction

Optimal central venous catheter (CVC) tip position is important for preventing catheter-related complications such as arrhythmia, thrombosis, cardiac perforation, and cardiac tamponade [1–6]. Several reports have indicated that placing the catheter tip in the safe zone has a low risk of catheter-related complications [7–11].

Several methods have been used to predict optimal depth for subclavian venous catheterization [12, 13]. Those studies were performed using the anatomical landmark technique. Ultrasound (US)-guided subclavian venous catheterization show superiority over the landmark technique in both success rate and safety [14]. No studies have been conducted about predicting the appropriate depth of the catheter during US-guided subclavian venous catheterization.

The purpose of this study was to devise a formula to predict CVC depth for US-guided subclavian venous catheterization. The clavicular notch and carina on the chest X-ray (CXR) were used as landmarks for this purpose.

Materials and methods

After obtaining institutional review board (Seoul National University Bundang Hospital, protocol number: B-1303/193-002) approval and patient informed consent,

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this observational study was performed in 48 patients (age, 18–80 years) who required subclavian venous catheterization for neurosurgery from June to December 2013. This study was registered with the Korean Clinical Trials Registry (CRiS, http://cris.nih.go.kr, Number KCT0000912).

After inducing general anesthesia, subclavian venous catheterization was performed with a double-lumen CVC (Arrow International Inc., Reading, PA, USA) under US guidance. All catheterizations were performed by one anesthesiologist (YTJ) who had >2 years of experience in US-guided subclavian venous catheterization.

The right subclavian vein (SCV) and internal jugular vein (IJV) areas were sterilized with povidone-iodine. An ultrasound machine (SonoSite S-nerve, SonoSite, Bothell, WA, USA) equipped with a linear 6–13-MHz transducer (HFL38x, SonoSite, Bothell, WA, USA) was used. The surface of the transducer was coated with sterilized gel and then wrapped in a sterile cover. We used the infraclavicular approach and obtained the longitudinal-axis view of the SCV. After confirming venous flow by the color Doppler view, the needle was advanced under real-time US guidance toward the lumen of vein while it was directed toward the acoustic shadow of the thoracic rib. When venous puncture was confirmed, another anesthesiologist saved the US image and measured the required parameters to calculate catheter insertion depth before the guidewire was advanced. After advancing the guidewire, the IJV area was examined with US to exclude the chance of malposition. Catheter depth was determined according to the devised formula.

We measured five parameters to determine the distance between the needle insertion point and the CVC tip: insertion point to vein puncture point (*A*), insertion point to skin point indicating a vertical location above the vein puncture point (*B*), insertion point to the clavicular notch (*C*), clavicular notch to the carina (*D*), and catheter tip to carina (*E*). These parameters are shown in Fig. 1.

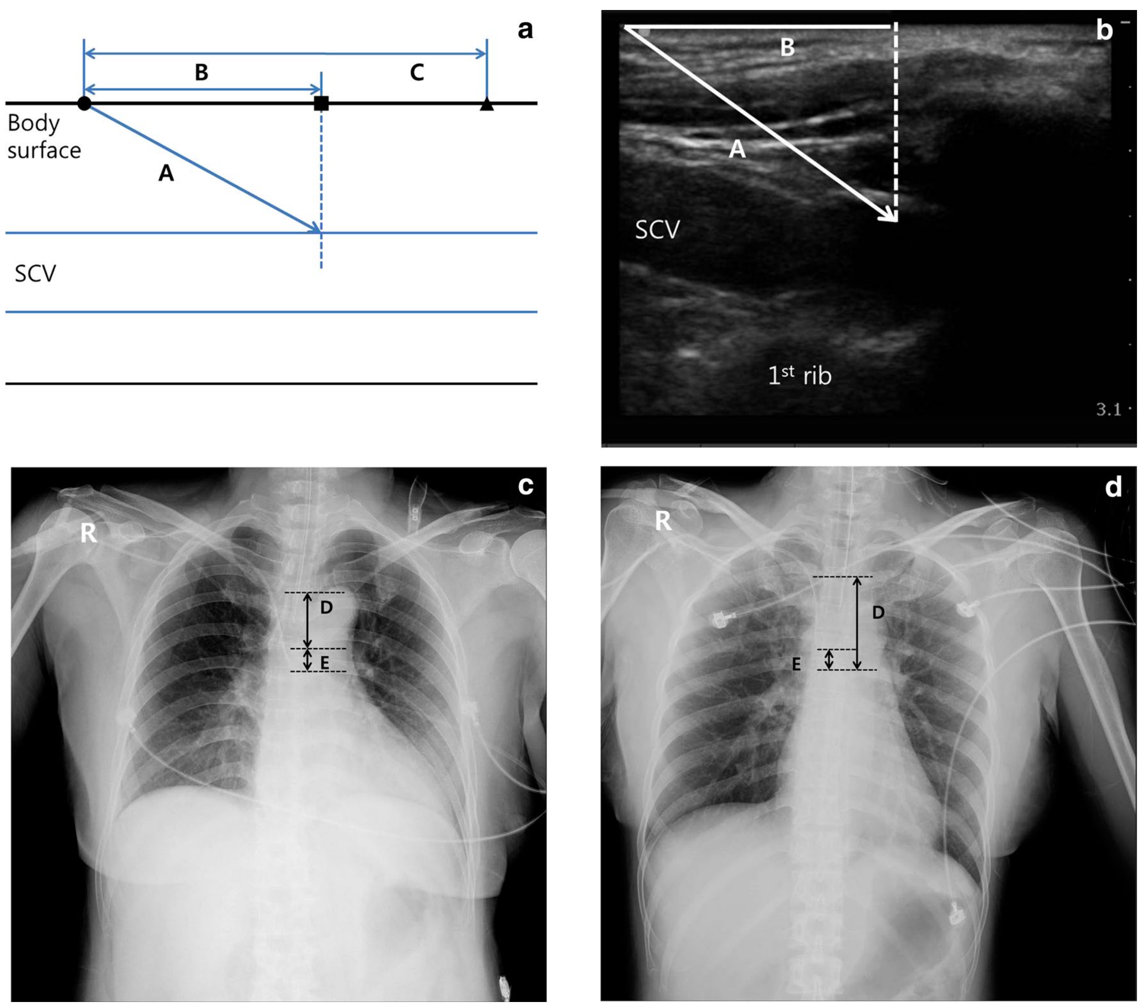

Fig. 1 The diagram of ultrasonographic view (**a**), ultrasonographic view of the infraclavicular region (**b**), chest X-ray images after insertion of catheters (**c**, **d**); *A* insertion point to vein puncture point, *B* insertion point to skin point indicating a vertical location above the vein puncture point, *C* insertion point to the clavicular notch, *D* clavicular notch to the carina, *E* catheter tip to carina, *SCV* subclavian vein

A and *B* were measured on the US images using the measuring function during catheterization. *C* was measured on the body surface of patients with a sterilized paper ruler advancing the guidewire. *D* was measured on the antero-posterior CXR using the internal measuring tool available on our hospital's picture archiving communication system before catheterization.

Catheter insertion depth during central venous catheterization was determined using the following formula:

$$\text{Calculated catheter insertion depth} = A - B + C + D$$

The distance between the catheter tip and the carina (*E*) was measured on a postoperative CXR image; CVC tips positioned above the carina level were considered positive values and those below the carina were in negative values. We calculated actual catheter depth using the value of *E* as follows:

$$\text{Actual catheter insertion depth} = (A - B + C + D) + E$$

We then compared the two values of calculated and actual catheter insertion depth.

This study had a power of 80 % and a type 1 error of 0.05. We regarded 1 cm away from the carina as a safe position for the catheter tip and calculated a sample size with and SD of 1.2 cm, which was described in a previous study [13]. Forty-eight patients were required in the present study.

Table 1 Patient characteristics ($n = 48$)

Age (year)	50.9 ± 13.9
Weight (kg)	64.5 ± 10.5
Height (cm)	162.1 ± 7.7
Gender (male/female)	18/30
Surgery time (min)	266.7 ± 120.5
Anesthesia time (min)	338.1 ± 125.7

Data are expressed as mean ± SD or number of patients

Data are expressed as mean ± SD. The statistical analysis was performed using the *t* test to compare calculated CVC insertion depth with the actual distance between the needle insertion point and the carina. The SPSS ver. 18.0 (SPSS Inc., Chicago, IL, USA) software was used for data analyses, and a *p* value <0.05 was considered to indicate significance.

Results

Forty-eight patients were enrolled in this study, and no patients were excluded. The patients' characteristics are presented in Table 1.

The data measured for each parameter (*A*–*E*) are shown in Table 2. The calculated CVC insertion depth ($A - B + C + D$, mean ± SD) was 15.4 ± 1.5 cm from the needle insertion point to the carina (95 % confidence interval [CI], 15.0–15.9 cm). The actual distance [$(A - B + C + D) + E$, mean ± SD] from the needle insertion point to the carina was 15.4 ± 1.5 cm (95 % CI, 15.0–15.9 cm) (Table 2). No significant difference was observed between the calculated CVC inversion depth and the actual distance from the needle insertion point to carina ($p = 0.940$). The CVC tip position was 0.0 ± 0.7 cm ($p = 0.861$) below the carina (95 % CI, 0.2 cm below the carina–0.2 cm above the carina).

No complications were observed during or after catheterization such as arterial puncture, hematoma, hemothorax, or pneumothorax.

Discussion

This prospective observational study reports a clinically relevant formula to determine the depth of CVC via the subclavian vein under real-time US guidance. The CVC tip could be reliably placed near the carina when the CVC was inserted via the right SCV to a depth derived by our formula.

Table 2 Measured distances and CVC insertion depth (cm, $n = 48$)

Insertion point to vein puncture point distance (*A*)	3.7 ± 0.6
Insertion point to skin point indicating a vertical location above the vein puncture point distance (*B*)	2.9 ± 0.6
Insertion point to clavicular notch distance (*C*)	9.5 ± 1.0
Clavicular notch to carina distance (*D*)	5.0 ± 1.1
Catheter tip to carina distance (*E*)	0.0 ± 0.6
Calculated CVC insertion depth[a]	15.4 ± 1.5
Actual distance between the insertion point and carina[b]	15.4 ± 1.5

Data are expressed as mean ± SD

CVC central venous catheter

[a] $A - B + C + D$

[b] $(A - B + C + D) + E$

US is an excellent tool for subclavian venous catheterization. US-guided subclavian catheterization is associated with a higher success rate, reduced access time, and reduced number of attempts [14]. Several studies have predicted the optimal catheter depth for subclavian catheterization using the landmark technique. Those studies proposed formulae using patient height of skin-to-vein distance [9, 10, 15], chest X-ray images [16], or the topographical method [13]. However, no prospective studies have been conducted concerning the optimal catheter depth when using the SCV approach under US guidance. The US-guided method is different for the needle insertion point and the advancing angle compared with those of the landmark technique. The SCV is approached at a fairly steep angle with the puncture site lateral to the clavicle when using US [17]. Most landmark techniques use a much flatter angle of approach with the vein punctured more medially behind the clavicle. Mean insertion depth was about 15.4 cm in this study in contrast to 12.9–13.8 cm with the landmark technique [12, 13]. This difference may be due to a more infero-lateral insertion site of US-guided technique compared with that of the landmark technique. Moreover, the point of venipuncture is near the junction where the axillary vein and SCV join, which allows a longer path with the US-guided technique.

The carina level was used as the landmark to locate the catheter tip in this study. Placement of CVC catheters has a risk of potentially serious complications. Because cardiac tamponade is a tragedy, it has been suggested that the CVC tip should be located above the cephalic limit of the pericardial reflection, not merely above the superior vena cava-right atrial junction [4] to minimize risk. The level of the carina is near the level of the pericardial reflection in fresh and preserved cadavers and in computerized tomography studies of adult patients [7, 18, 19], and the landmarks are easily identifiable on CXR. There is a debate about the optimal position of catheter tip [18, 20], and we have adopted a carina level.

Some limitations of the present study should be discussed. First, we did not compare differences in catheter insertion depth between the US-guided and landmark techniques. Estimation of insertion depth using the landmark technique is well established in the literature. Second, this estimate is not applicable to patients who have no CXR before central venous catheterization. However, most patients who require a central line may have a CXR taken before surgery. Third, only longitudinal approach was investigated. We suppose that it was not much different from the transverse approach.

In conclusion, the appropriate length of a CVC inserted through the SCV can be estimated by a formula using US images and CXR without complications.

Conflict of interest There are no competing interests to declare.

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