Nutrition 27 (2011) 557–560

Contents lists available at ScienceDirect

Nutrition

journal homepage: www.nutritionjrnl.com

Applied nutritional investigation

Optimal prediction of the central venous catheter insertion depth on a routine chest x-ray

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ARTICLE INFO

Article history:
Received 3 February 2010
Accepted 11 July 2010

Keywords:
Central venous catheter
Chest x-ray
Complications
Pericardial reflection
Internal jugular vein
Subclavian vein
Carina

ABSTRACT

Objective: Cardiac tamponade is a serious complication of central venous catheter (CVC) insertion. The position of the carina has been shown to be near the pericardial reflection and can easily be identified as a landmark on routine chest x-ray (CXR). The purpose of this study was to show a simple way to predict optimal CVC depth, thereby facilitating safe positioning of the CVC tip.
Methods: Subjects included 119 inpatients undergoing gastroenterologic surgery. Central venous catheterization was performed through the right internal jugular vein or the right subclavian vein. The insertion depth was measured. Postoperatively, the CVC tip position was confirmed by CXR and the distance between the CVC tip and the carina was measured. We compared the "original measurement" up to the carina from the insertion point with the "calculated measurement" derived by adding half the length of the right clavicle and the vertical length between the sternal head of the right clavicle and the carina on the CXR.
Results: There was a significant correlation between the original measurement and the calculated measurement when performed through the internal jugular vein and the subclavian vein.
Conclusion: The appropriate length of CVC inserted through the right internal jugular vein or right subclavian vein could be estimated by the calculated measurement of adding half the length of the right clavicle and the vertical length between the sternal head of the right clavicle and the carina.

Introduction

After its insertion, the central venous catheter (CVC) tip has been recommended to be positioned in the superior vena cava (SVC) and outside the pericardial sac [1] to prevent serious complications such as cardiac tamponade [2,3]. Several reports have proposed radiographic landmarks for proper positioning of the CVC [4–8]. In a recent study, Albrecht et al. [7] stated that the level of the carina is near the level of the pericardial reflection in fresh and preserved cadavers.

The purpose of this study was to devise a simple formula that could predict CVC depth using the position of the carina and the clavicle on chest x-ray (CXR).

Materials and methods

After institutional review board approval, this retrospective study was performed in 242 consecutive patients who received right-side central venous catheterization in Department of Gastroenterological Surgery, Nagoya City University Graduate School of Medical Sciences, Nagoya, Japan from April 2004 through March 2007. Fifteen patients who had a portable anteroposterior CXR were excluded from the data analysis because the shadow differs from posteroanterior CXRs. Informed consent was obtained from the 119 patients who were enrolled in this study. The right internal jugular vein (IJV; $n = 75$) and the right SCV ($n = 44$) were catheterized in patients undergoing gastroenterologic surgery.

The right IJV was catheterized using the Seldinger method according to a previous report [9]. In brief, the head was slightly turned away from the site of the puncture. The assumptive puncture point was the lesser supraclavicular fossa at the level of the cricoid cartilage, usually at the level of the apex of the two heads of the sternocleidomastoid muscle (Fig. 1). The catheterization was performed by an anesthesiologist who was managing the patient. The right SCV was catheterized using a direct puncture method according to a previous report [10]. In brief, the catheter was inserted into the right SCV through an infraclavicular approach. The catheterization was performed by the surgeon managing the

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0899-9007/$ - see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.nut.2010.07.005

patient. The assumptive puncture point of entry was below the midpoint of the clavicle (Fig. 1) and a needle with an introducing cannula was slowly advanced to the cross section of the clavicle and the clavicular head of the sternocleidomastoid muscle until venous blood was freely aspirated. The needle was advanced with the cannula another 2 to 3 mm. After free aspiration of venous blood was confirmed, the needle was withdrawn. The cannula was not threaded over the needle in most cases.

The CVC tip position was confirmed on the postoperative posteroanterior CXR using the internal measuring tool available on the hospital's picture archiving communication system. The distance between the CVC tip and the carina was then measured. Insertion depths used for calculations were obtained from the values that were recorded in the patients' records. Using these two measurements, the total length of the catheter from the insertion point to the carina was calculated. This was regarded this as the "original measurement" up to the carina (Fig. 2). In addition, the right clavicle was measured and the length was divided in half. This value was added to the vertical distance between the sternal head of the right clavicle and the carina on the CXR for a combined total length. This was regarded as the "calculated measurement" (Fig. 3). Then, the original measurement was compared with the calculated measurement.

Statistics

Statistical analysis was performed using SPSS 15.0 for Windows (SPSS, Inc., Chicago, IL, USA). All measurements were expressed as mean ± standard deviation (range). Correlations between the original and calculated measurements were determined using the Pearson product-moment correlation coefficient (r). To identify concordance between the original measurement and the calculated measurement, intraclass correlation coefficients were used. To identify concordance between the original measurements performed through the IJV and the SCV, the Welch test was used. $P < 0.05$ was considered statistically significant.

Results

Patient characteristics are listed in Table 1. Half the length of the right clavicle, the distance between the sternal head of the right clavicle and the carina, the original measurement, and the calculated measurement are listed in Table 2. The original measurement of 75 CVCs placed through the right IJV was 13.9 ± 1.4 cm (10.5–17.5) and the original measurement of 44 CVCs placed through the right SCV was 14.1 ± 1.4 cm (10.8–16.6). The calculated measurement of 75CVCs placed through the right IJV was 13.9 ± 1.4 cm (9.5–17.4) and the calculated measurement of 44 CVCs placed through the right SCV was 14.5 ± 1.3 cm (11.7–16.7). The correlations between the original and calculated measurements are presented in Figure 2. The results verified significant correlations in the IJV ($r = 0.804$, $P < 0.001$; Fig. 4A) and the SCV ($r = 0.881$, $P < 0.001$; Fig. 4B) CVC depths. The intraclass correlation coefficients were 0.852 in the IJV and 0.806 in the SCV. The original measurement was not significantly different between the IJV and SCV ($P = 0.309$).

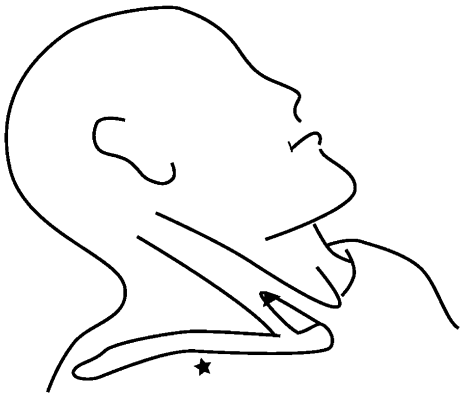

Fig. 1. Assumptive puncture point of central venous catheter. The assumptive puncture point of the right internal jugular vein was the lesser supraclavicular fossa at the level of the cricoid cartilage, usually at the level of the apex of the two heads of the sternocleidomastoid muscle (arrow). The assumptive puncture point of the right subclavian vein was below the midpoint of the clavicle (star).

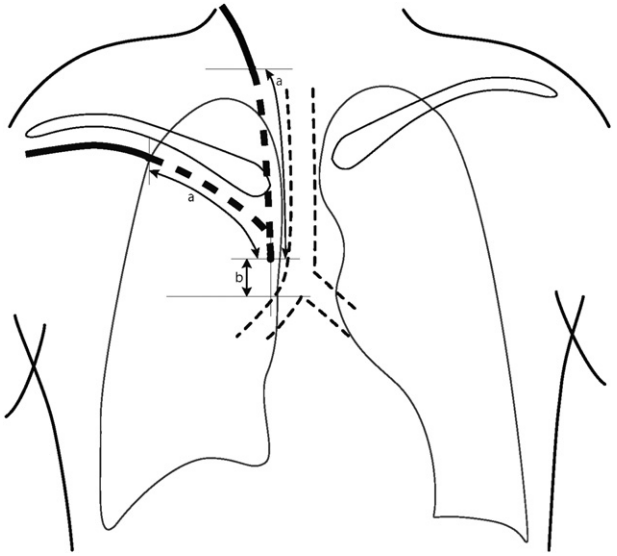

Fig. 2. Scheme of the "original measurement" on the chest x-ray film. The bronchus is indicated by heavy dotted lines. (a) The insertion depths obtained from values that were recorded in the patients' records. (b) The distance between the central venous catheter tip and the carina. The original measurement consists of (a) plus (b).

Discussion

Central venous catheter insertion is a common procedure in modern medicine. Complications often include sepsis, vessel perforations, hydro- or pneumothorax, thrombosis from endothelial damage, and embolism [11–15]. In particular, misplacement of the CVC tip is a frequent complication [16], with cardiac tamponade being one of the most serious, albeit rare,

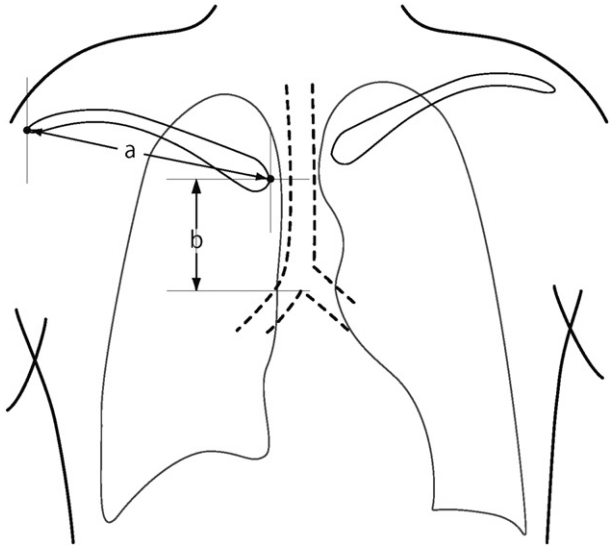

Fig. 3. Scheme of the measured distance on the chest x-ray film. The bronchus is indicated by dotted lines. (a) The distance of right clavicle. (b) The vertical distance between the sternal head of the right clavicle and the carina. The "calculated measurement" is defined as half of (a) plus (b).