Applied anatomy of the superior vena cava—the carina as a landmark to guide central venous catheter placement

K. Albrecht1*, H. Nave2, D. Breitmeier1, B. Panning3 and H. D. Tröger1

1Institute of Legal Medicine, 2Department of Anatomy and 3Department of Anaesthesiology, Medical School Hannover, D-30623 Hannover, Germany
*Corresponding author. E-mail: albrecht.knut@mh-hannover.de

Background. Cardiac tamponade is a serious complication of central venous catheter (CVC) insertion. Current guidelines strongly advise that the CVC tip should be located in the superior vena cava (SVC) and outside the pericardial sac. This may be difficult to verify as the exact location of the pericardium cannot be seen on a normal chest x-ray. The carina is an alternative radiographic marker for correct CVC placement, suggested on the basis of studies of embalmed cadavers.

Methods. We set out to confirm this radiographic landmark in 39 fresh cadavers (age 58.4 (3.4) (mean and SE) yr) and to compare the results with those from ethanol–formalin-fixed cadavers.

Results. We found that the carina was 0.8 (0.05) cm above the pericardial sac as it transverses the SVC. In no case was the carina inferior to the pericardial reflection and our study confirmed the previous findings. All the measured distances were significantly greater in fresh cadavers.

Conclusions. We confirm that the carina is a reliable, simple anatomical landmark that can be identified in vivo for the correct placement of CVCs outside the boundaries of the pericardial sac.

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Material and methods

We studied 39 subjects. All measurements are reported as mean (SD) and range. There were 11 females and 28 males—height 169 (1.9) cm (146–195 cm)—undergoing forensic autopsy. The examinations were carried out by the same person (K.A.). The mean age at the time of death was 58.4 (SD 3.4) (range 19–88) yr. The autopsies were carried out within 48 h of arrival in the Forensic Institute. We did not study cadavers aged under 16 yr or those with advanced autolysis.

After opening the rib cage and keeping the pericardium intact, the sternum and the medial parts of the ribs were removed. Extrapерicardial fat tissue was displaced and a lambda-shaped incision was made in the pericardium. The dimensions of the intrapericardial part of the SVC and the medial side of the SVC (where a duplication of the pericardium strengthens the vessel wall) were measured in situ. We took care to avoid any stretching of the heart, blood

Central venous catheter (CVC) insertion is a routine procedure in intensive therapy. CVC misplacement can be lethal.1–6 As well as causing life-threatening cardiac tamponade, the tip of the catheter can perforate the right heart or great veins such as the superior vena cava (SVC).6–10 During insertion, the position of the tip of the CVC can be estimated by marks on the catheter or by ECG-guidance. The final position should be checked by x-ray. Current guidelines recommend that the tip of the catheter should be located in the SVC, outside the pericardium, to avoid the danger of complications such as cardiac tamponade. Different radiographic landmarks for safe positioning have been described.8–11 Schuster and co-workers12 proposed that the carina was a reliable, simple radiographic marker for the correct placement of a CVC, but this suggestion was based on the examination of embalmed cadavers. We set out to verify this landmark in fresh cadavers.
vessels and the soft tissue to achieve reproducible results. The thoracic organs (tongue, the organs of the neck, heart, and lungs) were removed en bloc. While observing these organs from the dorsal aspect, the carina was palpated and a small metal cannula was inserted and pushed anteriorly towards the carina. The organs were then turned to inspect the ventral aspect and the distance was measured between the cannula tip (at a right angle) and the pericardium where it transversed the SVC (Fig. 1).

Data are expressed as means (SE) (standard error of the mean). We compared our data with data published previously using Student’s t-test for unpaired data and one-way ANOVA. A value of $P<0.05$ was assumed to be significant.

**Results**

The duplication of the pericardium crossed the SVC at a diagonal to horizontal angle (range 0–15°). The pericardium was fixed to the medial wall of the SVC up to the beginning of the aortic arch, near to the brachiocephalic trunk. The intrapericardial part of the SVC (A in Fig. 2) was 5.3 (0.2) cm (range 3.0 (69 yr, female) to 8.0 cm (84 yr, female) with a comparable body height). The length of the medial side of the SVC, fused with the pericardium (B in Fig. 2), was 3.4 (0.2) cm (range 1.4 (82 yr, female, height 147 cm) to 5.5 cm (84 yr, female, height 158 cm)). The carina was located at a distance of 0.8 (0.05) cm (range 0.3 (41 yr, male, height 172 cm) to 1.5 cm (88 yr, female, height 169 cm)) above the pericardial reflection (C in Fig. 2). In no case was the carina located below the pericardial duplication on the medial side of the SVC.

**Discussion**

CVC insertion is a common procedure in modern medicine, with up to 6 million insertions in the US each year. Many complications, some fatal, can occur, often 2±6 in the first week after CVC placement. Misplacement of the catheter tip is a frequent complication. Cardiac tamponade after CVC placement is one of the most serious complications. Schneider and Maxeiner reported cardiac tamponade causing death of a 17-yr-old girl. The CVC was inserted in the brachial vein to allow parenteral nutrition. Although initially placed correctly, the catheter tip penetrated the anterior wall of the right ventricle after movement of the catheter tip into the heart, because of arm movement. Often complications include sepsis, vessel perforations, hydro- or pneumothorax, thrombosis from endothelial damage, and embolism.

To prevent such complications, especially cardiac tamponade, many suggestions have been made for assessing correct placement of CVCs, most based on clinical investigations and analysis of x-rays of the chest. However, the pericardial sac is not visible radiographically, so reliable landmarks are needed to allow reliable radiographic checking of adequate positioning. Schuster and colleagues showed that the carina can be used, because in all cases the pericardium crossed the SVC below this point, which can be seen on x-ray. Keeping the CVC tip outside the boundaries of the pericardial sac will avoid perforation of the intrapericardial part of the SVC or the right atrium or ventricle. Schuster and colleagues also emphasized that the lateral side of the SVC was weaker because there was no

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**Fig 1** The heart, great blood vessels, and opened pericardium. (A) The intrapericardial part of the SVC. (B) The medial side of the SVC, attached to the pericardium. (C) The longitudinal distance between the carina and the pericardium as it transverses the superior vena cava. The anatomical location of the carina is shown by the dotted lines. *Superior vena cava; Aa=ascending aorta; ra=right atrium; rv=right ventricle; la=left atrium; lv=left ventricle; Ac=apex of the heart; p=pericardium.

**Fig 2** Distances in embalmed compared with fresh cadavers. The differences are statistically significant.
strengthening by the pericardium. Radiological confirmation that the CVC tip is above the level of the carina may reduce the risk of pericardial perforation.

We studied the three distances in cadavers, where death had taken place up to 48 h before the investigations started, allowing almost authentic anatomical conditions. Our results confirmed the report of Schuster and colleagues, but we found significantly greater distances. Embalming solutions containing formalin cause tissue to shrink. Comparison of our measurements with those of Schuster and colleagues shows that all the dimensions in our study were greater than in the fixed anatomical cadavers (Fig. 2). In all ‘fresh cadavers’ the pericardial boundaries were below the border of the carina. The point for a safe position of the catheter tip, outside the boundaries of the pericardial sac, or above the part where the pericardium fortifies the vessel wall of the SVC, should be at least 4 cm above the carina. It is important that we found no relationship between the lengths measured in the thorax and body height or sex.

Our study strengthens the case for the carina as a safe landmark in CVC placement. Pericardial tamponade after insertion of a CVC is a rare, but often fatal complication. Tamponade will be unlikely if all catheter tips are seen to be above the carina tracheae on chest x-ray.

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