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Bairbre Connolly
John B. Mawson
Cathy E. MacDonald
Peter Chait
Haverj Mikailian

Fluoroscopic landmark for SVC-RA junction for central venous catheter placement in children

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B. Connolly (✉) · J. B. Mawson ·
C. E. MacDonald · P. Chait · H. Mikailian
Department of Diagnostic Imaging,
The Hospital for Sick Children,
555 University Avenue, Toronto,
Ontario, M5G 1X8, Canada
e-mail: bairbre.connolly@sickkids.on.ca
Tel.: + 1-416-8136034
Fax: + 1-416-8137591

B. Connolly · J. B. Mawson ·
C. E. MacDonald · P. Chait · H. Mikailian
Department of Medical Imaging,
University of Toronto, Toronto, Canada

Abstract *Background*. Vascular access devices are commonly placed under image guidance. The usual aim is to place the tip at the superior vena cava-right atrial juntion (SVC-RA).
Objective. To identify a radiographic landmark for the SVC-RA junction that would be useful for accurate central venous catheter tip placement in children.
Materials and methods. Images from 56 children undergoing contrast studies of their upper limb venous systems were examined for location of the SVC-RA in relation to a radiographic landmark.
Results. Most patients (92.5 %) showed the SVC-RA junction to lie at the sixth thoracic vertebral level or the interspace above or below. The SVC-RA junction lay lower than the right main bronchus and the notch on the right cardiomediastinal contour.
Conclusion. The vertebral body provides a useful and radiographically visible landmark for accurate central catheter tip placement.

Introduction

With the increase in use of both centrally and peripherally placed central venous catheters, the anatomy of the upper venous system has taken on new clinical and practical significance. Increasingly, image-guided placement in interventional radiology has enabled accurate line placement and tip positioning with good long-term results [1–4]. Erosions through the vessel wall and venous thromboses have been described with central venous catheters located in the SVC and in the right atrium. The appropriate position for placement is thought to be at the junction between the superior vena cava and the right atrium (SVC-RA junction), but this remains to be determined [5–11]. Where precisely this junction is can sometimes be difficult to determine at fluoroscopy, especially in infants and young children with large cardiothymic shadows, and if during placement the patient is in the Trendelenberg position. The purpose of this study was to find a consistent, reliable, and easily usable landmark to identify the SVC-RA junction by fluoroscopy, without the need for contrast injection. Furthermore, this landmark might be useful for assessment of tip position post-placement on a chest radiograph.

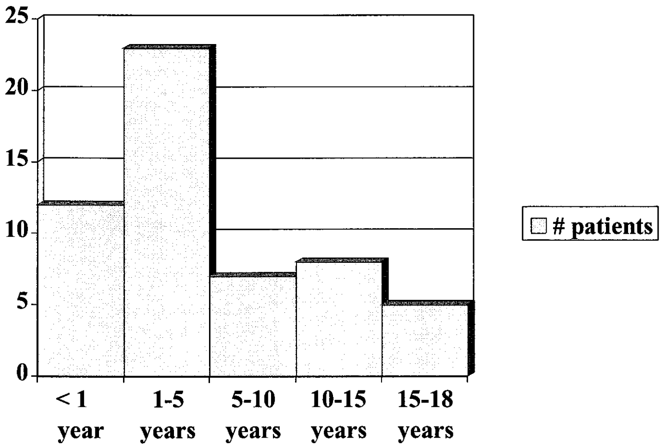

Fig. 1 Graph of patients age distribution in the 56 patients studied

Patients and methods

We studied the location of the SVC-RA junction in two groups of patients, totaling 56 patients. Patients with tetralogy of Fallot (ToF) undergoing angiography prior to complete surgical repair routinely have superior caval injections to identify a left SVC draining to a coronary sinus, with or without a bridging mediastinal vein. The cineangiocardiograms of 20 consecutive patients with ToF and a left aortic arch ($n = 10$) and with a right aortic arch ($n = 10$) were reviewed. Patients with tetralogy variants [tetralogy-type pulmonary atresia, tetralogy with absent pulmonary valve and double outlet right ventricle (DORV)] were excluded from the study. A further 36 patients were selected randomly, with normal cardiac and venous anatomy who were undergoing upper limb venography for suspected deep venous thrombosis, and they were also reviewed. As the purpose was not to compare the location of the SVC-RA landmark as judged between the two groups of patients, they were not age-matched and were analyzed as a total group of 56 patients.

All patients were supine on the fluoroscopic table. Simultaneous biplane (frontal and lateral) projections were obtained in those having cardiac angiography. Frontal projections were only obtained in those having upper limb venography, with the beam centered over the SVC. The image intensifier and patient were both parallel in the horizontal position to avoid parallax. Venography was performed using a hand injection of non-ionic contrast material on a Siemens HI-COR at 15 frames/s in the cardiac group and on a Siemens Polytron 1000VR, ± DSA at 2 frames/s in the venogram group. In all 56 patients, the SVC was correlated with the vertebral body level (VB) and intervertebral disc spaces (IVDS). In the ToF group, the SVC-RA junction (identified on both projections) was also correlated with the "notch" at the top of the right atrial contour (where it joins the right lateral margin of the mediastinum) and with the right main stem bronchus.

Results

Patients ranged in age from 1 month to 18 years with the mean age being 4.5 years, and 21 % being less than 1 year (Fig. 1). Correlation with the vertebral body level in all 56 patients showed that SVC-RA junction lay at the level of T5 VB in 1.8 %, T5–6 IVDS in 29 %, T6 VB level in 29 %, T6–7 IVDS in 34.5 %, and T7 VB in 5.2 % (see Figs. 2, 3). Therefore, the SVC-RA junction was at the level of T6 or one of its adjacent intervertebral disc spaces in 92 % of the total numbers studied. The SVC-RA junction in all patients was below the level of the right main bronchus in the 20 children with tetralogy of Fallot, as the usual location of the right main bronchus was at T4 (25 % at T3–4, 60 % at T4, 10 % at T4–5 and 5 % at T5). The SVC-RA junction was not

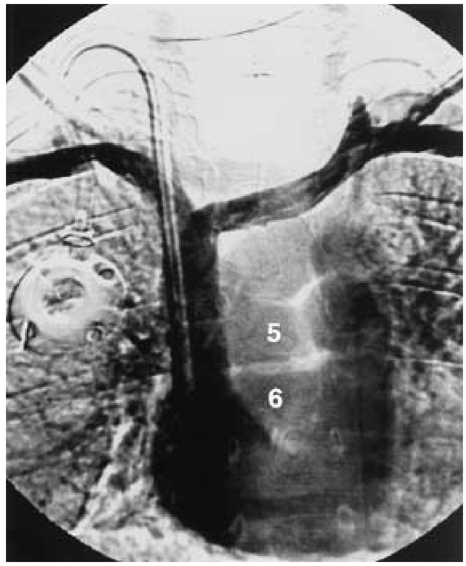

Fig. 2 Digital subtraction image of the upper venous system in a child with a port. The SVC is seen to terminate at the upper aspect of T6 where it enters the right atrium. Note the pedicles are visible on this subtraction image to enable localization

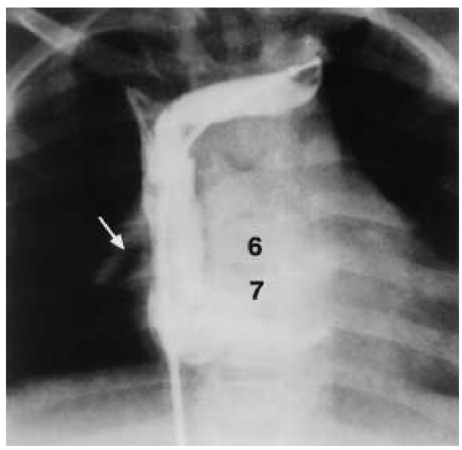

Fig. 3 Image of the superior vena cava opacified by contrast during a hand injection, showing the SVC to terminate at the T6–7 intervertebral disc space. This is lower than the right main bronchus (*arrow*)

plotted against the right main bronchus in the upper limb venogram group, as the bronchus was not always clearly visible. The distance below the right main bronchus and the bulge in the right contour of the heart was very variable. With a right aortic arch, the level of the junction was not altered, but the upper SVC was displaced more laterally so that the angle of the junction was oblique. No difference with age was identified, and no difference in the levels was identified between the two patient populations.

Discussion

Thrombosis, traumatic complications, and impaired function (aspiration of blood or infusion) of central venous catheters are well known if the catheter tip is not well positioned [1, 5–9, 12]. By convention, the tip is positioned at the SVC-RA junction [1, 9]. However, this junction may be difficult to identify using thoracic landmarks. Even with contrast injection via the catheter, it may not be easy to identify due to the small volumes of contrast medium that can be injected through fine catheters in small children and the possible jet effect caused.

Anatomy texts place the SVC-RA junction at the anterior third intercostal space [10]. This is difficult to see fluoroscopically in children and therefore not of great practical use. In everyday practice, one might think to place the tip of a central venous catheter at the level where the straight right mediastinal border expands into the right atrial contour. However, the right atrial appendage wraps around the distal SVC and accounts for part of the upper part of the right heart contour bulge, with the SVC descending lower to enter the heart. The problem of position is compounded in infants and young children in whom the entire right cardiac border is cloaked by a bulky thymus. If the patient is in the Trendelenberg position at the time of central venous line placement, the abdominal contents may push up the diaphragm, and the mediastinal contents may be compressed cephalad making positioning according to soft tissue landmarks more difficult. A fluoroscopically identifiable landmark for this important junction in the supine horizontal position is therefore necessary in order to place the tip appropriately at the time of insertion.

Vertebral bodies, their intervertebral disc spaces, and usually the pedicles are visible in small children, and these were therefore used for localization. Such a radiological landmark could also be very useful in determining PICC catheter positions on chest X-rays. A limitation of these results is that the venograms were obtained in the supine position and a standard chest X-ray is obtained upright and with the arms above the head in infants.

Other methods have been used to assess the SVC-RA junction for non-radiologically placed central lines [13–19], including hypertonic saline and ECG wave changes [14, 15, 19] electromagnetic devices, and mathematical formulae for intravascular length in adults [16, 18]. Many are compared to the chest radiograph, fluoroscopy, and contrast studies. Implicit is an acceptance that the SVC-RA junction is easily recognized on X-ray, which may not be so. Contrast venography as part of the procedure immediately prior to line placement may not be either appropriate or practical, e.g., when inserting a jugular line or in a patient with no peripheral access.

Intuitively, in very small babies who require PICC or CVL placement, the landmark for the SVC-RA junction might be slightly different given the wider, shorter thoracic cage configuration. Additionally, children in whom there is an enlarged RA or cardiac malposition may have a different position for their SVC-RA junction. On angiography of the SVC in children with tetralogy of Fallot, the SVC-RA junction corresponds with the rightward lateral margin of the T6 VB or T6–7 IVDS. While the angle of entry is altered by the presence of a right aortic arch, the level of the junction in this selected population is not.

In small infants the difference in length between an appropriately positioned catheter tip and one that is “too short” or “too long” may be as little as 0.5 cm, rendering accurate placement important. This contrasts with the wider range of safety affordable in adults or older children. In the upright position the mediastinal contents are less compressed, and a catheter tip, appropriately positioned originally when supine, may ride higher into the mid-SVC. Our tendency therefore is to leave the catheter on the low side of the SVC-RA junction because of the thrombotic problems associated with short catheters, and taking into consideration that a 3- and 4-F silicone PICC and CVLs are very soft, thin, pliable catheters [5, 6, 11]. In our experience, we have had less trouble from “long” lines than “short” lines. Similar experience has been quoted by others [11, 12]. A short catheter, especially from the left, has insufficient purchase in the SVC to be secure, with the real potential to flip up into one or other innominate vein if left short. This may lead to a very real problem of thrombosis [12].

Some limitations of this paper include the fact that the numbers are too small to apply rigorous statistical analysis, and there were not equal numbers of patients in each age group and that single plane fluoroscopy was only performed in the venography sub-group. Because normal blood flow is what carries the contrast to the SVC-RA junction and venous flow is a low pressure system, we feel there is little chance of a jet phenomenon causing a jet effect in these patients that would effect the SVC-RA level. No difference was found between the level of the SVC/RA junction identified in either subgroup, suggesting a jet effect is not influencing the level. The vertebral bodies vary from 0.5 cm high in the neonate to 1.5–2 cm in the older child, but for each child the vertebral level acts as internal reference point. Given all these variables, we feel that the vertebral bodies and IVDS provide a visible, easy to use, and moderately accurate landmark sufficient for this purpose.

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