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PICTORIAL ESSAY

Central venous catheters in premature babies: radiological evaluation, malpositioning and complications

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Abstract Central venous catheters are important in the care for prematurely born children in the neonatal intensive care unit. The purpose of this pictorial essay is to illustrate correct positioning, malpositioning and possible complications of such devices.

Keywords Premature infants · Central venous catheters · Malpositioning · Complications

Introduction

Central venous catheters (CVCs) are routinely used in neonatal intensive care units (NICU) for parenteral nutrition, fluids and pharmaceuticals. Percutaneous catheters were first used by Shaw in 1973 [1], and they are now widely used [2].

Correct positioning of CVCs is of the upmost importance for avoiding complications [2–5], and the radiologist is central in this evaluation. Knowledge of the prenatal and postnatal anatomy of the circulatory system is required.

CVCs may be inserted into an arm, jugular, scalp or lower limb vein. There are four main groups of CVCs: peripherally inserted central catheters (PICCs), temporary non-tunneled CVCs, permanent or long-term tunneled CVCs, and implantable ports [2–7]. PICCs are preferred in children due to ease of insertion, multiple access sites, safety, low procedural stress, good clinical results and easier access [5]. CVCs are contraindicated in case of skin infection at the site of insertion, bacteraemia or septicaemia [2, 5]. The optimal positioning of the CVC tip is in the middle of the right atrium (RA) or in the distal third of the superior vena cava (SVC), or inferior vena cava (IVC) very close to the RA when inserted via a lower limb vein. Tip position is a source of debate and controversy both in children and adults [2, 4, 6, 8] (Fig. 1). The CVC tip may be difficult to locate when blurred by the heartbeat. It may also change position due to changes in the child's posture or arm position [6, 9, 10]. It may also migrate [11] (Fig. 2). Chest radiographs are used to assess CVC position. Due to very fine catheter dimensions, opacification by injection of contrast material may be necessary [12]. US may satisfactorily establish the catheter position and possible complications, such as heart tamponade or thrombus [3, 13–16].

The aim of this essay is to review our experience with CVCs in a large NICU.

Catheters

In our institution, polyurethane catheters with a 2-F bore (Nutrilene, Vygon, France) were used in very low

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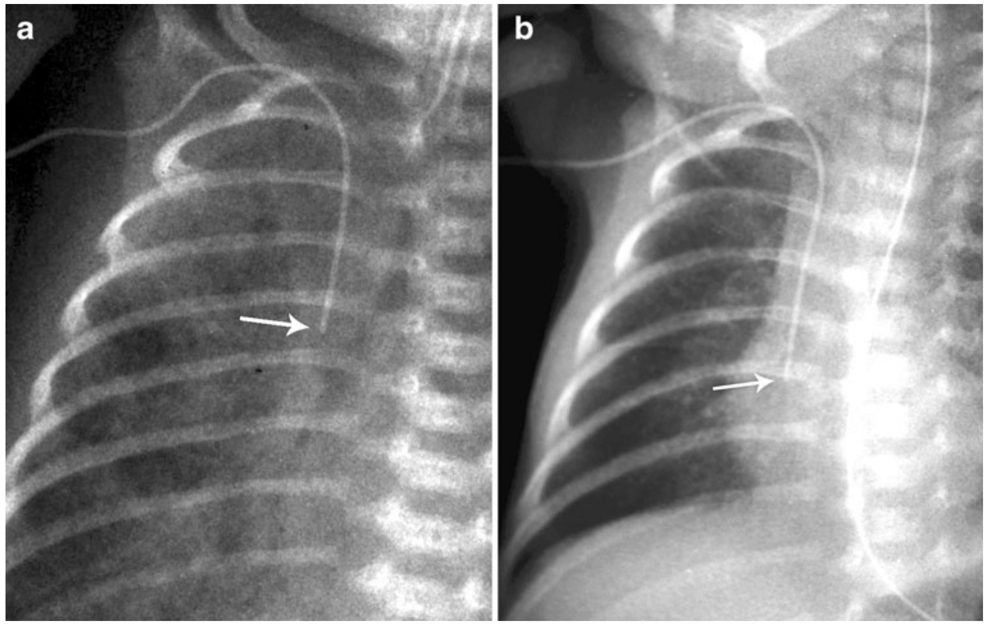

Fig. 1 Correct position of the tip (*arrows*) of the central venous catheter within the distal portion of the superior vena cava (**a**) and within the proximal right atrium (**b**)

birthweight infants and polyurethane catheters with a 1-F bore (Premicath, Vygon, France) in extremely low birthweight premature infants. Notwithstanding the manufacturers' classification of CVC lines as radiopaque, contrast media (Iopamiro 300; Bracco, Milan, Italy) was used in a sufficient amount to opacify the catheter to properly assess its position, in accordance with published evidence [2, 12].

Malpositioning

Some CVC malpositioning was seen as coiling of the catheter within the upper trunk vessels, i.e. in the axilla, in the SVC (Figs. 3, 4 and 5) or in other thoracic vessels (Figs. 6, 7, 8, 9, 10 and 11). CVCs may also be seen traversing the RA from the SVC to enter the IVC or the hepatic veins (Figs. 12, 13).

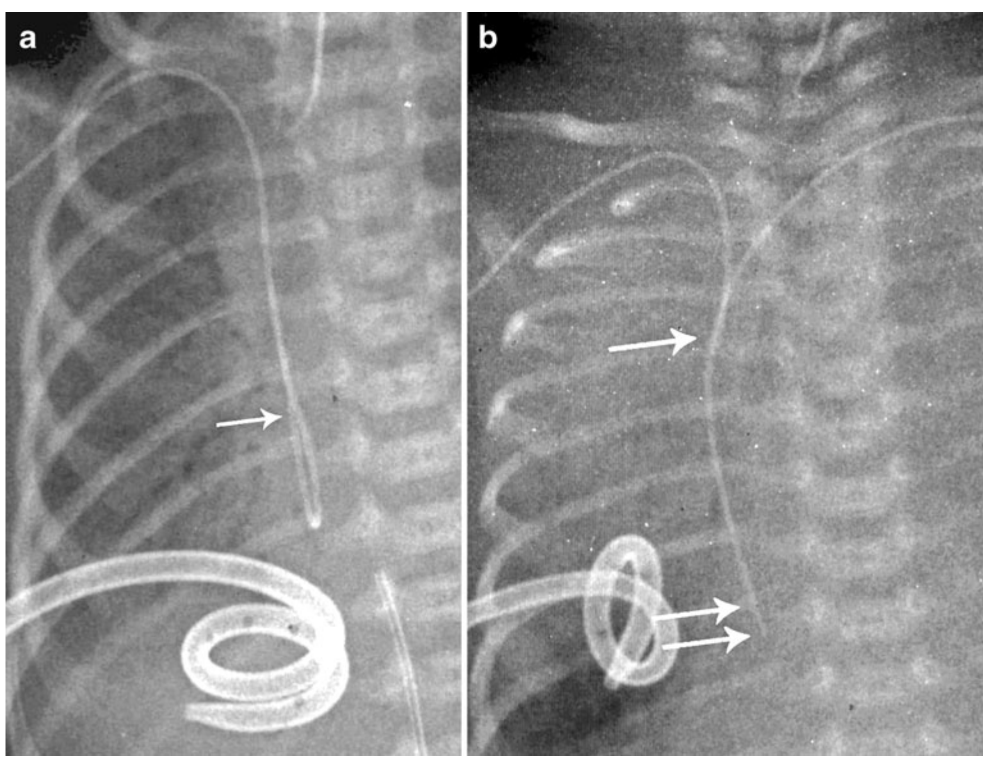

Fig. 2 Coiling. **a** The tip of the central venous catheter (CVC) is coiled in the right atrium and its tip is turned upward (*arrow*). **b** The CVC has been pulled back and now has its tip in the superior vena cava (*arrow*). A new catheter from the left is too low in the right atrium (*double arrows*)

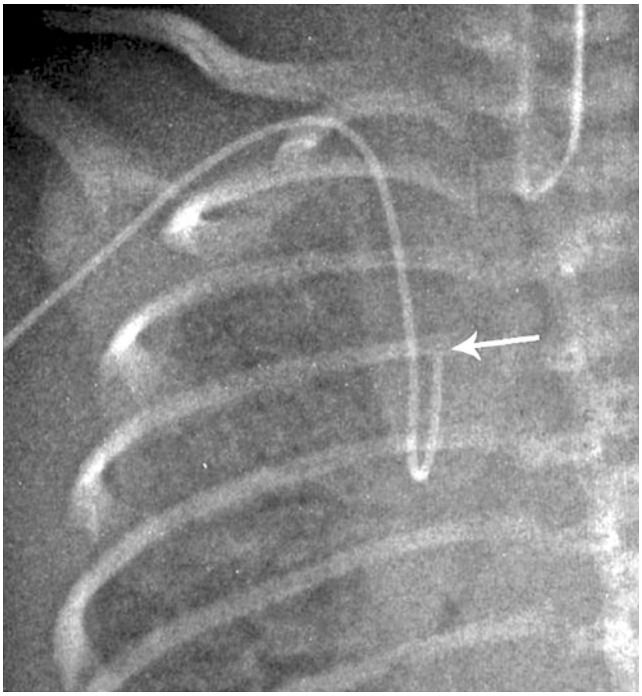

Fig. 3 The central venous catheter is coiled in the superior vena cava (SVC), with its tip (*arrow*) pointing upward

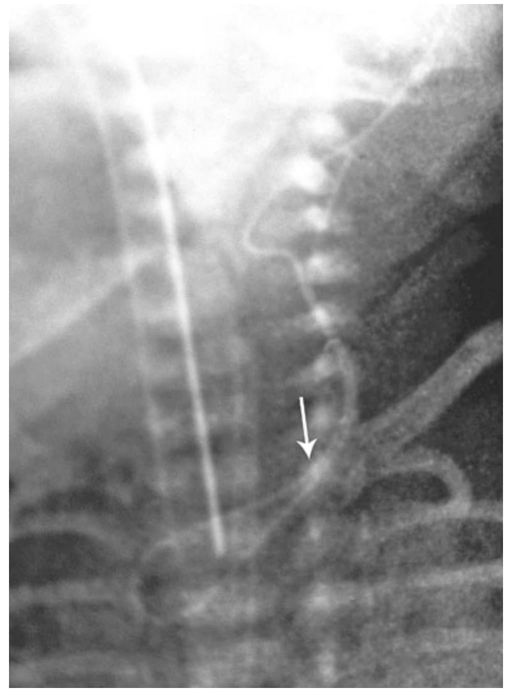

Fig. 5 A central venous catheter from a scalp vein runs via the jugular and subclavian veins to the superior vena cava (SVC) where it loops back on itself to reach the middle portion of the subclavian vein (*arrow*)

We have also seen CVCs entering the pulmonary artery outflow tract, looping back on itself with its tip within the RA (Fig. 14), others looping back within the RA with their tips against the endocardium (a position regarded as dangerous [8]) (Fig. 15), and, very uncommonly, looping back with their tips high in the right jugular vein (Fig. 16).

Contrast extravasation

Malpositioned CVCs are prone to extravasation. We have seen extravasation of contrast medium in the left armpit following the rupture of the catheter (Fig. 17). In another child vein transfixion by the catheter caused extravasation into the soft tissues of the right elbow/distal humerus (Fig. 18). Opacification of a subsegmental lobe of the

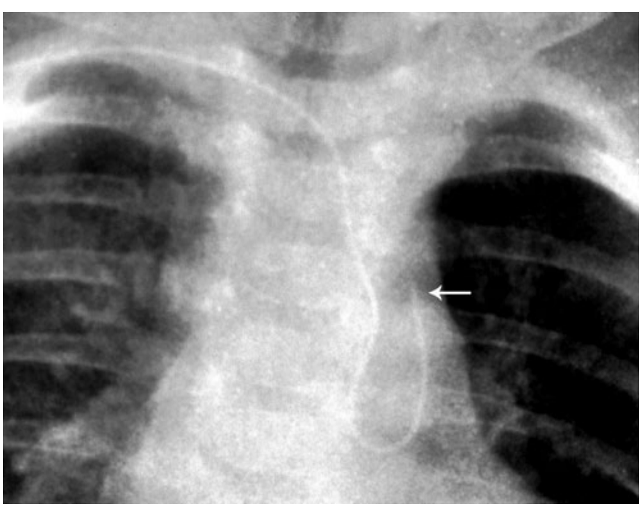

Fig. 4 The tip (*arrow*) of the central venous catheter is coiled in a left superior vena cava

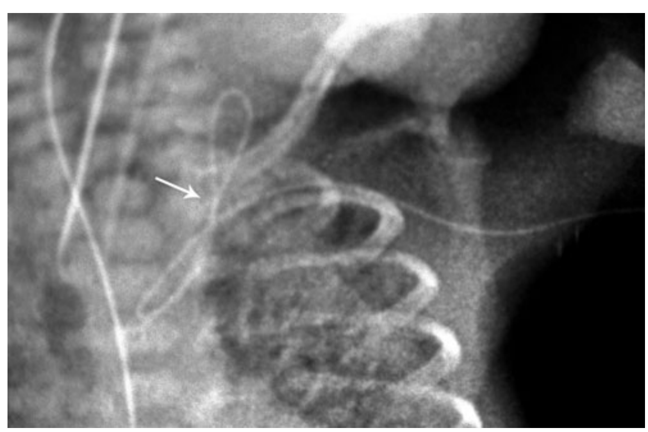

Fig. 6 A central venous catheter from a left arm vein runs via the subclavian vein, loops back on itself and then continues into the left jugular vein where it twists again. The tip (*arrow*) is finally located in the distal subclavian vein

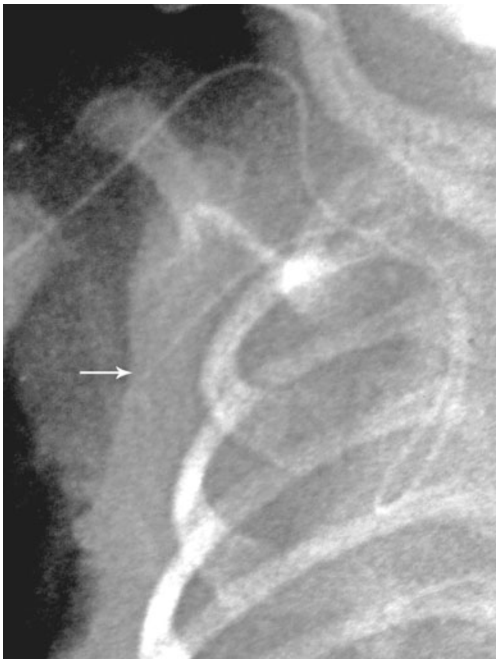

Fig. 7 A central venous catheter from a right arm vein coils in the upper vena cava and runs back to terminate in the axillary vein (*arrow*) via the subclavian vein

left lung was seen in one child where the CVC tip was located within a left pulmonary artery branch (Fig. 19).

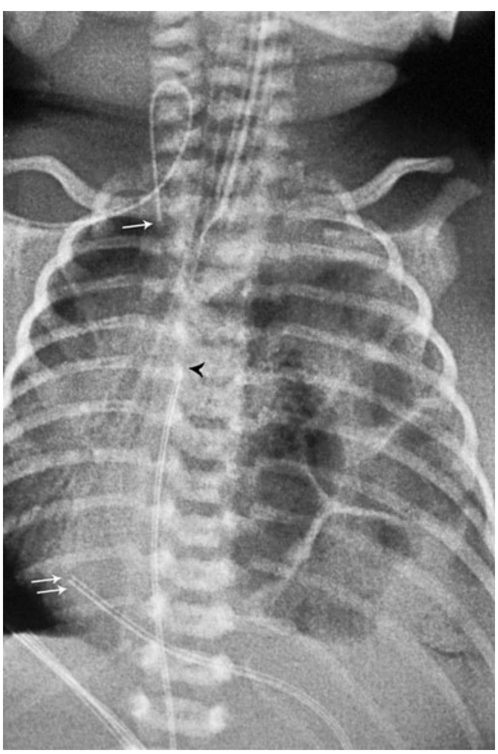

Fig. 8 A central venous catheter has a loop in the right jugular vein and its tip in the right subclavian vein (*arrow*). In addition, due to a left diaphragmatic hernia, the umbilical venous (*double arrow*) and arterial (*arrowhead*) catheters appear displaced to the right

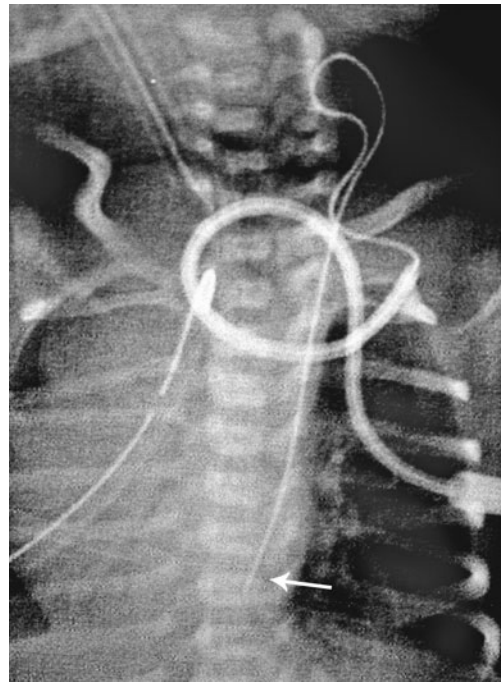

Fig. 9 Chest radiograph following oesophageal atresia repair shows a right-sided heart. The central venous catheter forms a large loop within the jugular vein and continues within a left superior vena cava into the coronary sinus (*arrow*)

We have also seen retrograde opacification of the left diaphragmatic and internal mammary veins via a malpositioned CVC (Fig. 20) and left subclavian vein

Fig. 10 Chest radiograph following oesophageal atresia repair. The central venous catheter runs straight from the left arm vein to the distal jugular vein (*arrow*)

Fig. 11 The central venous catheter tip (*arrow*) has relocated to a left thoracocostal vein via the axillary vein

opacification from a right-sided CVC crossing the mediastinum (Fig. 21).

Fig. 12 The tip (*arrow*) of the central venous catheter is located in a hepatic vein

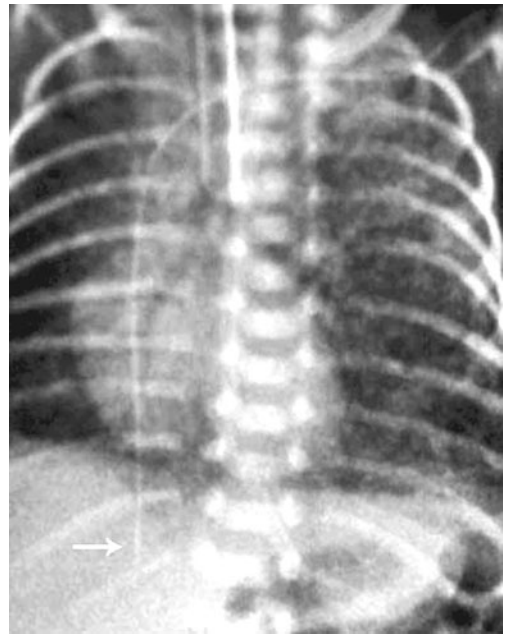

Fig. 13 The tip (*arrow*) of a central venous catheter from a left arm vein is within the inferior vena cava

Complications

In two children with symptoms of desaturation, bradycardia and hypotension, a cardiac tamponade due to the malposition and coiling of a catheter in the right atrium was diagnosed by an increased heart size on radiographs and pericardial fluid on US (Fig. 22). A US-guided pericardial puncture drained clear fluid that was similar to the perfusion solution. Both children recovered.

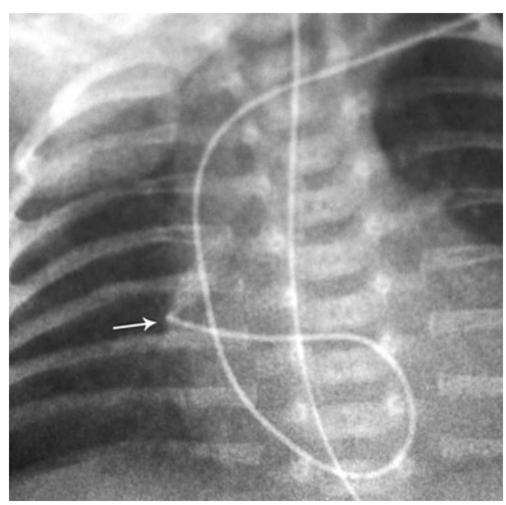

Fig. 14 A central venous catheter from a left arm vein coils in the lower right atrium and runs back with its tip (*arrow*) pointed to the chamber wall, which is considered dangerous due to the risk of cardiac perforation

Fig. 15 A central venous catheter entered the pulmonary outflow tract, then loops back on itself into the right ventricle (*arrow*)

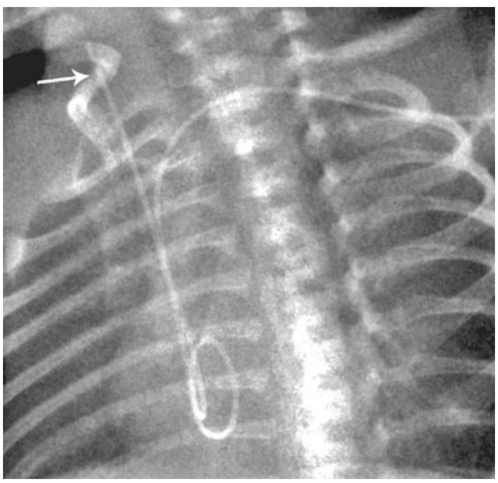

Fig. 16 A central venous catheter from a left arm vein, excessive in length, coils back on itself in the right atrium to terminate (*arrow*) in the right jugular vein

Fig. 17 Central venous catheter tip in the right axillary vein (*arrow*). Contrast medium is seen within dilated veins and extravasated into the axillary soft tissues

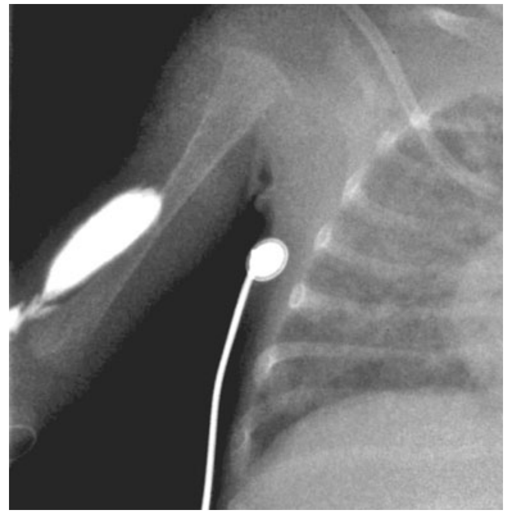

Fig. 18 Extravasated contrast medium pools within the soft tissues of the right arm tissues

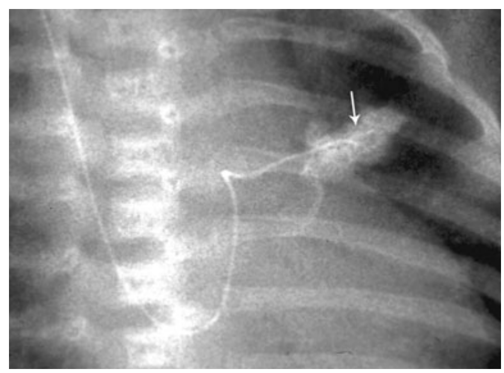

Fig. 19 The central venous catheter tip is located in a subsegmental left pulmonary vein and contrast medium opacifies the surrounding lung parenchyma (*arrow*)

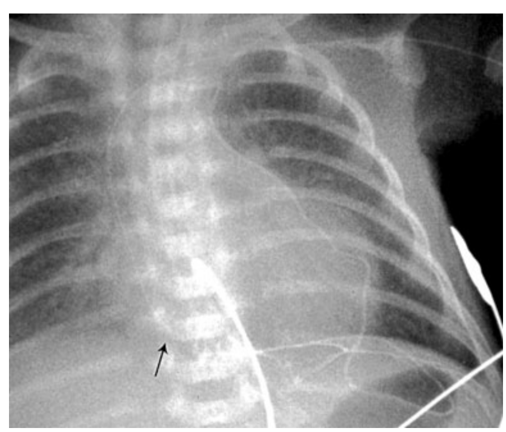

Fig. 20 The tip (*arrow*) of the central venous catheter is in the right diaphragmatic vein. Contrast medium opacifies the left diaphragmatic and internal mammary veins

Fig. 21 From the right arm vein, the central venous catheter crosses the mediastinum veins and enters the left subclavian vein, which is partly opacified by contrast medium (*arrow*)

As a late consequence of long-lasting indwelling CVCs, SVC wall calcifications were observed in one child (Fig. 23).

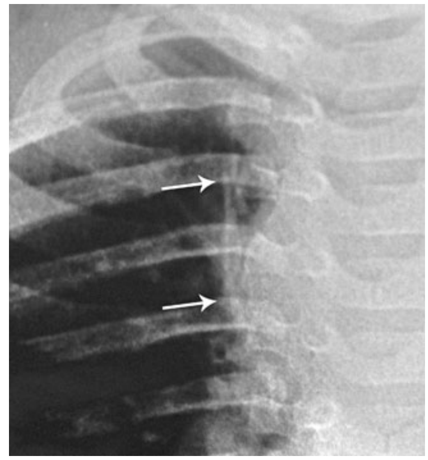

Fig. 23 Superior vena cava wall calcification (*arrows*) due to previous indwelling central venous catheter

Discussion

The use of CVCs is essential in the clinical handling of very small preterm infants (in our experience about two-thirds of newborns admitted to our NICU require these devices), yet they are not devoid of malpositioning and other complications.

Malpositioning is more frequent when a CVC is placed without direct imaging guidance [5]. Coiling, back-looping and tip in more peripheral veins is clearly improper. However, the lack of consensus on the optimal location of catheter tips may sometimes make the radiological assessment difficult [2, 4, 6, 10, 17].

The most frequent malpositioning in our experience is within thorax vessels such as the axillary, subclavian, jugular and brachiocephalic veins, in the IVC, right ventricle and pulmonary arteries.

CVC-related complications predominantly correspond with the type of catheter used and its site of entry [2, 4, 18]. PICCs introduced in an upper arm vein have significantly lower risk of mechanical, septic or thrombotic complications compared with PICCs inserted through scalp or leg veins [3, 5]. There has been much debate about the CVC tip position as it relates to the occurrence of complications. Cartwright [2] advocates the RA location, while a review by Vesely [6] agrees with FDA recommendations [19] and supports placement within the SVC, particularly in adults. A recent report by Ramasethu et al. [4] discussed pros and cons of previously reported approaches [2, 20, 21], comparing these with a strategy based on CVC positioning just above the SVC/RA junction or at the IVC/RA junction when insertion is from the upper extremity or lower extremity/umbilical vein, respectively [3, 4].

In case of improper position locking, CVCs may not only change their tip position due to the child's arm, head and trunk movements [2, 5, 9, 10], but they may also migrate from a position outside the heart [2, 21] into the heart cavity which may cause cardiac perforation [2, 5, 9, 19]. Migration of jugular or subclavian venous catheters into inferior tributaries of the brachiocephalic veins or into the azygos

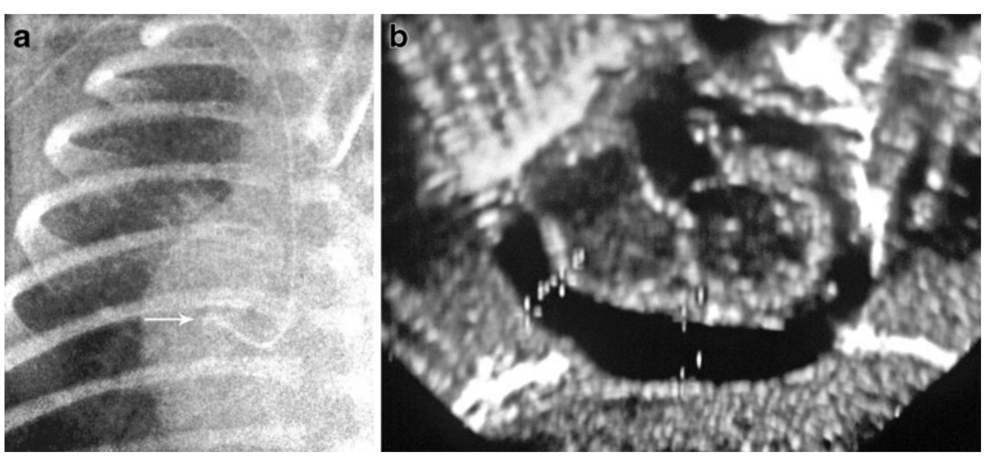

Fig. 22 Cardiac tamponade as a complication to central venous catheter. **a** The heart is enlarged and the tip (*arrow*) of the coiled catheter points toward the right atrial wall. **b** Sonogram shows a large amount of anechoic fluid (between markers) in the pericardium

vein has also been reported [11]. Other reported complications during catheter insertion include pneumothorax [16, 18], pleural effusion [2, 21], haemothorax and arterial puncture [18], ascites (tip in IVC) [22], abdominal wall oedema and abscess [23], pericarditis (tip in SVC) [24], parenteral nutrition extravasation into the lung following pulmonary artery and right bronchus perforation [25], paraplegia and myoclonus (tip to the ascending lumbar vein) [26], perforation of the kidney (catheter inserted from the femoral and saphenous veins) [27], internal jugular vein thrombosis [15], SVC syndrome [28], subclavian artery pseudo-aneurysm [29] and cardiac tamponade from the catheter tip entering the RA [4, 17, 21, 30–32] or right ventricle [33] due to the thin heart wall in premature infants [8].

Assessment of CVC position is crucial, but not always feasible in NICU babies, e.g., due to lack of portable fluoroscopic equipment, or risk associated with the required radiation dose. In our experience, CVC position needs to be ascertained by opacification of the entire lumen with a nonionic iodinated contrast agent unless the catheter is sufficiently radiopaque on plain radiographs. US may be very useful in this endeavour, especially if coupled with colour Doppler, and also enables detection of rare complications such as pneumothorax [16] or more frequent complications such as thrombi around the tip of the catheter or pericardial fluid [2, 14, 15].

Conclusions

In our experience, malpositioning of and complications to CVCs were infrequent. In most cases these represented minor problems in the overall care. Nevertheless, in a few cases, they represented significant risk. Caution and proper expertise is required for the safe employment of CVCs in preterm infants, and adherence to existing guidelines for placement, assessment and maintenance is essential. Our review highlights that CVC positioning must be carefully ascertained on chest (or other relevant) radiographs, stressing the role of the radiologist in the management of CVCs.

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