9 Neonatal Vascular Access

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Abstract

Advances in the medical and surgical management of neonates are often predicated upon secure vascular access. Requirement for vascular access may be for physiological monitoring (arterial or central venous pressure), direct treatment (antibiotics, chemotherapy), supportive therapy (nutrition, transfusion, dialysis, ECMO), diagnostic radiological, and procedural purposes (drainage of CSF or chyle, minimally invasive cardiac interventions). It is important for the surgeon to have a broad working knowledge of this field, as, given the multidisciplinary nature of modern neonatal intensive care, the options for and scope of vascular access are expanding alongside the number of subspecialties with interests and relevant skills in this area.

Keywords

Vascular access • Central venous catheter • Newborn surgery

9.1 Introduction

Advances in the medical and surgical management of neonates are often predicated upon secure vascular access. Requirement for vascular access may be for physiological monitoring (arterial or central venous pressure), direct treatment (antibiotics, chemotherapy), supportive therapy (nutrition, transfusion, dialysis, ECMO), diagnostic radiological, and procedural purposes (drainage of CSF or chyle, minimally invasive cardiac interventions). It is important for the surgeon to have a broad working knowledge of this field, as, given the multidisciplinary nature of modern neonatal intensive care, the options for and scope of vascular access are expanding alongside the number of subspecialties with interests and relevant skills in this area.

Despite its obvious importance, neonatal vascular access has yet to attract a large specific evidence base in support of its related practices. Therefore, as the subject is explored, important inferences will be drawn from the paediatric and also adult literature which might reasonably be considered to have a bearing on the sub-

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ject, or which might be worthy of future research to determine applicability to neonatal vascular access.

9.2 Historical Considerations

The history of intravenous access can be traced back to the seventeenth-century and the general description of the circulation by William Harvey. In the same century Sir Christopher Wren administered a potent mix of ale, opium and beer to dogs using a quill for intravenous access and a pig's bladder as a fluid reservoir. Access to the venous circulation became practical with the development of the hollow needle by Francis Rynd in 1845, and the use of these reusable steel needles continued into the 1950s. The modern IV catheter can be traced back to 1950s when the "Rochester plastic needle" was developed, rapidly to be superseded by the first generation of "over the needle" plastic catheters led by the Intracath™ (Beckton Dickinson 1957) and then in 1964, by the Angiocath™ [1].

Dr. Latta described the use of an IV solution for the treatment of cholera in a letter to the Lancet in 1832. This intravenous rehydration therapy saved thousands of lives in the Paris cholera epidemics of 1832 and 1849. Turning to intravenous nutrition, Elman and Weiner reported pioneering nutritional experiments in 1937 using intravenous infusions of carbohydrates and protein hydrolysates in adults. The major difficulties encountered were loss of peripheral access and the large volumes of fluid required to even approach provision of adequate calories. Further important advances in understanding the physiology of protein calorie malnutrition arose out of the horrors of World War II, including the appreciation of gut mucosal atrophy in starvation and the potential for reversing this process and inducing mucosal proliferation with "intravenous feeding". The modern approach to total parenteral nutrition (TPN) was developed in the Harrison Department of Surgical Research at the University of Pennsylvania initiated in the 1940s by Harry Vars, later championed by Jonathon Rhodes and finally "perfected" by Stanley Dudrick, who was the first to demonstrate in 1966 that reliable long term nutritional support could be provided using TPN in beagle puppies [2]. The same group applied this technique with spectacular success for nearly 2 years in an infant with ultra-short bowel syndrome [3]. The success of the Pennsylvania group was predicated both upon the development of a fat emulsion using cottonseed oil, and the development of polyvinyl central venous catheters which were biologically inert. (Central venous catheters in current usage are manufactured almost exclusively from silicon or polyurethane.)

The formal organization of neonatal intensive care began in the 1960s with the establishment of dedicated intensive care units and the development of technologies for neonatal ventilation, central venous access and TPN. During the subsequent half century significant advances have been made in improving the morbidity and mortality of premature infants. Much emphasis is rightly placed on evidence-based approaches to medical care, and an attempt has been made in the remainder of this chapter to emphasize these developments with respect to neonatal vascular access.

9.3 Commonplace Neonatal Vascular Access Procedures

Although the majority of the procedures outlined below are the prerogative of the neonatologist, a passing understanding is the minimum expected of the surgeon who might interfere with such access in the event of laparotomy, or who might be called upon to assist in the management of an occasional complication resulting from vascular access procedures.

9.3.1 Umbilical Venous and Arterial Cannulation

The neonatal umbilicus provides immediate reliable short term access to both arterial and venous circulations. The umbilical arteries and vein can readily be dilated to allow passage of a polyurethane catheter in the first 24 h of life. Measured graduations on the catheter allow for positioning which is later confirmed radiologically (Figs. 9.1 and 9.2). The catheters are secured by suture to the umbilical stump and fixed by tape to the abdominal wall.

With respect to umbilical venous catheterization (UVC), the formula for inserted catheter length (cm) is estimated by ***weight (kg) × 1.5 + 4.5 + length of cord above the skin***. The catheter tip should lie centrally at the level of or just above the diaphragm ie. within the inferior vena cava, but outwith the cardiac silhouette [4, 5]. Heparinization of the infusate is unnecessary as volume alone is usually sufficient to maintain patency. A study of 142 neonates with UVC's identified accurate central positioning in 75% and identified four life threatening complications (pericardial and pleural effusions, rupture into the liver parenchyma and rupture into the abdominal cavity causing ascites) [6]. There is now considerable experience with multi-lumen umbilical catheters suggesting that their use is associated with a significant reduction in the need for additional peripheral intravenous catheters, albeit at the price of increased catheter malfunction [7].

In the case of umbilical arterial catheterization (UAC), similar catheters are used (3Fr for babies <1500 g, 4Fr 1500–2000 g, and 5Fr >2000 g). The required insertion length (cm) is estimated by the formula ***weight (kg) × 3 + 9 + length of cord above the skin surface*** [5]. The preferred tip position is "high" (thoracic aorta T6—T9), [5, 8–10] although a "low" tip position *(abdominal aorta L3–4)* is also acceptable [10, 11]. A high position is thought to be associated with a lower incidence of ischaemic complications. Patency is ensured by continuous infusion of heparinised 0.45% saline (0.5 IU/mL). Circulation in the lower extremities should be documented hourly, and signs of significant vascular compromise should prompt rapid removal of the catheter. Damping of the arterial trace is often the first indication of an impending thrombotic problem and if persistent should prompt consideration of catheter removal.

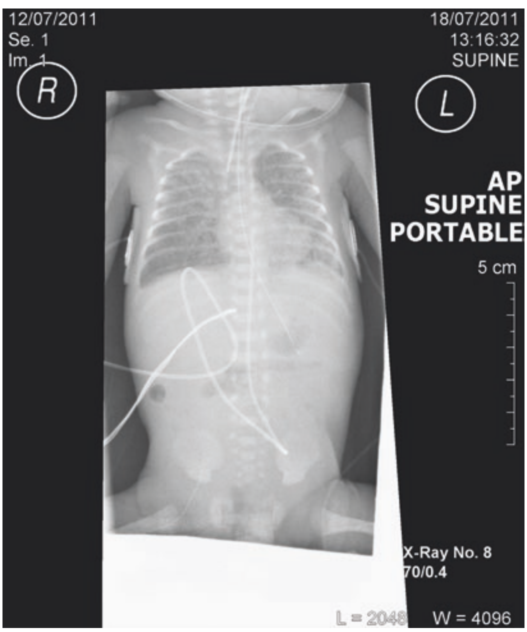

Fig. 9.1 Umbilical arterial catheter placed in ventilated neonate with tip in high position in thoracic aorta (T7–T8)

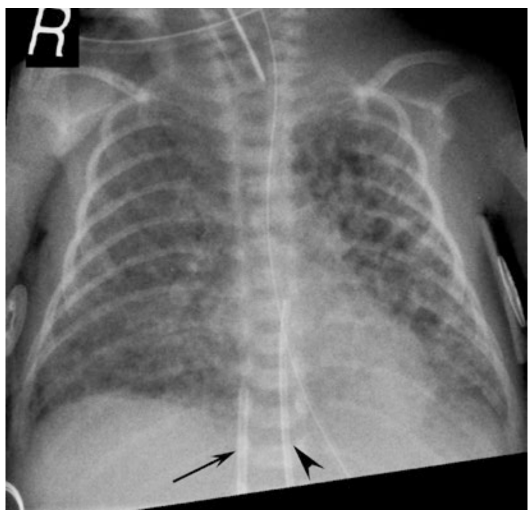

Fig. 9.2 Neonate with respiratory distress syndrome and unilateral pulmonary interstitial emphysema. The umbilical venous catheter (UVC) is positioned optimally and terminates at the diaphragmatic IVC (*arrow*). The UVC should not terminate in either the liver or the heart. The umbilical arterial catheter (arrowhead) lies to the left of the UVC and should terminate between T6 and T9 vertebral levels. *Image courtesy of Dr. Gurdeep S. Mann MRCP FRCP, Liverpool Women's Hospital*

These procedures are often used in emergency neonatal resuscitation. Infection and major vessel thrombotic complications become more common with increasing line longevity. Necrotizing enterocolitis is also associated with umbilical catheterization and when suspected, is similarly an indication for prompt line removal. Treatment of UAC-related thrombosis includes consideration of unfractionated (UFH) or low molecular weight heparin (LMWH) for 10 days. If life-, limb-, or organ-threatening symptoms result from UAC-thrombosis, thrombolysis with tissue plasminogen activator (tPA) [10], or even the option of surgical thrombectomy should be considered [12]. Currently there is no RCT evidence comparing thrombolysis with anticoagulation so firm conclusions about the relative merits of each treatment are impossible [13]. The risk of these medical interventions must be carefully weighed against the risk of haemorrhagic problems, particularly intra-ventricular haemorrhage.

9.3.2 Percutaneous Central Venous Cannulation

Peripherally inserted central lines (PICC's) are the preferred elective form of medium term vascular access in the premature neonate. The favoured routes are via the antecubital (basilic/cephalic), scalp (superficial temporal), or lower limb (saphenous) veins, although any peripheral vein can be used. Having accessed the vein, a long polyurethane catheter is "floated" into a central vein over a guidewire and the catheter tip position confirmed radiologically. There is clear guidance that the tip position of PICC lines should be outwith the cardiac silhouette to avoid the risk of tamponade [14]. The small diameter of these catheters often necessitates the use of radiological contrast to confirm tip position (Fig. 9.3).

The longevity of PICC lines is variable and is dependent on the neonate's co-morbidities in addition to prematurity. Judicious use of PICC lines includes appropriate and timely removal in the event of catheter complications, and the use of simple venous cannulae to "bridge the gap" to another PICC line insertion, when the neonate might have been compromised with respect to vascular access

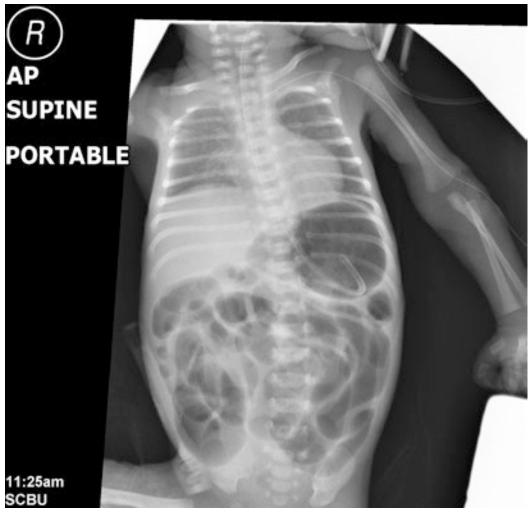

Fig. 9.3 Radiograph showing PICC line inserted via left cephalic vein with tip positioned optimally in the distal SVC but outwith the cardiac silhouette

(usually as a result of sepsis). This type of management in extremely premature neonates often obviates the need for surgical venous access and is a tribute to the skill of many a neonatologist.

There is increasing experience with central venous line insertion via internal jugular [15], femoral [16] and subclavian routes. Those with particular familiarity with the Seldinger approaches in these access locations often tunnel the catheter to the site of percutaneous access, thereby adding an extra level of protection from infectious catheter complications. There is an increasing willingness amongst surgeons to abandon the traditional open techniques of central venous access in favour of the percutaneous route, as it is thought that this approach is more likely to preserve the vein for future use. NICE guidelines now dictate that real time 2D ultrasound is mandatory (a gold standard) to assist catheterization via jugular (Fig. 9.4) and femoral routes in neonates over 3 kg, and that the operator (Fig. 9.5) should be appropriately trained in using ultrasound for the procedure [17]. A meta-analyses has been published which failed to show an advantage for US-guided as opposed to landmark insertions [18], but the patient base for this study was heavily weighted towards cardiac anaesthesia and as such is probably not completely representative of the population at large. This paediatric

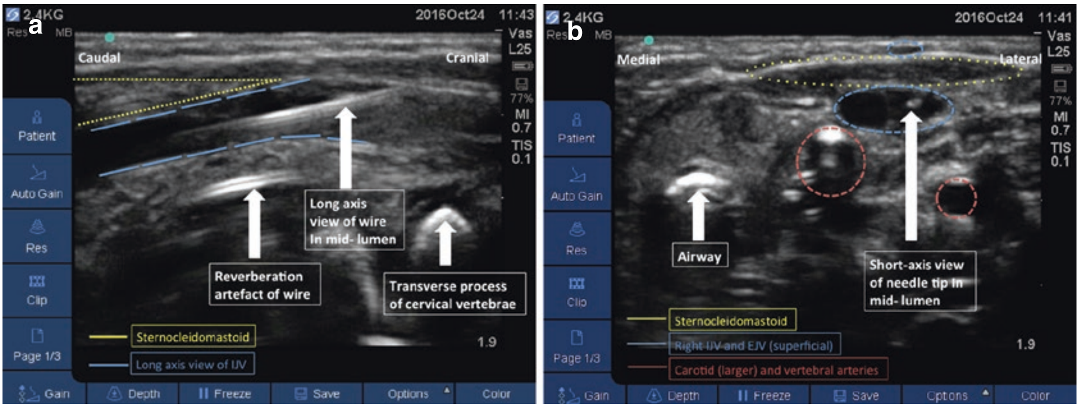

Fig. 9.4 (**a**) Ultrasound image of right side of neck in a 2.4 kg neonate. Note the proximity of significant other structures and the IJV midpoint is only 5 mm from skin. (**b**) Ultrasound image of right side of neck in a 2.4 kg neonate. Note the wire from a Seldinger CVP kit passing down the mid lumen of IJV. The wire can be followed distally into the thorax indicating correct placement. What cannot be appreciated from these static images is the significant compression of tissues that occurs during needle advancement. *Images courtesy of Dr. Peter Murphy, Consultant Anaesthetist, Royal Liverpool Children's Hospital NHS Trust*

Fig. 9.5 Shows the technique of US-assisted venepuncture of the internal jugular vein. The operator uses the US probe to locate the vein and to follow continuously the progress of the needle tip/guide wire throughout the procedure. *Images courtesy of Dr. Peter Murphy, Consultant Anaesthetist, Royal Liverpool Children's Hospital NHS Trust*

Fig. 9.6 Landmarks for percutaneous subclavian venous access. The insertion point is inferior to the clavicle at the junction of the medial two thirds with the lateral third of the clavicle (*arrow head*). The needle is advanced medially and cranially skirting just inferior to the clavicle and superior to the first rib, aiming in the direction of the suprasternal notch (*cross*)

meta-analysis and the "3 kg window" offered by NICE give some degree of flexibility to those favouring the "landmark approach" for smaller neonates (Figs. 9.6 and 9.7), but clearly a degree of familiarity with ultrasound-assisted central venous cannulation is becoming increasingly necessary.

9.3.3 Peripheral Arterial Catheterization

When arterial catheterization is required for invasive pressure monitoring outside the first 2 days of life, peripheral arterial cannulation is indicated. The radial and posterior tibial arteries are the preferred choice since catheterization of fem-

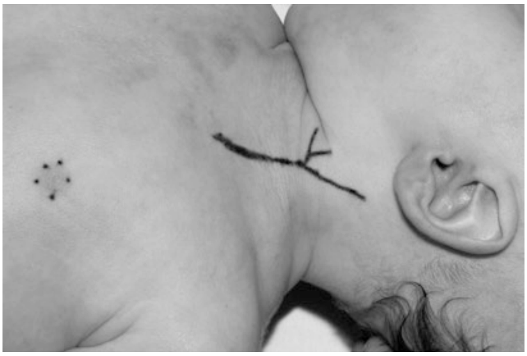

Fig. 9.7 Landmarks for percutaneous internal jugular venous access. The insertion point is over the sternomastoid muscle at the junction of its distal third with proximal two thirds (*arrow head*). The needle is advanced in the direction of the ipsilateral nipple at an angle of 30° to the skin surface whilst aspirating the syringe to confirm successful venepuncture

oral or brachial arteries carries significant risk of limb threatening consequences from distal thrombotic complications. These risks should always be carefully weighed against the potential benefits. The use of ultrasound or cold light transillumination may offer considerable assistance to arterial cannulation. As with umbilical arterial catheterization low dose heparin infusions are necessary to maintain arterial patency. In the event of distal ischaemic changes it is necessary to remove the catheter immediately. Where these changes are progressive options include passive observation, anticoagulation with UFH or LMWH, and thrombolysis usually with tPA. Not infrequently the risk of the intervention in terms of haemorrhage outweighs the potential benefit and non-viable tissues are frequently left to demarcate over time into dry gangrene before consideration of formal amputation.

9.3.4 Surgical Venous Access

As discussed earlier, technological improvements with catheters, new formulations of TPN, and the skills of both neonatologists and allied practitioners mean that surgical involvement in neonatal venous access is by no means inevitable even in the setting of extreme prematurity. However with increasing difficulty of access, requirement for "specialist" access (haemodialysis or ECMO), or when prolonged venous access is likely in a neonate undergoing surgery, surgical central venous catheterisation becomes mandatory. Additionally, when undertaking operative management of necrotising enterocolitis, complex meconium ileus or neonatal tumours (e.g. sacrococcygeal teratoma), a significant transfusion requirement may be anticipated. Under such circumstances it is advisable to insert a surgical venous catheter which allows for rapid volume expansion in the event of brisk haemorrhage.

Surgical central venous access is a routine procedure in a busy neonatal service and, although an excellent "training" operation, should not be undertaken without appropriate pre-operative planning, and meticulous attention to detail during surgery and in post-operative line management.

9.3.4.1 Pre-Operative Planning

As with any procedure undertaken under general anaesthetic, communication between neonatal, anaesthetic, surgical, laboratory, radiography and nursing personnel is vital. Clotting abnormalities should be corrected where possible and platelets should be available for peri-operative infusion should the platelet count be low ($<75 \times 10^9$/L). The size and type of line inserted, and whether single- or dual-lumen, both require careful consideration. A detailed knowledge of the vascular access history, and any requirement in the future for complex cardiac surgery will inform the choice of potential access sites. Clinical examination is mandatory as the sick neonate may have loss of epithelial integrity in neck flexural creases, or rarely a tracheostomy, which might similarly increase the risk of catheter infection at the time of surgery. Such considerations may suggest the use of (normally) second choice venous access sites.

Although urgent venous access may be required, where possible, surgery should not be undertaken without getting control of any prior catheter-related (or other) focus of sepsis, to avoid seeding microorganisms onto the newly inserted surgical line. Previous use of the intended vascular access site is an indication for vascular imaging if the clinical situation permits. Ultrasound will determine patency of the relevant access vein but cannot provide information concerning "central run off". In practice, this is rarely a problem unless the central veins have been repeatedly accessed or there is clinical evidence of SVC or IVC thrombosis. Under such circumstances magnetic resonance venography (MRV) would be advisable to avoid predictable central access failure and consequent prolonged surgery.

9.3.4.2 Surgical Procedure: Open Technique

The internal jugular vein is most commonly the access vein of choice. The external vein is often useful but is less reliable in terms of achieving reliable access to the SVC. The procedure is performed supine under general anaesthesia, with both modest neck extension and the face turned away from the chosen side of access to expose the anterior and posterior triangles with the intervening sternomastoid muscle. A small transverse incision is made in the lower third of the neck over sternomastoid. Its two heads are split to reveal the internal jugular vein within the carotid sheath. The vein is controlled with an appropriately sized monofilament or silastic "sloop" (Fig. 9.8), taking care to handle the vein directly as little as possible as it readily undergoes venospasm. The catheter is tunnelled from the anterior chest to the cervical incision. Cutting the catheter to the appropriate length is a matter of judgement, but using the inter-nipple line as a guide, it usually needs to be trimmed a variable length above this. The venotomy can be made either with scissors or a venepuncture needle in an attempt to avoid the need for suture closure with fine prolene (Fig. 9.9). After passing the catheter, intra-operative fluoroscopic screening is required to determine the position of the catheter tip often with the aid of a bolus of radiological contrast medium should the catheter be smaller than 4.2Fr. The catheter is secured at the exit site by suture fixation and dressings. Access to the inferior vena cava is usually achieved using the saphenous vein just proximal to where it joins the femoral vein. It is important to control other tributaries of the sapheno-femoral junction to prevent the catheter from being misdirected. Other routes include the inferior epigastric vein and the external iliac vein approached extraperitoneally.

The literature concerning optimum tip position is reviewed in more detail later. In routine open surgical vascular access the "distal SVC to proximal atrium" (for upper extremity access) has been recommended [19], although this remains highly controversial [20]. When using lower extremity access the ideal tip position is in the IVC level with the base of the 12th thoracic vertebra (T12), corresponding to the diaphragmatic IVC.

Rarely surgical haemodialysis access is required in the neonate. The catheters (e.g.

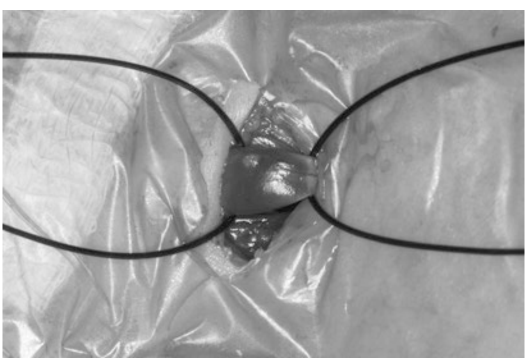

Fig. 9.8 Surgical exposure of the internal jugular vein between the heads of sternomastoid. The vein is "slooped" with silastic or monofilament suture prior to venotomy

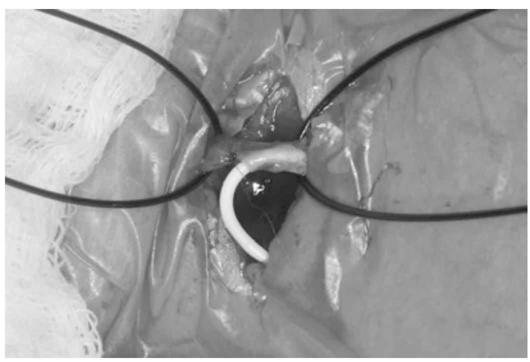

Fig. 9.9 The broviac line has been cut to length and passed via the venotomy to an estimated "junctional" position. The venotomy has been closed with fine prolene prior to confirming satisfactory tip position by fluoroscopy

Gamcath®) which are used for this purpose are of necessity quite rigid and therefore cannot exit on the chest wall when the internal jugular vein is accessed. For this reason an open procedure tunnelling the catheter is technically challenging and therefore these catheters are best inserted percutaneously. (Permcath® catheters, which are sufficiently flexible to exit the chest wall, are too large for most neonates.) To achieve and maintain long term adequate flow in the haemodialysis circuit it is advisable to use the largest internal lumen possible, preferably accessing the internal jugular vein rather than other access sites [21], and many (including the author) would argue in favour of having the catheter tip position preferentially sited within the proximal right atrium.

9.3.5 Percutaneous Versus Open Central Access

There is a developing body of opinion which believes that percutaneous access is superior to the open surgical approach [19, 22]. Given the lack of trauma to the vein associated with percutaneous access, this is an eminently reasonable proposition, especially with respect to the risk of thrombotic occlusion and potential future re-use of the vein. However there is no good supportive evidence in the literature to favour one approach over the other.

9.3.6 Complications of Venous Access

Venous access is associated with many complications. However, the three most frequent are catheter infection which may progress to septicaemia, occlusive complications such as fibrin sheath/vessel thrombosis and mechanical catheter complications such as dislodgement, migration and fracture.

9.3.6.1 Catheter Infection

The potential for the introduction of infection at the time of catheter insertion provides the rationale for consideration of the use of prophylactic antibiotics and other aseptic precautions at surgery. Although there is currently no strong evidence in relation to neonatal central line associated bloodstream infections (CLABSI's), level B evidence supports the following interventions to reduce the risk of CLABSI associated with whole population administration of TPN via central venous catheters; tunnelled/implanted catheters (confirmed only in long term use), antimicrobial coated catheters (demonstrated only in short term use), single lumen catheters, peripheral access as opposed to central access, appropriate central venous insertion site choice (internal jugular preferred to femoral vein), ultrasound guided venous access, maximal barrier precautions, and use of 2% chlorhexidene as a skin antiseptic [19]. Whether or not the benefits of these interventions will prove to be transferable to the neonatal cohort, we advocate the use of 2% alcoholic chlorhexidene pre-operative skin preparation, occlusive (opsite) draping, and a "no-touch" catheter handling discipline. At the very least, this focuses the mind of the surgeon on the danger of introducing infection. Logic also suggests that accurate fast surgery, minimal tissue handling, and the reduction of theatre "traffic" may also mitigate against primary catheter sepsis.

Cochrane reviews of systemic antibiotic prophylaxis at the time of central venous access in neonates [23] and in adult patients [19, 24] do not recommend their routine use. It has been suggested that fluconazole prophylaxis might be of value in certain high risk neonates. However a recent review of the literature has concluded that no trial has demonstrated a significant reduction in morbidity or mortality [25]. Contrary to generally received wisdom [19], and that of a prior Cochrane review in neonatal practice [26], a recent large RCT investigated the addition of 0.5 IU/mL Heparin to TPN administered through neonatal long lines (the HILLTOP trial) and demonstrated a significant reduction of culture-positive catheter-related sepsis [27]. Heparin-bonded catheters have failed to show any benefit in preventing catheter-related infection in children [28]. The use of antibiotic/heparin "locks" has also been shown to reduce the risk of catheter-related infection in high risk groups [24, 29]. A neonatal study has recently recruited but not reported on the utility of a 15 min, 70% ethanol lock every third day. However, the benefit for neonates may be largely theoretical given that the requirement for continuous infusions effectively prevents the use of an antibiotic lock, or other form of lock for that matter.

Colonization of the exit site with microorganisms does not necessarily lead to invasive infection but provides a good rationale for tunnelling central catheters. It is advisable to monitor the skin flora at the exit site by regular swabs, thereby anticipating any invasive infection, and enabling active treatment of local cellulitis with an "informed choice" of intravenous antibiotics. There is no good evidence to suggest that any particular dressing is to be favoured in terms of preventing catheter-related infection [30]. Meticulous nursing care is essential both to keep the entry site infection free and to prevent the introduction of infection at the time of accessing the catheter. Where possible the line should not be used for routine sampling, and line interventions for treatment should be kept to the absolute minimum and performed with full aseptic technique. A Cochrane review investigating the use of in line filters has not conclusively demonstrated any benefit in terms of prevention of morbidity or mortality from introduction of secondary infection in neonates [31].

There is evidence that significant reductions in the incidence of CLABSI have been achieved in individual neonatal and paediatric intensive care units as a result of the implementation of "evidence-based catheter care bundles" [32]. This strategy postulates that CLABSI's result from lapses in technique at several levels of care [33]. Care bundles address multiple levels of intervention from insertion practice to daily line care. Level B evidence underlines the efficacy of such measures as; education and specific training, adequate hand washing policy, appropriate exit site care/dressing, hub disinfection/needle-free connectors, and regular changes of administration sets [19].

The incidence of catheter related sepsis is difficult to determine and depends critically on definition. The gold standard for line sepsis requires a positive culture from the catheter tip, once removed for presumed CLABSI. A positive blood culture, where the sample has been taken through the catheter, is a reasonable proxy, but does not exclude another potential source of blood stream infection. Exit site infection as evidenced by cellulitis or discharge of pus from the exit site may also be considered, but does not necessarily equate with colonization of the line and blood stream infection. Early diagnosis of CLABSI requires a high level of clinical suspicion and certainly should be considered in any neonate who is not "handling well". Changes in blood parameters such as C-reactive protein, liver function tests, white cell and platelet count, whilst all useful surrogate markers of infection, are frequently found to lag behind the onset of infection by 24 h or longer.

Quoted infection rates vary and are likely dependent on many variables. A recent large neonatal study of 294 peripherally inserted central catheters (PICC's) suggested a CLABSI rate of 17 per 1000 catheter days [34]. Another larger recent study of ultrasound guided percutaneous insertion of 500 Hickman® lines in children and neonates identified an infection rate of 3.2 per 1000 catheter days [22]. Local unpublished data from the author's institution of predominantly (87%) open surgical insertion of 336 central lines in children and neonates yielded an infection rate of 2.3 per 1000 catheter days. An exclusive study of 79 surgical neonates quoted a CLABSI rate of 9.9 per 1000 catheter days. A significant risk factor associated with CLABSI in this latter study was the presence of an intestinal stoma [35]. The inherent variability in the study populations, and variations in line type and mode of insertion, all conspire to make it difficult to draw firm conclusions about the factors that may be associated with neonatal CLABSI.

The commonest responsible organism is coagulase-negative *Staphylococcus* (representing 89% of blood culture isolations in a neonatal study [34]), thereby informing the choice of "best guess" antibiotic when treating suspected line sepsis. Other organisms such as coliforms are not infrequent culprits in surgical neonates. It has been suggested that translocation of these organisms from the neonatal bowel may be the cause of such infection. Provided the neonate is not unduly compromised by the suspected line infection, an attempt to "sterilize" the line with a prolonged course of antibiotics is usually the first line of treatment. Overwhelming line sepsis demands urgent removal of the line. Where infection is due to more aggressive pathogens such as fungal species, *Pseudomonas* and *Staphylococcus aureus*, primary removal of the line is probably the best option. Failure to eradicate the organism after two attempts at sterilizing the line is another indication for line removal. However, in the setting of precarious venous access, or when venous access is likely to be prolonged (e.g. short bowel syndrome), consideration should be given to changing the line down the same track with appropriate antibiotic cover. Using this approach, the same vein can be used repeatedly over prolonged periods. Persistent low grade sepsis in the presence of a central line mandates the exclusion of bacterial endocarditis by echo-cardiography, since the consequences of missing this diagnosis may be disastrous. Timing of further central access following significant catheter-related sepsis ideally requires that the infection is appropriately treated before further surgical catheter manipulations are attempted.

9.3.6.2 Occlusive Catheter Complications

The presence of a catheter evokes the formation of a fibrin sheath around it which can usefully be employed to facilitate re-use of the catheter track for line "exchange" (see above). Sometimes, a fibrin sheath forms around the intravenous part of the catheter which, if extensive, can occlude the catheter lumen. Even in high-flow central veins the catheter can be a prothrombotic stimulus, resulting in partial or complete venous occlusion. Instillation of tissue plasminogen activator (tPA) or recombinant urokinase into a blocked catheter may be sufficient to re-establish patency. Sufficient urokinase (5000 units/mL saline) to fill the dead space of the catheter is left in situ for 30 min before attempting to aspirate the line. This procedure may be repeated once before removing the line and investigating to exclude line-related thrombosis if patency has not been restored. If successful, a contrast study through the line may reveal a fibrin sheath or local thrombosis, and give information both on tip position and adequacy of catheter "run off". The use of heparin "locks" to preserve line longevity in relation to occlusion is only of value when the line is accessed intermittently. There is grade 1B evidence to recommend against the prophylactic use of heparin in children with central venous catheters [10]. Similarly neonatal studies do not support the use of heparin in TPN as prophylaxis against catheter related thrombosis [26]. The use of heparin-bonded catheters cannot currently be recommended to prevent thrombosis or occlusive complications [28]. The general literature emphasizes (grade B) that thrombotic problems are reduced if the smallest possible catheter lumen size compatible with therapy is chosen, if an ultrasound-guided insertion technique is employed, and if the tip position is at or near the atriocaval junction [19].

When a neonatal central venous line or umbilical venous line is associated with confirmed thrombosis it should be removed. Management options include initial anticoagulation (grade 2C) with UFH or LMWH, or radiological monitoring alone (grade 2C). If thrombus propagation is demonstrated over time, anticoagulation with LMWH is recommended (grade 1B) for a minimum of 6 weeks [10].

The incidence of neonatal venous thromboembolism (VTE) is difficult to determine accurately, but data from Dutch and German national registries suggest an incidence of 0.1-0.5 cases per 10,000 births. The presence of a central line is the single most important contributory factor. It is often difficult to relate mortality directly to VTE, but certainly there is an appreciable mortality including stroke from paradoxical embolus [10].

9.3.6.3 Mechanical Complications

There is no fool-proof way of securing a central venous catheter before the Dacron cuff (if present) is firmly incorporated into the subcutaneous tissue. Reliance is usually placed on some form of exit stitch and the catheter dressing. Not infrequently incorrect application of the catheter clamp to the non-reinforced part of the catheter results in fracture of the line. If sufficient undamaged external catheter is available distal to the fracture site, these can often be repaired with a commercially available kit. Prior to repair, the fracture site should be sealed with an adhesive clear dressing.

Extravasation of fluid into the subcutaneous tissue around the line track may similarly indicate fracture of the line or possibly occlusion due to a fibrin sheath (see above). A contrast study is indicated which usually identifies the underlying cause.

Removal of a central catheter can usually be performed under local anaesthetic at the cot side. This is not without risk and should not be left to the most junior member of the team. Usually the Dacron cuff can be dissected free via the entry site wound, but occasionally a second incision is required. Careful dissection on the fibrin sheath distal to the cuff allows the catheter to be retrieved. The major risk is cutting through the catheter beyond the cuff which might result in a catheter embolus (Fig. 9.10). Should this occur the retained catheter should be removed (size-permitting) by an interventional cardiologist using a snare inserted via the femoral vein.

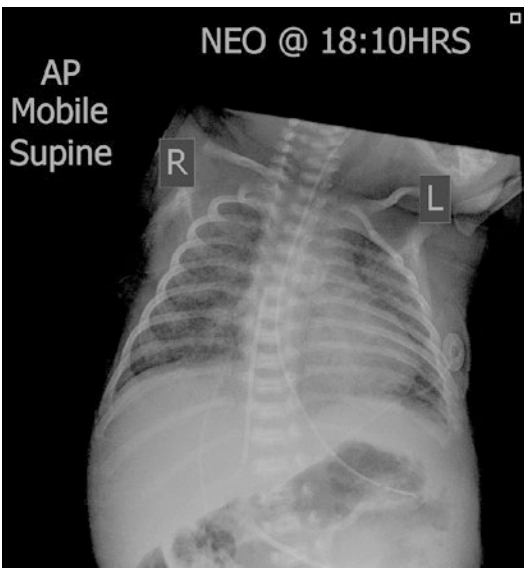

Fig. 9.10 Radiograph showing distal catheter embolus with the retained fragment free-floating in the right heart chambers following an unsuccessful attempt at removal. Such procedures should not be left to the surgical novice. This line was subsequently successfully snared and removed transfemorally in the cardiac catheter suite

9.3.6.4 Anatomical Variations

Variations in venous anatomy can trap the unwary. The most common of these is the left sided SVC. This structure drains into the coronary sinus and therefore a catheter tip lying in close relation to this structure should not be accepted. Occasionally manipulation of the catheter allows it to be directed through the innominate vein to the right SVC, but if this is not possible the attempt should be abandoned or the catheter left abnormally short as a temporizing measure.

Abnormalities of the inferior vena cava may result in dominant azygous or hemi-azygous systems. Neonates with congenital cardiac abnormalities may have significant abnormalities of venous drainage, and care needs to be taken not to encroach on the territory of the cardiac surgeon with respect to future cardiac surgical reconstruction.

9.3.6.5 Catheter Migration

There has been considerable debate about what constitutes an acceptable catheter tip position and consensus is by no means complete. The traditional approach has been to aim for a catheter tip position in the SVC. However, there is a body of expert opinion that emphasises improved performance and durability of a catheter if its tip is within the upper right atrium [20]. The European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines recommend a position in the lower third of the SVC, in a junctional position, or in the upper portion of the right atrium [19]. However, in a neonate the evidence probably supports a distal SVC tip position for PICC lines. Strictly applied this latter definition of acceptability leaves very little margin for error and probably results in many of these lines being left "short". Open insertions of central lines allow for greater control of final tip positions. Although the ideal tip position under such circumstances would be distal SVC or "junctional", many surgeons (including the author) would accept a proximal atrial position. Clearly what is "ideal" is not always possible, and for the individual neonate a sub-optimal position may occasionally have to be accepted.

Significant migration of the catheter tip either proximally or distally has been described even when a satisfactory tip position has been documented at initial insertion. Distal migration of an upper extremity line can be the cause of arrhythmia, tricuspid valve vegetations, or pericardial effusion/tamponade. Proximal migration has been described with final line tip locations in the innominate, subclavian or internal jugular veins where occlusive/thrombotic problems are much more common.

9.3.6.6 Extravasation

Although subcutaneous extravasation is relatively common, this complication should be considered in unexplained pleural effusion or ascites. The diagnosis can readily be made by diagnostic tap of the relevant cavity, and removal of the offending catheter resolves the problem. The fatal association of cardiac tamponade with neonatal PICC lines led to the guideline that the tips of these catheters should always be left out with the cardiac silhouette [14].

9.4 Concluding Remarks

Vascular access in the neonate is a challenge to neonatologists, anaesthetists and surgeons alike. In common with other interventions in sick preterm infants, these procedures are associated with considerable morbidity and a significant mortality. The early recognition of complications related to vascular access and the subsequent assessment of management options requires considerable clinical judgement and experience. There remains ample scope for clinical research and technological advances in this field.

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