Pediatric Radiology (2018) 48:1964–1970
https://doi.org/10.1007/s00247-018-4214-9

PICTORIAL ESSAY

Sonographic features of umbilical catheter-related complications

Swathi Selvam [1] · Terry Humphrey [1] · Helen Woodley [1] · Sharon English [2] · Jeannette K. Kraft [1]

Received: 8 March 2018 / Revised: 9 June 2018 / Accepted: 13 July 2018 / Published online: 4 August 2018
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

Abstract
Umbilical catheters are commonly used in the neonatal period for blood sampling or for administering medication or parenteral nutrition. The position of the catheter is usually confirmed with radiography. However, many complications associated with the use of umbilical catheters, such as liver collections from extravasation or vascular thrombosis, are not apparent on radiographs but can be easily diagnosed with ultrasound. This pictorial review illustrates the sonographic findings of complications that should be excluded in the sick neonate with an indwelling catheter.

Keywords Complications · Neonates · Ultrasound · Umbilical catheter

Introduction

Umbilical catheters are commonly used in the neonatal period to administer medication, parenteral nutrition, hypertonic solutions, or blood transfusions, or to monitor blood pressure. Despite their many valuable applications, the use of umbilical catheters carries significant risks. If a baby with a central venous catheter deteriorates, the question of catheter-related complication will be raised by the neonatologist, who is especially looking for infection, thrombosis, extravasation or tamponade [1]. In this pictorial review we demonstrate how ultrasound can be used to investigate these neonates, and we illustrate the ultrasound imaging features of these complications.

Umbilical catheter position

An umbilical venous catheter follows the umbilical vein and traverses the central part of the left portal vein (Rex segment) into the ductus venosus to reach the inferior vena cava. The ductus venosus ends in the middle or right hepatic vein, close to the inferior vena cava (Fig. 1) [2]. Intracardiac placement of an umbilical venous catheter should be avoided and can have fatal complications such as cardiac arrhythmias, intracardiac thrombosis, myocardial perforation, pericardial effusion or tamponade [3, 4]. Umbilical venous catheter tips sited below the vertebral body T10 and overlying the liver on a radiograph carry a significantly higher risk of extravasation into the liver parenchyma [5]. If venous access is difficult to obtain, it might be necessary to use a low-lying umbilical venous catheter for a short time, but the line should be replaced at the earliest opportunity [1]. Assessing the position of the catheter tip with ultrasound is more accurate than estimating the umbilical venous catheter tip position by its relationship to external structures on a radiograph [2, 6–8].

An umbilical arterial catheter follows one of the umbilical arteries to either the right or left iliac artery into the aorta (Fig. 1). The position of an umbilical arterial catheter tip is defined as high if the tip is in the descending aorta above the level of the diaphragm and below the left subclavian vein. An umbilical arterial catheter is low positioned when the tip is above the aortic bifurcation and below the renal arteries [9]. A recent Cochrane review by Barrington [9] showed that high-positioning of umbilical arterial catheter tips leads to fewer complications and reduced need for replacement than low-positioning [10]. Umbilical arterial catheter tips between the high and low position are inappropriate because of the risk of thrombosis to the kidneys or bowel. Infusion into the coeliac axis could cause refractory hypoglycaemia and infusion into

✉ Jeannette K. Kraft
Jeannette.Kraft@nhs.net

1 Clarendon Wing Radiology Department
Leeds Children's Hospital at Leeds General Infirmary,
Belmont Grove, Leeds, West Yorkshire LS2 9NS, UK

2 Department of Neonatology
Leeds Children's Hospital at Leeds General Infirmary,
Leeds, UK

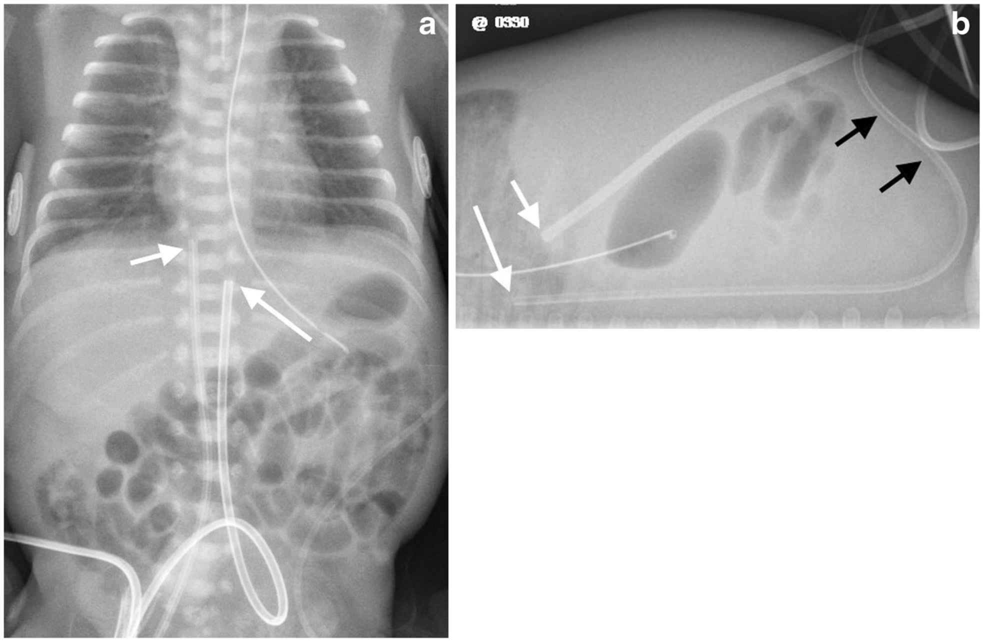

Fig. 1 Correct umbilical catheter position in a 3-day-old boy. **a** Anteroposterior radiograph shows the umbilical venous catheter tip (*short arrow*) correctly sited. An umbilical venous catheter follows the umbilical vein and traverses the central part of the left portal vein (Rex segment) into the ductus venosus to reach the inferior vena cava. The line tip should ideally be sited at the cavo-atrial junction or upper inferior vena cava but outside the heart, which usually corresponds the level of the vertebral bodies T8–T9 or the level of the diaphragm. The umbilical arterial catheter tip (*long arrow*) is positioned high, well above the level of the renal arteries and superior mesenteric arteries, which normally arise from the aorta at the level of the vertebral bodies L1–L2. **b** Lateral radiograph shows the umbilical venous catheter, which traverses the abdomen from the umbilicus at the anterior abdominal wall to the level of the diaphragm superiorly and posteriorly (*short white arrow*). The umbilical arterial catheter courses from the anterior abdominal wall inferiorly (*black arrows*) along the iliac arteries before it reaches a posterior position overlying the aorta, with the tip (*long white arrow*) correctly positioned above the level of the diaphragm

the artery of Adamkiewicz, which supplies the spinal cord, could cause paraplegia [11, 12]. Therefore, a catheter that is seen in this intermediate position needs to be pulled to a low position. A catheter below the bifurcation or the vertebral body L5 needs to be removed for risk of gluteal skin necrosis [13]. Four-French (4F) umbilical catheters are used in newborns; smaller sizes might be needed in premature neonates [14].

Complications related to central catheters are usually caused by malposition of the catheter.

Thromboembolic complications

Indwelling intravascular catheters can cause thromboembolic events by introducing a foreign surface with thrombogenic properties and by damaging the vessel wall. Neonates are at a high risk of thrombosis because they have underdeveloped clotting mechanisms, small vessel diameter and often underlying disease such as perinatal asphyxia, hypovolaemia, septicaemia, polycythaemia or congenital cardiac disease [15, 16]. Persistent bacteraemia might be associated with vascular thrombosis at any site within the body [16]. If a thromboembolic event is determined to be related to an intravascular catheter, this catheter should be removed immediately unless it is vital for the survival of the infant or for administering thrombolytic therapy [15].

Arterial thrombosis

Umbilical arterial catheters are sometimes related to thromboembolic complications involving the aorta, iliac, renal and mesenteric vessels in neonates (Figs. 2 and 3) [17, 18]. If the renal arteries are involved, the child may present with systemic hypertension with or without renal failure [16]. Ergaz et al. [19] and Boo et al. [20] reported that the risk of developing aortic thrombosis increases with the length of time an umbilical arterial catheter is in situ. Thrombus occluding a larger vessel such as the aorta can be visualised well on grey-scale ultrasound with high-frequency transducers (Figs. 2 and 3). Most aortic thrombi resolve, but no correlation has been found between size of thrombus and time to resolution [19, 20]. Small remnants of calcified thrombus can remain long-term [20]. Partial occlusion causing stenosis of an artery leads to reduced perfusion of the organ supplied, such as the kidney. A parvus tardus waveform is demonstrated on spectral Doppler (Fig. 3). Children with aortic thrombosis after umbilical artery

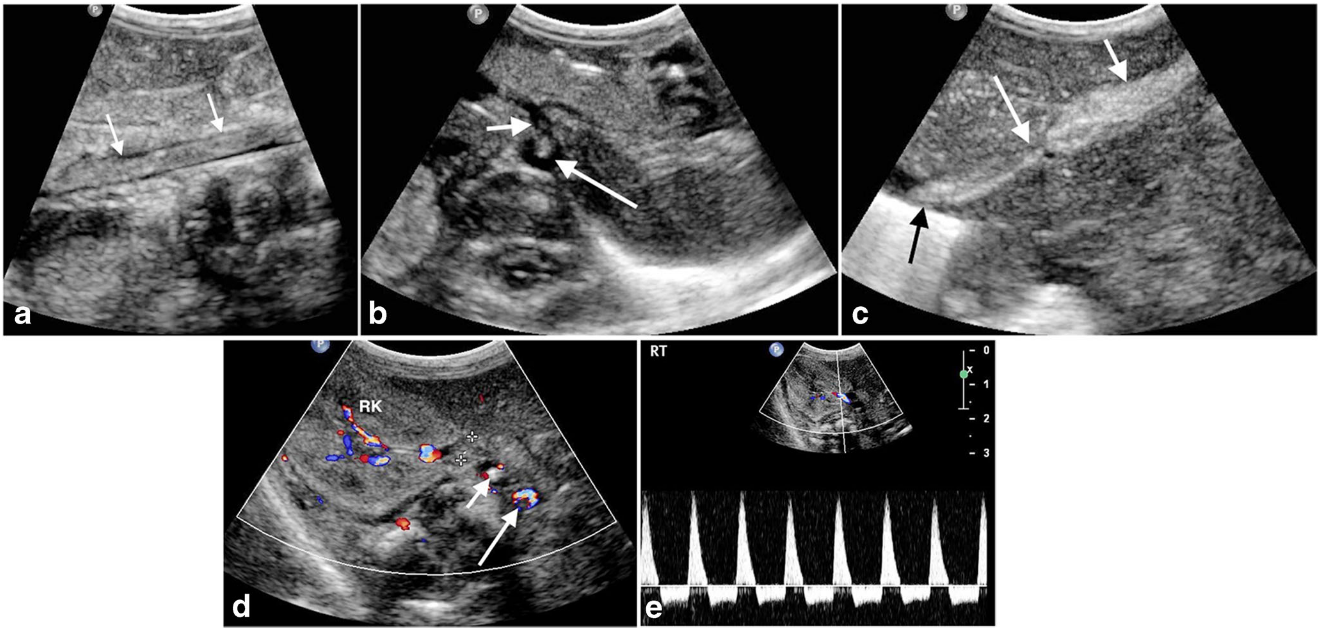

Fig. 2 Aortic, inferior vena cava, portal vein and renal vein thrombosis in a 16 day-old girl born at 29-week-gestation. The baby had an umbilical venous catheter and umbilical arterial catheter prior to this ultrasound. **a** Longitudinal ultrasound image of the midline upper abdomen shows a large echogenic aortic thrombus (*arrows*). Acute thrombus can appear hypoechogenic and completely occlude the vessel, which usually appears expanded. With time the clot becomes more echogenic and might retract, and the vessel re-canalises. **b** Transverse ultrasound image of the upper abdomen shows extension of the thrombus from the aorta (*long arrow*) into the coeliac axis (*short arrow*). **c** Longitudinal ultrasound image of the upper abdomen demonstrates thrombus extending from the umbilical vein (*short white arrow*) through the ductus venosus (*long white arrow*) into the inferior vena cava (*black arrow*). **d** Transverse ultrasound image of the abdomen at the level of the renal vessel demonstrates thrombus in the right renal vein (*calipers*). A small thrombus is seen in the inferior vena cava at this level (*short arrow*). Note aorta with thrombus (*long arrow*). *RK* right kidney. **e** Spectral Doppler ultrasound of the right renal artery shows a high-resistance flow pattern with reversed end-diastolic flow in keeping with renal vein thrombosis

catheterisation should be followed up long-term because they can develop complications including renovascular hypertension or leg-length discrepancy [18].

Venous thrombosis

Catheter-related venous thrombosis can be asymptomatic or lead to severe complications such as deep venous thrombosis, superior vena cava syndrome, intracardiac thrombosis or pulmonary embolism [16]. This can damage vital organs through thrombus propagation, embolisation or infection. A thrombus in a vein is shown on ultrasound as a filling defect with reduced flow surrounding it or as complete obstruction of the vein. In the acute phase the vessel is usually expanded and filled with echogenic material (Fig. 2). The vessel could re-canalise or in the case of a large thrombus remain occluded, and collateral vessels can be seen on ultrasound.

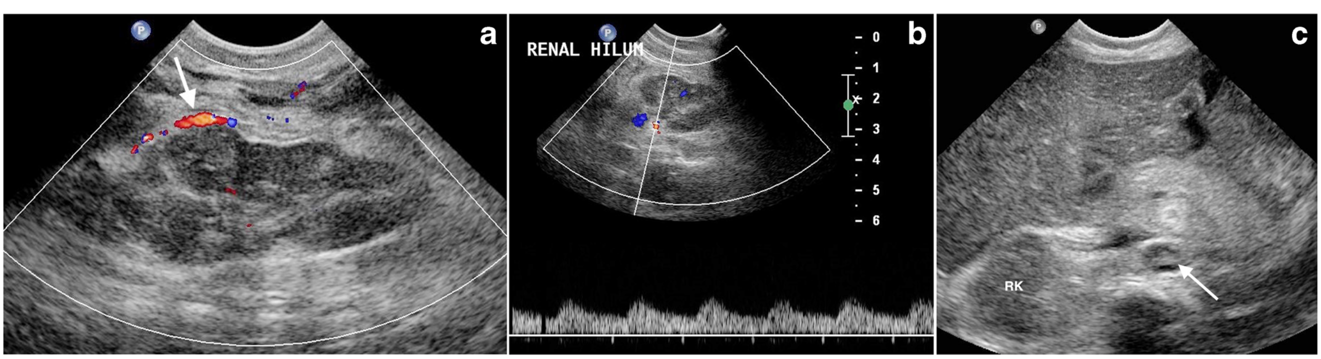

Fig. 3 Renal artery and aortic thrombosis in a 9-day-old premature girl. **a** Longitudinal colour Doppler ultrasound image of the left kidney shows abnormally increased renal echogenicity with only minimal vascularity and a capsular collateral vessel (*arrow*). **b** Spectral Doppler ultrasound of a small hilar vessel shows a parvus tardus waveform and very low velocities. **c** Transverse ultrasound image of the abdomen shows aortic thrombus (*arrow*) at the level of the renal arteries. *RK* right kidney

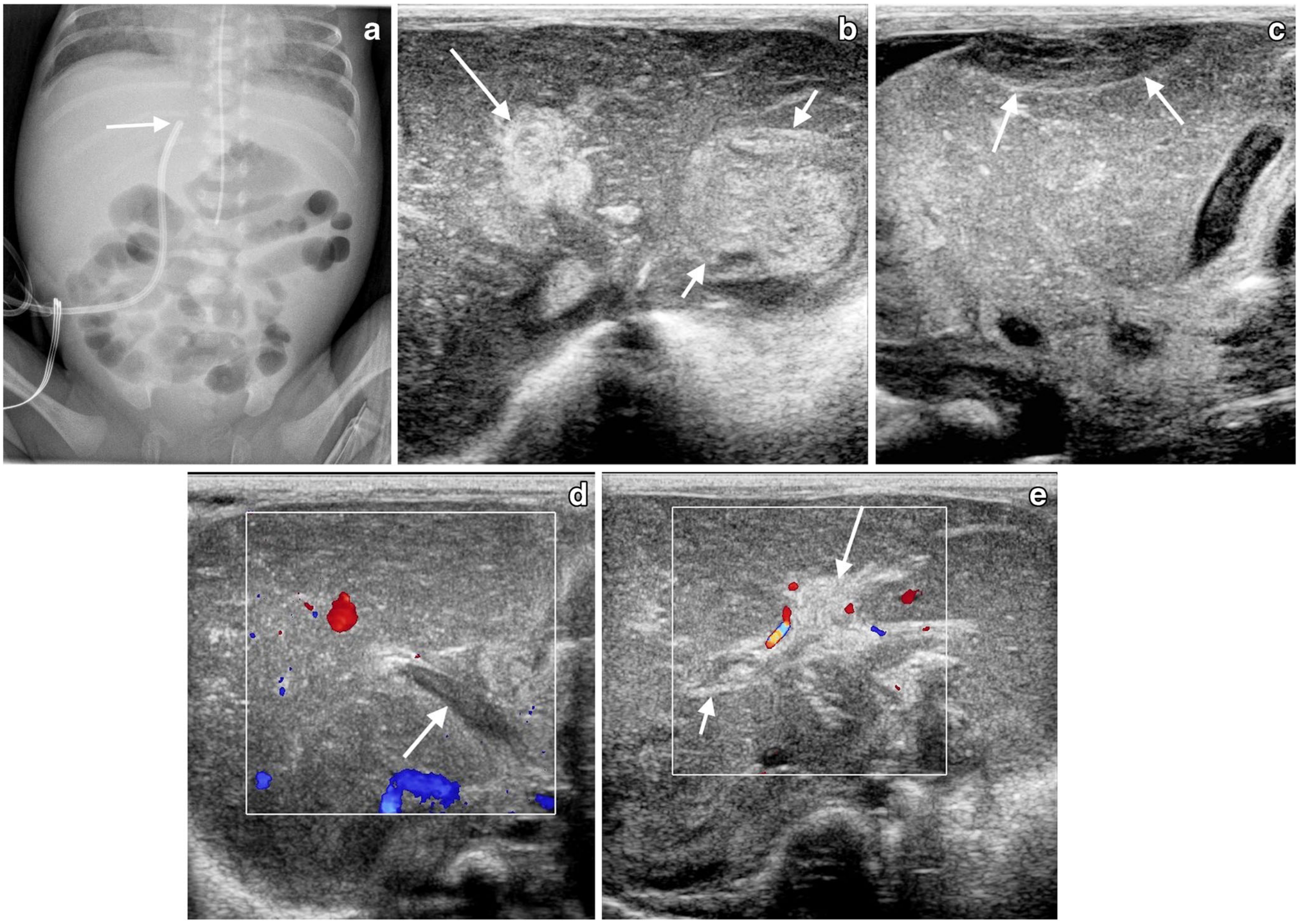

Fig. 4 Parenteral nutrition extravasation in a 25-week-gestation premature girl. **a** Abdominal radiograph at 11 days old shows the umbilical venous catheter tip (*arrow*) in a low position overlying the liver parenchyma. **b** Transverse ultrasound image of the upper abdomen at 12 days old demonstrates an echogenic area within the left lobe of the liver, part of a large intrahepatic collection (*short arrows*). An echogenic collection in the right lobe of the liver surrounds the portal vein, which is thrombosed (*long arrow*). Central collections within the liver are thought to be related to direct trauma caused by the indwelling umbilical catheter. **c** Longitudinal image through the right lobe of the liver demonstrates a hypoechoic subcapsular collection (*arrows*). Subcapsular collections could be related to preferential flow of the infusate into the periphery of the liver parenchyma, where it causes local irritation. **d** Longitudinal colour Doppler ultrasound image of the liver hilum shows absent portal venous flow in keeping with thrombus (*arrow*). **e** Transverse colour Doppler ultrasound image of the liver shows extensive echogenic thrombus within the right (*short arrow*) and left (*long arrow*) main branches of the portal vein

Renal vein thrombosis and adrenal haemorrhage

Umbilical catheters are a well-recognised risk factor for the development of renal vein thrombosis [21–23]. Adrenal haemorrhage is associated with renal vein thrombosis and inferior vena cava thrombosis [24]. It is more commonly seen on the left side because the left renal and adrenal veins are connected, aiding extension of thrombus [23, 25]. Renal vein thrombosis is thought to arise in the arcuate or interlobular veins and propagate to the main renal vein and into the inferior vena cava [21, 23]. In cases of an indwelling catheter, however, there might be continuation of an inferior vena cava thrombus into the renal vein [23, 26]. In the acute stage, a kidney affected with renal vein thrombosis is enlarged and shows echogenic stripes related to intrarenal thrombosis. A thrombus in the renal vein might be visible on high-resolution images (Fig. 2). Over time the affected kidney can recover perfusion or atrophy [23, 26].

Portal vein thrombosis

Portal vein thrombosis in neonates has been described as a rare event but is becoming increasingly recognised with the use of routine ultrasound [27]. In neonates portal vein thrombosis is commonly associated with indwelling umbilical venous catheters, with or without infection [27–30]. Other factors that increase the risk of portal vein thrombosis in neonates include composition of the solution infused, low birth weight,

Fig. 5 Hydrops, misplaced umbilical venous catheter and liver collection from extravasation in a 1-day-old girl. **a** Transverse ultrasound image of the liver demonstrates a large mixed-echogenicity collection within the liver parenchyma (*calipers*). **b** Longitudinal ultrasound image shows the umbilical venous catheter tip (*long arrow*) within the liver parenchyma, which has perforated the umbilico-portal confluence (Rex segment; *short arrow*). The ductus venosus is narrowed at its origin and not always perfectly aligned with the umbilical vein, which can lead to malposition of an umbilical venous catheter within the left branch of the portal vein or liver parenchyma. **c** Longitudinal ultrasound image shows the position of the umbilical venous catheter after it was pulled back. The tip is now seen within the umbilico-portal confluence (*long white arrow*). It does not enter the ductus venosus (*short white arrow*). The traumatic tract (*black arrows*) caused by the catheter can still be seen in the liver parenchyma

low flow state, hypercoagulability, hypoxia, sepsis, gestational diabetes and congenital malformation. Most thrombi resolve spontaneously and therefore do not cause portal hypertension. However, portal vein thrombosis is a major cause of portal hypertension in childhood [27, 31, 32]. Prolonged catheterisation and transfusion through the umbilical venous catheter increases the risk of portal vein thrombosis [30]. The highest rate of portal vein thrombosis is seen with catheter placement in the portal vein, with the main site of thrombosis at the umbilico-portal confluence (Rex segment). If the umbilical venous catheter is placed outside the portal vein, no particular catheter position is significantly associated with increased risk of portal vein thrombosis [30]. On ultrasound, a thrombus within the left portal vein only might be seen; extensive thrombosis of the main and intrahepatic portions of the portal vein is seen in severe cases (Fig. 4).

Hepatic extravasation

A correctly placed umbilical venous catheter traverses the umbilical vein past the left branch of the portal vein (umbilico-portal confluence, or Rex segment) into the ductus venosus [2]. There is a higher risk of hepatic injury and abdominal extravasation if an umbilical catheter is used in a low-lying position, especially if it is used to infuse hypertonic solutions or vasoactive drugs (Fig. 4) [5]. Another risk for extravasation is prolonged use of the catheter. Sequin et al. [33] reported the mean duration of umbilical venous catheter use in neonates was

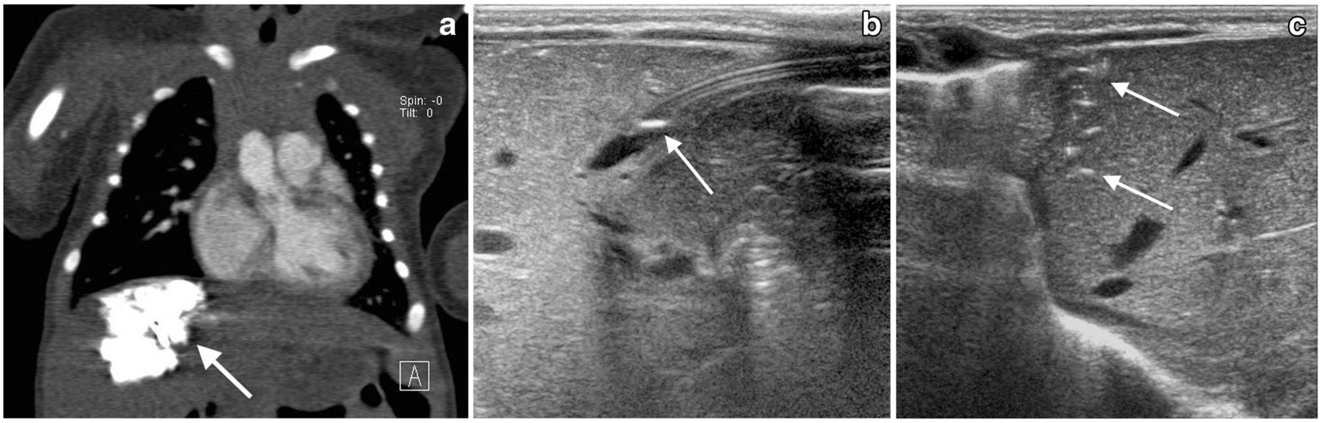

Fig. 6 Hypoplastic aortic arch in a 6-day-old boy. **a** Coronal image from a cardiac computed tomography (CT) scan (with injection of contrast agent performed via an umbilical venous catheter) shows contrast agent pooling within the liver parenchyma (*arrow*). **b** Transverse image from an ultrasound performed the next day demonstrates the umbilical venous catheter tip (*arrow*), low lying within the umbilical vein as it enters the liver. The catheter tip did not perforate the vessel wall. During scanning infused liquid was seen to flow preferentially into the liver parenchyma and not through the ductus venosus toward the inferior vena cava. **c** During scanning, small bubbles are seen in the peripheral liver parenchyma (*arrows*) close to the diaphragm, but no collection. This explains the contrast pooling seen on the CT. The line was removed and we no longer use umbilical catheters for contrast injection

4.4 days, with longer use of up to 5.5 days in neonates with low birth weight. In a series by Coley et al. [34] the mean umbilical venous catheter use before extravasation was 8.9 days. Hepatic injuries from extravasation have a high morbidity and mortality [35–39]. These complications are usually found along the course of the umbilical vein and ductus venosus, but subcapsular collections have also been reported [35]. It is thought that collections found along the course the umbilical venous catheter are related to direct trauma, whereas subcapsular collections could be related to preferential flow of the infusate into the periphery of the liver parenchyma (Figs. 4, 5, 6, and 7) [37]. Lim-Dunham et al. [35] described a change in the sonographic appearances of the liver collections over time. Initially they are well-defined with a hyperechoic rim and a hypoechoic centre with cystic areas (Figs. 4 and 7) [35]. Levkoff and Macpherson [36] thought this appearance might be caused by separation of parenteral nutrition infusate into a layer of fat peripherally and central, more liquid material. With progression, the collections become more echogenic, presumably from initial absorption of the liquid components. With further healing a calcified rim develops (Fig. 7). Complex ascites might be seen after disruption of the liver capsule and spilling of the collection into the peritoneum. Treatment is usually supportive, with removal of the umbilical venous catheter, but in case of large and complex liver collections drainage should be considered [40].

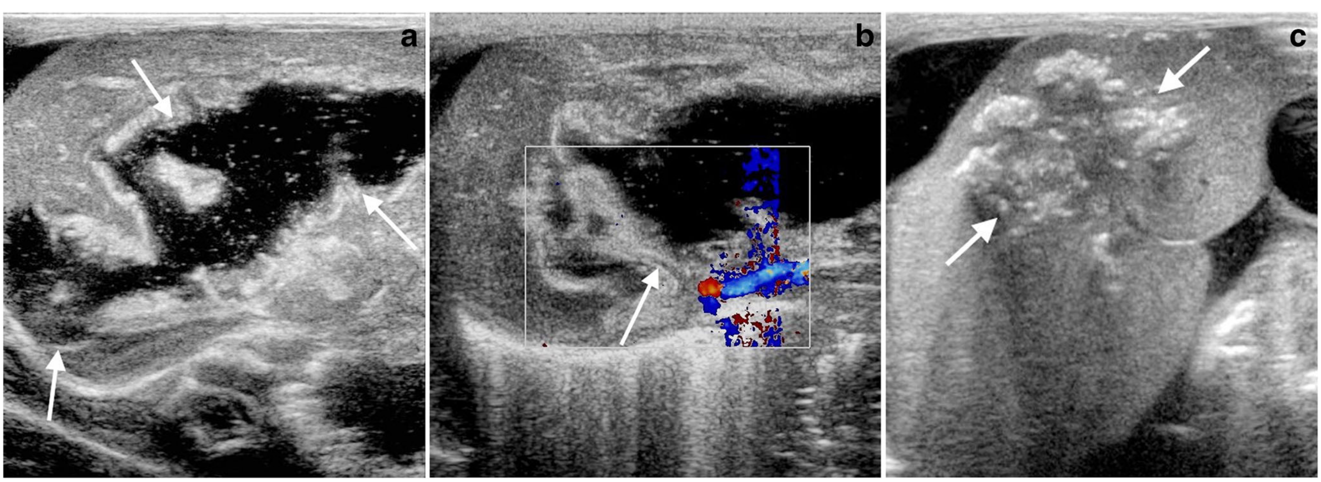

Fig. 7 Parenteral nutrition extravasation in a 25-week-gestation premature boy. **a** Transverse ultrasound image at 12 days old shows a large collection within the liver parenchyma (*arrows*). **b** Transverse colour Doppler image of the right lobe of the liver shows that the right hepatic vein is compressed/occluded (*arrow*). **c** Ultrasound follow-up at 4 weeks of age shows a large area of calcification (*arrows*) within the liver at the site of the previous collection as a sign of resolution

References

1. British Association of Perinatal Medicine (2015) Use of central venous catheters in neonates. A framework for practice. https://www.bapm.org/resources/use-central-venous-catheters-neonates-framework-practice. Accessed 2 July 2018
2. Ades A, Sable C, Cummings A et al (2003) Echocardiographic evaluation of umbilical venous catheter placement. J Perinatol 23:24–28
3. de Almeida MM, de Sousa Tavares WG, Furtado MMAA et al (2016) Neonatal atrial flutter after insertion of an intracardiac umbilical venous catheter. Rev Paul Pediatr 34:132–135
4. Schlesinger AE, Braveman RM, DiPietro M (2003) Neonates and umbilical venous catheters: normal appearance, anomalous positions, complications, and potential aid to diagnosis. AJR Am J Roentgenol 180:1147–1153
5. Grizelj R, Vukovic J, Bojanic K et al (2014) Severe liver injury while using umbilical venous catheter: case series and literature review. Am J Perinatol 31:965–974
6. Franta J, Harabor A, Soraisham AS (2017) Ultrasound assessment of umbilical venous catheter migration in preterm infants: a prospective study. Arch Dis Child Fetal Neonatal Ed 102:F251–F255
7. Greenberg M, Movahed H, Peterson B et al (1995) Placement of umbilical venous catheters with use of bedside real-time ultrasonography. J Pediatr 126:633–635
8. Michel F, Brevaut-Malaty V, Pasquali R et al (2012) Comparison of ultrasound and X-ray in determining the position of umbilical venous catheters. Resuscitation 83:705–709
9. Barrington KJ (1999) Umbilical artery catheters in the newborn: effects of position of the catheter tip. Cochrane Database Syst Rev 2:CD000505 http://cochranelibrary-wiley.com/doi/10.1002/14651858.CD000505/abstract;jsessionid=C1201DF1153EE5E151492FD2AF758FEF.f02t01. Accessed 2 July 2018
10. Mobrohisky ST, Levine RL, Blumhagen JD et al (1978) Low positioning of umbilical artery catheters increases associated complications in newborn infants. N Engl J Med 299:561–564
11. Munoz ME, Escriba R, Martinez-Bermejo A et al (1993) Flaccid paraplegia as complication of umbilical artery catheterization. Pediatr Neurol 9:401–403
12. Carey BE, Zellinger TC (1989) Hypoglycaemia due to high positioning of umbilical artery catheters. J Perinatol 9:407–410
13. Cumming WA, Buechfield DJ (1994) Accidental catheterization of internal iliac artery branches: a serious complication of umbilical artery catheterisation. J Perinatol 14:304–309
14. Eifinger F, Fuchs Z, Koerber F et al (2018) Investigation of umbilical venous vessel anatomy and diameters as a guideline for catheter placement in newborns. Clin Anat 31:269–274
15. Hermansen MC, Hermansen MG (2005) Intravascular catheter complications in the neonatal intensive care unit. Clin Perinatol 32:141–156
16. Ramasethu J (2008) Complications of vascular catheters in the neonatal intensive care unit. Clin Perinatol 35:199–222
17. Deeg KH, Wölfel D, Rupprecht T (1992) Diagnosis of neonatal aortic thrombosis by colour coded Doppler sonography. Pediatr Radiol 22:62–63
18. Seibert JJ, Northington FJ, Miers JF et al (1991) Aortic thrombosis after umbilical artery catheterization in neonates: prevalence of complications on long-term follow-up. AJR Am J Roentgenol 156:567–569
19. Ergaz Z, Simanovsky N, Rozovsky K et al (2012) Clinical outcome of umbilical artery catheter-related thrombosis — a cohort study. J Perinatol 32:933–940
20. Boo NY, Wong NC, Zulkifli SS et al (1999) Risk factors associated with umbilical vascular catheter-associated thrombosis in newborn infants. J Paediatr Child Health 35:460–465
21. Marks SD, Masscotte P, Steele BT et al (2005) Neonatal renal venous thrombosis: clinical outcomes and prevalence of prothrombotic disorders. J Pediatr 146:811–816
22. Winyard PJD, Bharucha T, De Bruyn R et al (2006) Perinatal renal venous thrombosis: presenting renal lengths predicts outcome. Arch Dis Child Fetal Neonatal Ed 91:F273–F278
23. Hibbert J, Howlett DC, Greenwood KL et al (1997) The ultrasound appearances of neonatal renal vein thrombosis. Br J Radiol 70:1191–1194
24. Lau KK, Stoffman JM, Williams S et al (2007) Neonatal renal vein thrombosis: review of the English-language literature between 1992 and 2006. Pediatrics 120:e1278–e1284
25. Orazi C, Fariella G, Malena S et al (1993) Renal vein thrombosis and adrenal haemorrhage in the newborn: ultrasound evaluation of 4 cases. J Clin Ultrasound 21:163–169
26. Kraft JK, Brandao LR, Navarro OM (2011) Sonography of renal vein thrombosis in neonates and infants: can we predict outcome? Pediatr Radiol 41:299–307
27. Williams S, Chan AKC (2011) Neonatal portal vein thrombosis: diagnosis and management. Semin Fetal Neonatal Med 16:329–339
28. Schwartz DS, Gettner PA, Konstantino MM et al (1997) Umbilical venous catheterization and the risk of portal vein thrombosis. J Pediatr 131:760–762
29. Sakha SH, Rafeey M, Tarzamani MK (2007) Portal vein thrombosis after umbilical vein catheterization. Indian J Gastroenterol 26:283–284
30. Kim JH, Lee YS, Lee SK et al (2001) Does umbilical vein catheterisation lead to portal venous thrombosis? Prospective US evaluation in 100 neonates. Radiology 219:645–650
31. Morag I, Shah PS, Epelman M et al (2011) Childhood outcomes of neonates diagnosed with portal vein thrombosis. J Paediatr Child Health 47:356–360
32. Oski FA, Allen DM, Diamond LK (1963) Portal hypertension — a complication of umbilical vein catheterization. Pediatrics 31:297–302
33. Sequin J, Fletcher MA, Landers S et al (1994) Umbilical venous catheterization: audit by the study group for complications of perinatal care. Am J Perinatol 11:67–70
34. Coley BD, Sequin J, Codero L et al (1998) Neonatal total parenteral nutrition ascites from liver erosion by umbilical vein catheters. Pediatr Radiol 28:923–927
35. Lim-Dunham JE, Vade A, Capitano HN et al (2007) Characteristic sonographic findings of hepatic erosion by umbilical vein catheters. J Ultrasound Med 26:661–666
36. Levkoff AH, Macpherson RI (1990) Intrahepatic encystment of umbilical vein catheter infusate. Pediatr Radiol 20:360–361
37. Pignotti MS, Monciotti F, Frati P, Fineschi V (2017) Hepatic laceration due to umbilical venous catheter malpositioning. Pediatr Neonatol 58:386–387
38. Yigiter M, Arda IS, Hiçsönmez A (2008) Hepatic laceration because of malpositioning of the umbilical vein catheter: case report and literature review. J Pediatr Surg 43:E39–E41
39. Carvajal-Barrios GA, Corrales-Cobos IF, Cuenca-Arias MC et al (2014) Absceso hepático asociado con cateterización umbilical en un neonato [Liver abscess secondary to umbilical catheterization in a newborn]. Infectio 18:158–161
40. Hagerott HE, Kulkarni S, Restrepo R et al (2014) Clinicoradiologic features and treatment of hepatic lesions caused by inadvertent infusion of parenteral nutrition in liver parenchyma due to malposition of umbilical vein catheters. Pediatr Radiol 44:810–815