Are Supine Chest and Abdominal Radiographs the Best Way to Confirm PICC Placement in Neonates?

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Abstract

Background: Peripherally inserted central catheters (PICCs) are commonly used in NICUs. Although they have many benefits, they also have many potential complications. Confirming catheter tip position is essential to decreasing complications, but the best method to achieve confirmation is unclear.

Objectives: Literature review for studies that address line position confirmation to assist health care providers in evaluating the available research and to identify gaps in the literature.

Method: A literature search of four major databases followed by an ancestry approach was performed. Articles reviewed specifically discuss PICC lines and PICC line placement confirmation.

Results: Data on confirming PICC placement were lacking. Fluoroscopic placement is ideal, but cannot be done at the bedside and is costly. Supine chest radiograph is the most widely used method and is convenient, but when line tip position is unclear, contrast or ultrasound confirmation can be used. When PICC lines are placed in the saphenous vein, infants may benefit from supine and lateral abdominal radiographs to ensure placement in the inferior vena cava.

Discussion: More studies are needed to generalize findings. PICC line tips should be located in the superior vena cava or inferior vena cava close to the junction with the right atrium (0.5–1 cm outside of the cardiac chambers in premature infants and 1–2 cm outside of the cardiac chambers in larger infants). Arm position is very important when performing radiographs for placement because movement of the arm can cause migration of the catheter. There is also significant inter-observer variability when identifying line tip position.

Peripherally inserted central catheters (PICCs) are commonly used in NICUs. Their use was first reported in the literature in the 1970s, they gained popularity in the 1980s, and they are now an accepted method of providing long-term intravenous therapy to newborns.[1]

The benefits of PICCs are numerous and well documented;[1–3] but, they have many complications.[1,2,4,5] They also have potentially life-threatening consequences.[1] A malpositioned catheter greatly increases the risk of complications. These complications include pericardial effusion and pleural effusion,[2] perforations of intrathoracic or intraabdominal veins,[1] as well as thrombosis and dysrhythmias.[4] Other rare complications reported include bilateral consolidation of the lungs in a preterm infant that occurred secondary to PICC line dislodgement[6] and extravasation of hyperalimentation into the liver parenchyma believed to be secondary to arterial placement of a PICC.[7]

PICCs in the upper extremities should have the line tip positioned in the superior vena cava (SVC).[2,8,9] In premature infants, lines should be positioned 0.5–1 cm outside of the cardiac chambers, and, in larger infants, 1–2 cm outside of the cardiac chambers.[2,10,11] Other authors specify the tip should be located in the lower third of the SVC, at the junction of the SVC and right atrium.[12–16] There is agreement, however, that lines should never be placed within the cardiac chambers. Lines can be malpositioned with the tip still peripheral, into the heart, or into the jugular venous system. Lines placed in the lower extremities may enter an ascending lumbar vein instead of continuing through the inferior vena cava (IVC).[8] If lines are placed in the lower extremities, the tip should reside close to the junction of the

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TABLE 1 ■ Summaries of Review Articles

Reference	Title	Purpose	Sampling Characteristics/Design	Findings	Limitations
Diemer[18] (1987)	Central venous silastic catheters in newborns: localization by sonography and radiology	Demonstrate that positioning of central venous catheters in newborns can be checked by sonography, reducing frequency of control radiographs	19 newborns (birth weight 700–3,950 g) 9 silastic catheters–PICCs 6 subclavian catheters 4 umbilical venous catheters Positioning confirmed by ultrasound and radiography	Silastic catheters easily detected by ultrasound In 4 cases, detection of malpositioning in radiographically "normal" films	Very small sample size Study done 21 years ago
Chait, et al.[12] (1995)	Peripherally inserted central catheters in children	Assess feasibility and complications of peripherally inserted central catheters in pediatric patients	122 patients aged 9 days to 19 years (mean age 6.82 years, median age 5 years) 9 patients 0–6 months of age	Fluoroscopic guidance was successful in 137 of 148 attempts Fluoroscopy allows PICCs to be inserted quickly and without risk of malposition	No distinction made between neonatal and pediatric patients makes it difficult to generalize a result to the neonatal population Study done 13 years ago
Neubauer[14] (1995)	Percutaneous central IV access in the neonate: Experience with 535 silastic catheters	Determine whether PICC placement under ECG monitoring can reduce incidence of malpositioning	535 silastic catheters inserted in 488 infants; between Jan. 1986 and Nov. 1988; catheter position confirmed by radiography with contrast compared with 273 catheters inserted between Nov. 1988 and Dec. 1991 positioned using intraatrial ECG monitoring Infants were 23–42 weeks GA (median 30 weeks); birth weight 480–6,300 g; postnatal age at time of insertion 0–279 days (median 4 days)	No side effects specific to ECG method Can be used safely and makes radiologic control unnecessary Incorrect placement 9.5% using ECG and 64.5% without ECG	Study done 13 years ago Need additional studies in neonatal population to support use
Madar, & Deshpande[20] (1996)	Reappraisal of ultrasound imaging of neonatal intravascular catheters	Assess ability of cross-sectional ultrasound to visualize intravascular catheters and locate catheter tips	28 neonates (birth weight 640–3,530 g, median 1,210 g; GA 23–40 weeks, median 28 weeks) 40 intravascular catheters (19 PICCs) Catheter location checked by radiograph, then ultrasound assessment by single operator who was unaware of radiographic assessment	In all but 2 instances, ultrasound exam was successful in visualizing tip	Study done 12 years ago Small sample size
Ohki et al.[19] (2000)	Ultrasonographic detection of very thin percutaneous central venous catheters in neonates	Assess ability of ultrasound to detect tip of very thin PICC in neonates	57 PICCs in 44 neonates PICC tip location was assessed using ultrasound and compared to location estimated using standard radiography	In 87% of cases, PICC tip position on ultrasound was consistent with that of standard x-ray; ultrasound could also illustrate 78% of cases of catheter tip dislodgement	Small sample size
Reece et al.[27] (2001)	Positioning long lines: Contrast versus plain radiography	Assess value of contrast versus plain x-ray in determining radiopaque long line tip position in neonates	68 lines inserted, 62 lines from 49 neonates included in study GA 23–40 weeks (median 29 weeks); birth weight 700–3,440 g (median 1,220 g) Plain x-ray done after insertion of radiopaque long lines, if tip was not visible on plain film, second film with contrast was obtained	31 of 62 cases required second x-ray; line tip was clearly visualized with contrast in 29 of these; 2 line tips could not be visualized because contrast had filled vein and obscured tip from view Contrast halves radiation exposure, decreases cost, and makes better use of medical time	Small sample size Upper limb PICC line tip position placed in right atrium

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Mitsufuji et al.[30] (2002)	Extravascular collection of fluid around the vertebrae resulting from malpositioning of a peripherally inserted central venous catheter in extremely low birth weight infants	Case reports of extravascular collection of fluid around vertebrae resulting from malpositioning of PICCs in two extremely low birth weight infants	2 saphenous PICCs inserted and position confirmed by standard supine radiograph Case 1: 28 weeks + 4 days GA; birth weight 990 g Case 2: 27 weeks + 6 days GA; birth weight 882 g	Upon lateral abdominal radiograph, both PICCs found to be in vertebral lumen PICC tip position when inserted through lower limbs should be confirmed by supine and lateral abdominal radiograph	Only 2 case reports
Clarke et al.[32] (2003)	Parenteral nutrition solution retrieved by lumbar puncture following left saphenous vein catheterization	Case reports of two left saphenous lines placed in the ascending lumbar vein	2 left saphenous percutaneous central venous catheters Case 1: 29 weeks GA, birth weight 1,065 g Case 2: 24 weeks GA, birth weight 680 g	Parenteral nutrition solution recovered in the cerebrospinal fluid heralded potentially life-threatening catheter malposition illustrates another percutaneous central line–associated morbidity that is avoidable by careful verification of line position. Supine and lateral chest and abdominal x-rays to verify PICC lines placed in lower extremities would identify lines that are malpositioned	Only 2 case reports
Evans et al.[28] (2004)	Long line positioning in neonates: Does computed radiography improve visibility?	Assess use of soft copy reporting of computed radiography images in determining intravenous long line tip position in neonates and compare visibility rates with hard copy printed images	Retrospective study of all long lines inserted in neonatal unit in 1 year; 45 lines in 30 neonates Assessment of images made by 3 independent observers by reviewing films on viewing console and as hard copy printed images (plain radiograph used)	Accurate identification of line tip made in 66.7% of cases using hard copy images and 95.6% of cases using soft copy reporting	Small sample size Only 2 reporters reviewed soft copy radiographs, 1 of whom also saw hard copy radiograph
Odd et al.[24] (2004)	Does radio-opaque contrast improve radiographic localization of percutaneous central venous lines?	Determine whether addition of radio-opaque contrast material improves localization of long line tips over plain x-rays	106 x-rays without contrast taken between Oct. 1999 and Aug. 2000 compared with 96 x-rays with contrast taken between Sept. 2001 and July 2002 Noncontrast group GA 23–40 weeks (median 28 weeks); birth weight 540–3,100 g (median 1,190 g) Contrast group GA 23–41 weeks (median 28 weeks); birth weight 475–4,380 g (median 1,110 g) 2 observers independently reviewed each radiograph to identify position of line tip; formal radiology report was third observer	Contrast increased proportion of radiographs in which all observers could see line tip; in x-rays where observers felt they could see line tip, use of contrast did not improve proportion in which they agreed	Only 3 observers Contrast and noncontrast done at different times; no mention as to change in catheters or procedures during that time

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Coit et al.[29] (2005)	Peripherally inserted central catheter using the saphenous vein: Importance of two-view radiographs to determine the tip location	Description of two cases in which PICC tips inserted through saphenous vein were located outside the IVC	2 saphenous PICCs were inserted; 1 had PICC tip position confirmed by standard supine and lateral radiographs; the other had a supine radiograph with contrast to confirm placement Case 1: 26 weeks GA, birth weight 1,122 g Case 2: 30 weeks GA, birth weight 1,555 g	Lateral view showed PICC running along anterior abdominal wall (possibly in interior epigastric vein); catheter was removed on Day 2 because it had infiltrated Second infant had increased apneic episodes, and milky white, blood-tinged cerebrospinal fluid upon lumbar puncture; lateral radiograph showed the tip to be directed posterior to the inferior vena cava Proper PICC placement through saphenous vein may be misleading with a single supine radiograph, 2 views would assure that catheter tip is in inferior vena cava	Only 2 case reports
Fricke et al.[13] (2005)	Placement of peripherally inserted central catheters without fluoroscopy in children: Initial catheter tip position	Determine how often placement of PICCs without imaging guidance results in initially correct central venous catheter tip location	843 PICCs placed in 698 patients Ages 0 days to 26 years (mean age 6.87 years, median age 4.96 years) PICCs were inserted and threaded blindly to previously estimated length and position verified by spot fluoroscopy	85.8% had noncentral initial PICC tip position and required further manipulation PICC placement with fluoroscopic guidance is highly successful and best performed in an angiography suite	No distinction made between neonatal and pediatric patients, therefore difficult to generalize to the neonatal population
Webster et al.[16] (2005)	Digital imaging does not improve localization of percutaneously inserted central lines in neonates	Determine whether digital imaging improves localization of PICC line tips compared to standard radiographs with contrast being used in both cases	117 digital x-rays from 98 infants were reviewed (24–40 weeks GA, median 29 weeks; birth weight 540–3,750 g, median 1,100 g; day of life of insertion 0–79 days; median 3 days) Digital x-rays identified between Oct. 2002 and Sept. 2003 were independently reviewed by 2 reporters who stated (1) whether tip could be confidently seen and (2) tip position	In 67% of x-rays in which reporters agreed that tip could be localized, they agreed on its position; in 52% of radiographs, reporters did not agree that tip could be seen but nevertheless agreed on its position in 59% of cases Level of agreement using digital imaging was not different from previous findings using standard radiography and contrast	Small sample size

GA = gestational age, IVC = inferior vena cava,

IVC and the right atrium (similar to above, not within, the cardiac chambers).[8,11] One study of complication rates related to catheter tip position found that PICC tips that were non-central were ten times more likely to develop a complication than those that were central.[15]

Confirming appropriate central venous placement is essential to decreasing the risk of complication and maximizing the benefits of this therapy, and there are different methods used to confirm PICC placement. These include supine and lateral chest radiographs, with and without contrast; computed radiography or digital imaging; ultrasound for vein localization as well as confirmation of tip position; intraatrial electrocardiograph (ECG) monitoring; and fluoroscopic guidance. Supine chest radiographs are the most widely used method of confirming placement. I performed a literature review with the goal of identifying available literature on confirming PICC line placement to decrease the risks associated with malpositioned catheters. The question for this review was: In infants with PICC lines, are supine chest and abdominal radiographs without contrast more accurate than ultrasound, fluoroscopy, supine x-rays with contrast, digital imaging, and ECG monitoring for confirmation of catheter tip placement?

METHODS

The target population for this literature review was infants less than one year of age requiring PICC line insertion. Some articles included infants and older pediatric patients. Because of the paucity of data related to PICC placement confirmation in infants, I included these studies in this review if they also included neonates. Single lumen and double PICC lines were included, and there was no differentiation based on the catheter material or manufacturer, because this information was not always available. However, there may be differences in x-ray interpretation related to the radiopacity of the catheter.

The literature review included published material of all types, with no exclusions based on article or research design. Because of limitations in accessing information, unpublished dissertation abstracts were not included in this review. Databases searched included the Cochrane Database of Systematic Reviews, PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and MEDLINE. Key words used included various combinations of "PICC," "NICU," "neonatal intensive care unit," "peripherally inserted central catheter," "line position," "catheter position," and "neonatal." Limits placed on the search were articles relating to infants from birth to 12 months. Articles retrieved were closely examined and included if they specifically discussed PICC placement confirmation in the neonatal population. An ancestry approach of the articles identified was then implemented. Ancestry approach refers to a method of locating published studies by using the references cited by later studies. Using this strategy, the researcher should be able to make his or her way back to the earliest research on the question at hand.

There is no researcher bias to identify. Although initial searches turned up numerous articles, few gave specific information relating to appropriate methods to confirm PICC tip position. Many articles mentioned a method of confirming PICC line placement, but few compared different methods and provided adequate information on which to base practice. Table 1 summarizes articles that met the inclusion criteria.

ANALYSIS AND INTERPRETATION

Ultrasound

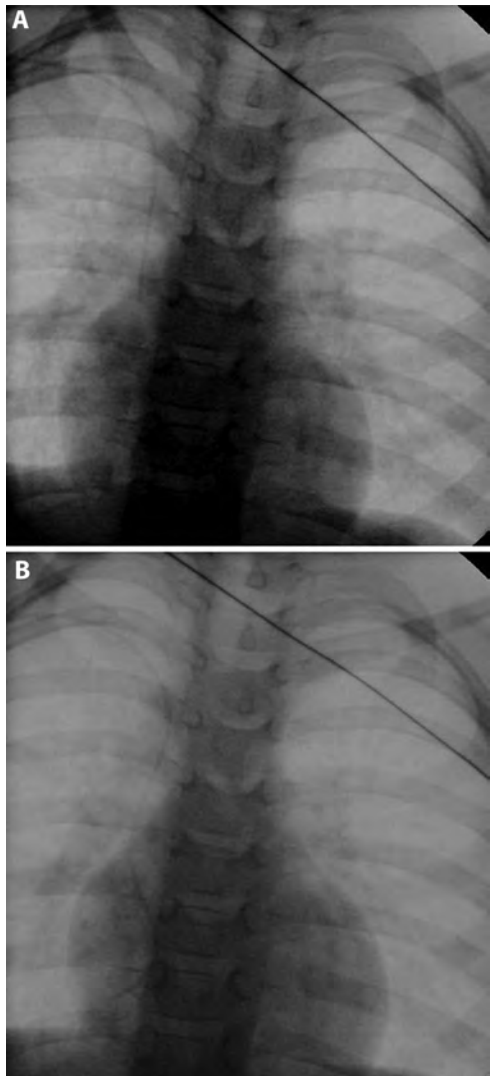
Bedside real-time ultrasonography has been useful in placement of umbilical venous catheters.[17] Three articles were found that compared real-time ultrasound and supine radiographs for confirming PICC line placement. The earliest study, by Diemer in 1987, compared ultrasonography and radiographs in 19 newborns. Diemer concluded that non-radiopaque silastic catheters without contrast were easily identifiable by sonar. In four cases, sonography enabled detection of malpositioning in radiographically "normal" films (after catheter placement using ultrasound, a corresponding x-ray was done with contrast).[18] The article does not go into great detail as to the location of each of the four malpositioned catheter tips, but gives the examples of the line tips being in the foramen ovale or passing the tricuspid valve to the right ventricle. Limitations of this study include its age and its small sample size of only 19 patients.

Ohki and colleagues studied 44 neonates in whom 57 PICCs were inserted and found that the anatomic location of the PICC tips visualized by ultrasound were consistent with that assumed by radiography in 48 cases (87 percent). Six PICCs could not be identified by ultrasound due to preclusion by intestinal gas (1 case), hyperinflated lung (1 case), migration in cervical vessels (2 cases), and unknown causes (2 cases), but were visible on the x-ray. They conclude, however, that ultrasound should be used much more in the NICU to confirm PICC placement, thus reducing the need to expose the infant to ionizing radiation. They also state that, with ultrasound the PICC tip position can be evaluated with changes in the infant's posture and arm position, which is a strong advantage over standard radiography and would decrease the need for further x-rays.[19]

Madar and Deshpande studied 28 neonates (birth weights 640–3,530 g) with a total of 40 intravascular catheters (18 umbilical arterial catheters, 3 umbilical venous catheters, and 19 silastic long lines), where line position was initially checked by a supine x-ray followed by ultrasound evaluation by an examiner who was unaware of the radiographic tip position. They found that, in all but two instances, ultrasound was successful at visualizing the tip and consistent with x-ray findings of tip position. In one case, the infant had a tender abdomen, making examination by ultrasound difficult. In the other case, the catheter was high in the SVC. The tip of 1 right atrial venous catheter lay close to the tricuspid valve and was observed on ultrasound to pass into the right ventricle with cardiac contraction. Also, 2 venous catheters were noted

FIGURE 1 ■ Fluoroscopic images.

(A) A PICC line placed in the right arm, with the arm abducted 90° and the elbow straight. The tip is at the level of the posterior sixth rib interspace. (B) The same PICC line with the elbow bent and adducted. The tip is now at the level of the ninth posterior rib.



From: Connolly, B., Amaral, J., Walsh, S., Temple, M., Chait, P., & Stephens, D. (2006). Influence of arm movement on central tip location of peripherally inserted central catheters. *Pediatric Radiology, 36,* 847. Reprinted by permission.

on ultrasound to pass through the foramen ovale. These malplacements were not noted on x-ray, but the article did not discuss where the lines were noted to be on x-ray. As an aside, the authors also reported that aggregations were identified in the right atrium around the tip of the silastic long line in one infant and this catheter was removed without any embolic complications. They noted that the use of ultrasound allows the PICC position to be immediately adjusted, avoiding the need for repeat x-rays and extra handling.[20] Limitations of this study included its small sample size and early date. Also, a number of the central venous lines confirmed placement in the right or left atrium, which is not the recommended standard of practice. Although the article does not discuss optimal location of the line tip, this is a limitation in generalizing the data to current practice.

In addition to these three studies, two others discussed the use of real-time ultrasound in infants for central line placement. Donaldson andcolleagues discussed its use in relation to PICC lines and Hind and coworkers discussed its use in relation to placement of internal jugular lines. Both articles noted increased success and decreased time necessary for placement of these central lines with the use of ultrasound, but did not discuss confirmation of placement via ultrasound.[21,22]

Bedside ultrasonography is a convenient method of confirming PICC tip position and allows personnel to immediately manipulate the line at the time of insertion to an appropriate tip position. Decreasing radiation exposure and decreasing handling of neonates would also be clear benefits. However, the studies done are of limited generalizability because they have small sample sizes. It may also be a logistical challenge to have readily available an ultrasound device and personnel trained in using and interpreting the ultrasound. More studies need to be done along with a cost/benefit analysis before we can recommend widespread use of ultrasound to confirm placement.

Fluoroscopy

Fluoroscopy provides a real-time radiographic examination, as opposed to a static x-ray. What this means in relation to PICCs is that the clinician can view in real time exactly where the PICC is going and can confirm placement immediately. Fluoroscopy offers a significant advantage over a standard radiograph because viewing the real-time image decreases the time spent confirming placement and allows repositioning to be done immediately at the time of insertion. Fluoroscopy can also record static images. Drawbacks to using fluoroscopy include having to transfer the patient to a fluoroscopy suite (which makes it unrealistic for most NICU patients), as well as higher cost. Because fluoroscopy involves active diagnosis during an examination, radiologists are often involved to confirm placement. There are also increased costs related to the fluoroscopy suites and personnel needed to operate the equipment. Fluoroscopy uses the smallest necessary radiation output; indeed, when comparing static images, fluoroscopy exposes the patient to considerably less radiation than a standard x-ray. Though the dose of radiation increases with the length of the exposure, there is generally less radiation when compared to a standard x-ray. To help decrease the amount of radiation exposure patients receive, U.S. federal law requires a five-minute timer on the units, which needs to be reset, to remind the radiographer of the amount of time the patient has been exposed.[23]

Fricke and associates studied 843 PICCs that were placed in 698 patients aged 0 days to 26 years (mean age 6.87 years, median 4.96 years; the article does not specify how many

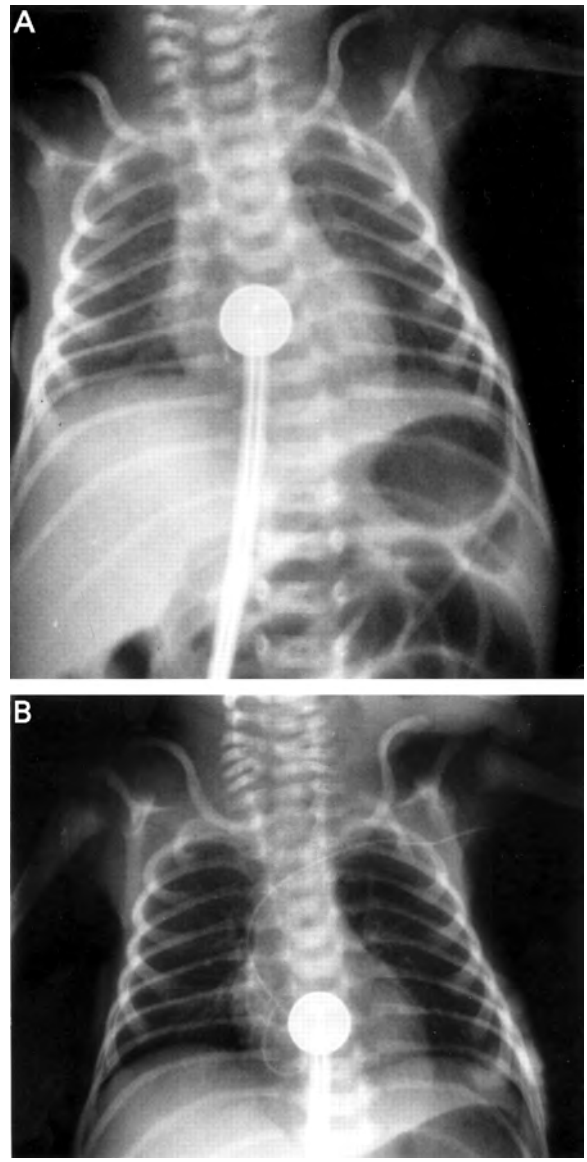
patients were neonates) to compare tip placement success with blind insertion and with the use of fluoroscopic guidance. After successful cannulation of the vessel, the PICC line was threaded to a predetermined length based on the recommendations of the National Association of Vascular Access Networks, and spot fluoroscopy was done to determine initial placement (this was done to show the initial PICC line tip position when inserted blindly, which would be the equivalent of confirming placement with a standard radiograph). The researchers found that 85.8 percent of the PICCs inserted blindly had a noncentral initial PICC tip position and required additional manipulation. After the catheter was repositioned using fluoroscopy, 90.2 percent of the PICCs had a final central venous location. The authors recommended that pediatric PICC placement be performed with fluoroscopic guidance and cautioned that it is best performed in an angiography suite.[13]

Chait and coworkers also studied the use of fluoroscopy for PICC line insertion and placement. They placed PICCs in 122 patients aged 9 days to 19 years and found that they were successful in 137 of 148 attempts. Benefits included instant correction of position and direction and decreased frequency of malposition when compared to blind insertions (inserting a PICC line and confirming tip position with a standard x-ray). Interestingly, success rates were lower in the younger patients, and 5 of the 11 patients in whom access failed were less than 1 year of age. The authors noted that the rate of successful PICC placement with fluoroscopic guidance in children with visible, palpable, or compressible venous structures approached 100 percent.[12] One limitation to this study was that it contained limited neonatal information with no ability to distinguish between the older and younger patients. Thus, it is difficult to generalize the findings of this study to the neonatal population. Figure 1 provides an example of confirmation of PICC line tip position with fluroscopy. It illustrates how the position of a line tip can change with changes in the infant's arm position and how this can be immediately seen by fluoroscopy.

The adult and pediatric literature shows that fluoroscopy is an excellent method to confirm PICC line tip position. But clear data are still lacking specific to the neonatal population. There are increased costs associated with fluoroscopy; however, it is argued that the decreased need for additional x-rays and further line manipulation could make the cost of fluoroscopy comparable to that of bedside placement with confirmation by standard radiograph.[13] Other factors to consider specific to neonates include the time and resources spent in transferring patients as well as the potential stress placed on the infants related to the transfer.

FIGURE 2 ■ Plain versus contrast radiographs.

(A) Plain radiograph does not show the long line tip with accuracy. Therefore, a film with contrast was taken. (B) The contrast film showing that the catheter is coiled in the heart.



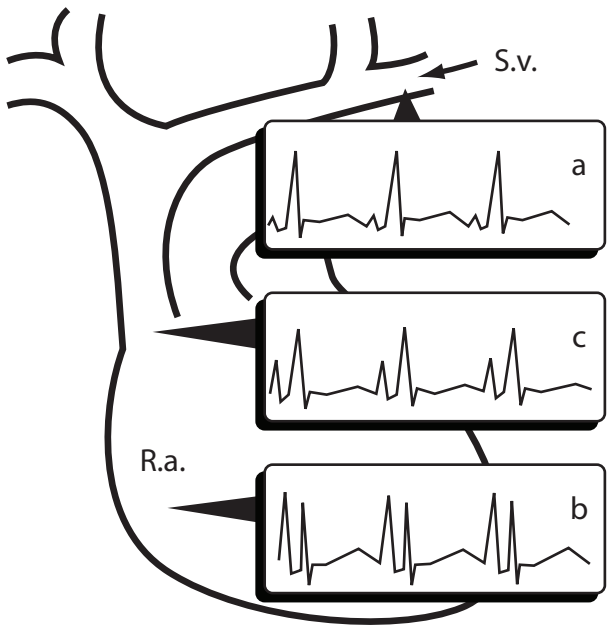
From: Reece, A., Ubhi, T., Craig, A. R., & Newell, S. J. (2001). Positioning long lines: Contrast versus plain radiography. *Archives of Disease in Childhood. Fetal and Neonatal Edition,* 84, F130. Reprinted by permission.

Contrast

Using contrast injection during plain radiography is another method used to confirm PICC placement. Most neonatal PICC lines are radiopaque; therefore, contrast is not used as frequently as it once was, and the use of contrast is not without risks. Water-soluble, nonionic, iodinated contrast is the type commonly used in neonates for PICC line placement confirmation, and the amount used is quite small and dependent on the size of catheter used, so the risk of side effects is minimal. The contrast is injected into the vessel, distributed within the extracellular fluid compartment, and excreted unchanged by glomerular filtration. Using a contrast injection allows radiographic visualization of the vessels and flow until significant hemodilution occurs. Although the

FIGURE 3 ■ Intravenous ECG between chest lead and catheter tip.

The tip is positioned in the (a) subclavian vein, (b) right atrium, (c) entrance area of the right atrium.



From: Neubauer, A. P. (1995). Percutaneous central IV access in the neonate: Experience with 535 silastic catheters. *Acta Paediatrica, 84,* 757. Reprinted by permission.

effects of contrast on neonates are poorly understood, the adult literature reports platelet dysfunction, anticoagulant effects, renal impairment, and, with large doses, an effect on thyroid function.[24] Dembinsky and colleagues found no hypothyroidism or hyperthyrotropinaemia at 4–45 days after injection of 0.3–1 mL of iopromide for placement of intravascular catheters in their study of 20 very low birth weight infants, but still recommend monitoring thyroid function in these infants.[25] There are also concerns related to hyperosmolality potentially producing changes in hemodynamics, as well as allergic responses to the contrast. The immature immune system of the neonate minimizes this risk; however, it is important to document adequate renal function before administering contrast to ensure appropriate elimination and avoid toxicity.[26]

Reece and associates studied 62 central venous lines placed in 49 neonates ranging from 23 to 40 weeks gestational age (median 29 weeks) and birth weights of 700–3,440 g (median 1,220 g), where supine radiography without contrast injection was used to confirm the initial PICC line tip location. Thirty-one of those lines required a second radiographic examination with contrast material injected into the catheter to confirm placement and tip location, and the line tip was clearly seen in 29 of these (Figure 2). The authors noted that using contrast injection for the initial x-ray provides clear visibility of the line (reducing the potential for complications related to tip location), halves radiation exposure (because there is no need for a second x-ray), reduces the cost of follow-up x-rays, and improves usage of medical time. Difficulties occurred in two cases because line tips were obscured by contrast filling the vein. The authors assumed that there was a delay in the exposure of the film, causing more contrast to be inserted, thus outlining the entire vein instead of just the catheter.[27] Limitations of this study included the small sample size and the fact that intended tip placement was in the right atrium for upper limb insertions. This is not the recommended standard of practice.

Odd and coworkers evaluated the use of contrast to improve radiographic localization of PICC lines in neonates. They performed a retrospective study of all neonates in their institution who had PICC lines inserted over a two-year period. During the first year, PICC line tip placement was confirmed by supine radiograph, but a change in unit practice resulted in radiopaque contrast being used in the second year. They examined 106 supine radiographs without contrast from 92 neonates (gestational age 23–40 weeks, median 28 weeks; birth weight 540–3,100 g, median 1,190 g) and 96 radiographs from 89 infants with contrast (gestational age 23–41 weeks, median 28 weeks; birth weight 475–4,380 g, median 1,110 g) and used two observers to independently review each radiograph to identify the position of the line tip. They also used the formal radiology report as a third observer. Their results indicated that the use of contrast improved the ability of all three observers to see the line tip (from 39 percent without contrast to 55 percent with contrast; $p = .02$) and increased the agreement on line tip position (from 37 percent without contrast to 59 percent with contrast; $p = .001$). They found, however, that when lines were seen by all three observers, the use of contrast did not increase the proportion in which they agreed on position. They concluded that contrast increased the ability to localize the line tip only when x-rays were more difficult to assess (when the line tip was not clearly visible initially).[24]

Digital Imaging

Webster and colleagues compared the use of digital imaging with contrast to standard radiograph with contrast for localizing PICC tips in 98 infants. Digital imaging consists of a standard x-ray loaded onto a digital picture archiving and communication system. It allows the viewer to manipulate the image (zooming in and out, black/white inversion, modifying the contrast). In this study, three independent observers evaluated 117 radiographs from 98 infants with PICCs (gestational age 24–40 weeks, median 29 weeks; birth weight 540–3,750 g, median 1,100 g; age at insertion 0–79 days, median 3 days) to ascertain whether or not they could see the line tip, and if so, its position. All three used the digital imaging system, but had different preferences as to the method of image modification. Their results were assessed by using Cohen's *kappa* coefficient for agreement. When they

compared results to a previous study they had done contrasting interobserver variability using standard radiography to standard radiography with contrast, they found that digital imaging was not significantly better than standard radiographs with contrast at identifying PICC placement and had a nonsignificant effect on interobserver variability (74/117, 63 percent vs 57/96, 59 percent).[16]

However, other investigators have found that digital imaging was better for location of PICC tips. Evans and associates demonstrated that PICC tip position could be identified in 30 out of 45 hard copy x-rays (standard films) and 43 out of 45 soft copy films (computer images able to be manipulated). This improvement was attributed to manipulation of image contrast and brightness and the use of image inversion to optimize line visibility.[28] The first study had a limited sample size, and there may have been some bias because one of the two reporters reviewing the digital radiograph also reviewed the standard radiograph.[16] A significant difference in these studies is that the Evans study reported whether or not the PICC line tip could be visualized and measured inter-observer variability based on that.[28] The Webster study measured interobserver variability based on reports of the line tip position.[16]

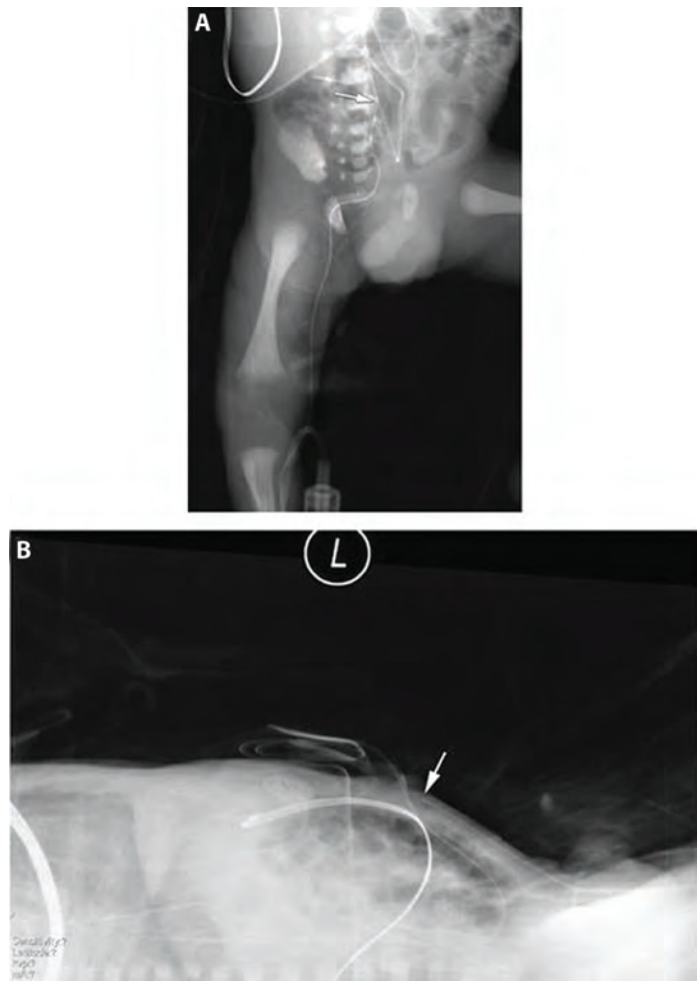
ECG Monitoring

Neubauer described the use of intraatrial ECG monitoring for PICC line placement. Using continuous ECG observation and a special "Alphacard" syringe as the electrical conductor between the catheter and the ECG conducting cable, the researcher inserted a silastic catheter filled with 5.85 percent sodium chloride solution into a suitable vein until a tall P-wave appeared, indicating a central position in the right atrium (Figure 3). The catheter was then withdrawn until the exact point where the P-wave became smaller, indicating positioning of the catheter in the vena cava at the entrance to the right atrium. If a tall P-wave did not appear, the catheter was withdrawn a short distance and advanced again as often as required until a tall P-wave occurred. Of 535 catheters (gestational age of patients 23–42 weeks, mean 30 weeks; birth weight 480–6,300 g, mean 1,330 g; postnatal age 0–279 days, mean 4 days), 273 were placed using intraatrial ECG monitoring and demonstrated accurate radiographic confirmation of placement. Of those inserted by ECG monitoring, 9.5 percent were incorrectly placed, whereas 64.5 percent of those placed without ECG were incorrectly placed. Neubauer noted 16 potentially dangerous malpositions in PICC lines inserted without ECG guidance that could not be corrected by simply withdrawing the catheter, whereas none occurred with the ECG method.[14]

As discussed earlier, catheters should not reside within the cardiac chambers. This method allows the catheter to enter the right atrium, but it is withdrawn immediately using the guidance of the ECG tracings. This could be a potentially dangerous practice because the catheter is allowed to enter the right atrium. However, it could be argued that the catheter is not allowed to stay within the right atrium except briefly, and during this study there were no complications noted with line placement when this method was used. It is also important to note that when lines are inserted blindly, it is not uncommon for the line to be malpositioned within the heart, and when subsequent x-rays demonstrate the malposition, the lines are repositioned. This is an important consideration when using this method for PICC line placement.

FIGURE 4 ■ Anteroposterior and lateral radiographs of the abdomen.

A. The arrow is pointing to the tip of the PICC at L5. B. The arrow is pointing to the tip of the PICC.

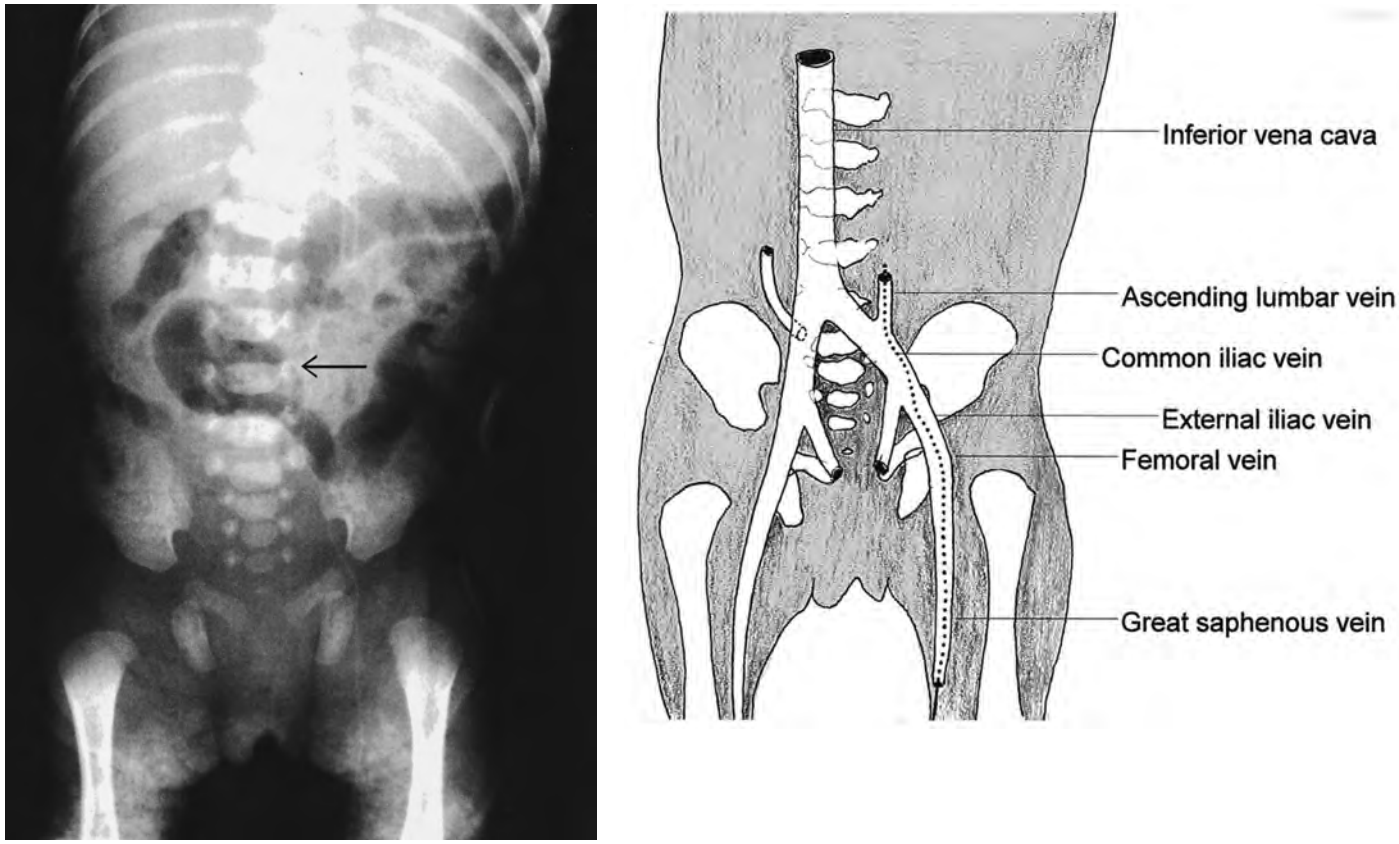


From: Coit, A. K., Kamitsuka, M. D., & Pediatrix Medical Group. (2005). Peripherally inserted central catheter using the saphenous vein: Importance of two-view radiographs to determine the tip location. *Journal of Perinatology, 25,* 674. Reprinted by permission.

Supine and Lateral Chest Radiographs

Coit and coworkers described two case reports of PICCs inserted through the saphenous vein that were malpositioned outside of the IVC. One tip position had been confirmed by supine radiograph and the other by supine radiograph with

FIGURE 5 ■ Left long saphenous percutaneous central line inserted into the ascending lumbar vein.



From: Clarke, P., Wadhawan, R., Smyth, J., & Emmerson, A. J. (2003). Parenteral nutrition solution retrieved by lumbar puncture following left saphenous vein catheterization. *Journal of Paediatrics and Child Health, 39,* 387. Reprinted by permission.

contrast (Figure 4). After clinical deterioration of the infants, lateral chest x-rays indicated PICC malpositions in the ascending lumbar vein.[29] Mitsufuji and colleagues describe two similar cases in which a single supine abdominal x-ray suggested placement in the IVC, but after clinical deterioration, a lateral view confirmed placement in the vertebral lumen.[30] Lussky and associates and Clarke and coworkers described two cases in which saphenous PICC lines inadvertently catheterized the ascending lumbar vein (Figure 5).[31,32] These studies suggest that when a PICC line is placed via the saphenous vein, supine and lateral x-rays should be performed to confirm placement. It could be argued that instead of taking two x-rays (supine and lateral), a single supine x-ray with contrast would be adequate for confirming placement. However, one of the cases of malposition that Coit and coworkers described did use contrast to confirm placement in a case in which the line was actually in the ascending lumbar vein. A lateral radiograph immediately showed the malposition.[29] No studies evaluated whether performing lateral x-rays would decrease the risk of complications and adequately illustrate PICC line tip position. The articles described were case reports discussing incidents related to lower extremity PICC lines, and recommendations were based on those experiences. In the situations mentioned, a lateral view of the PICC line did confirm that it was indeed malpositioned, whereas the supine film did not.

OTHER CONSIDERATIONS IN PICC LINE PLACEMENT

Follow-up Chest Radiographs for PICC Placement

Nadroo and associates conducted a national survey to determine the magnitude of neonatal death related to PICCs. The survey was done after they experienced two incidents of PICC-related pericardial tamponade leading to death. Using information from the surveys, they determined that migration of the catheter tip beyond the site of initial placement seemed to be a common problem. They recommended serial radiographs with the arm taken in the same position (preferably in adduction). They adopted a policy of x-rays twice a week as long as a PICC is in use.[33]

Arm Position and PICC Line Tip Position with Supine Chest Radiographs

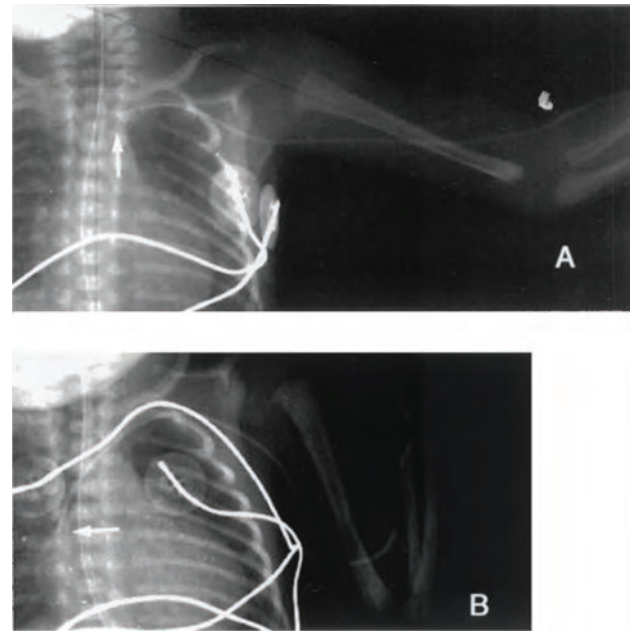
Arm position is a very important consideration when confirming PICC line tip position with chest radiographs. Nadroo and coworkers studied 280 radiographs of 60 neonates with

PICCs inserted in the upper limbs and found that catheters placed through the basilic or axillary vein migrated toward the heart with adduction of the arm and those that were placed through the cephalic vein moved away from the heart with adduction. Flexion of the elbow displaced catheters in the basilic or cephalic vein below the elbow toward the heart, but did not have any effect on catheters placed through the axillary vein. Basilic vein catheters moved the most with simultaneous shoulder adduction and elbow flexion (Figure 6). The researchers used arm movements to correct malpositioned catheters and recommended that monitoring of catheter tip position be done with the upper extremity in maximum inward movement for that vein.[9]

Connolly and colleagues studied 85 children ranging in age from newborn to 18 years (weight 700 g–61 kg) to evaluate the influence of arm movement on central tip location. The maximum range of motion of each PICC ranged from 0.5 to 3.5 rib spaces, with a mean of 2.2 rib spaces. They found no statistically significant difference between the range and extent of movement when comparing right and left arm insertions, basilic or cephalic venous systems, or insertions from above or below the elbow. They also found that the central tip descended deeper into the chest with elbow bending and with arm adduction.[34]

FIGURE 6 ■ Catheter placed in basilic vein.

Maximum inward displacement of the tip is caused by simultaneous shoulder adduction and elbow flexion from A to B.



From: Nadroo, A. M., Glass, R. B., Lin, J., Green, R. S., & Holzman, I. R. (2002). Changes in upper extremity position cause migration of peripherally inserted central catheters in neonates. *Pediatrics, 110,* 134. Reprinted by permission.

DISCUSSION

When analyzing PICC line tip position, it is also important to consider the degree of interobserver variability. Odd, Battin, and Kuschel performed an Internet-based survey using 20 clinical images with long lines *in situ,* receiving 27 responses from members of the Australian and New Zealand Neonatal Network and clinical staff of National Women's Hospital NICU. They found significant interobserver variation in the interpretation of long line tip position, with 68 percent agreement that the line tip was seen and 62 percent agreement in position. There was 86 percent maximum agreement on the action to take with the line tip position.[35] As mentioned earlier, a different study by Odd and associates found that the use of contrast with radiographs increased the proportion of agreement from 37 percent to 59 percent. Overall, however, they found the interobserver variation was substantial.[24]

It is clear that because of the potential complications with PICC lines, confirmation of PICC tip position is essential. Confirmation by fluoroscopy is the gold standard in the adult population and seems to be extremely reliable in neonates, based on the studies done so far. However, it is not always practical in the neonatal setting because PICC line insertions under fluoroscopy cannot be done at the bedside and, for neonates, the procedure would cause increased stress related to movement and transfer and increased cost and exposure to radiation (although, as mentioned, the radiation exposure is less than a standard x-ray). Ultrasound reports have shown promising results and might be a way to avoid exposure to radiation; but the data from the neonatal population are inadequate to recommend widespread use. Furthermore, more training would be required for clinicians to be able to safely interpret ultrasounds, and there are also logistical problems with performing ultrasound examinations at the bedside. Cost related to equipment and training would have to be considered; however, if numerous x-rays are being used for confirmation of line tip position, ultrasound could prove to be a cost-effective alternative. Fluoroscopy and ultrasound both have the benefit of evaluating tip position in real time as it is being inserted, allowing the line tip position to be adjusted immediately, avoiding any extra handling and manipulation of the line and patient. They also have the benefit of evaluating upper extremity line tip position with the infant's arm in different positions. Intraatrial ECG monitoring has been shown to be beneficial, but its use is not widespread. There are also potential risks related to having to advance the line into the right atrium to confirm placement. More studies need to be performed in neonatal populations.

Supine chest x-rays are the most convenient way to identify tip position, although the technique has limitations. The PICC line inserter is inserting the line blindly to a predetermined length, and the film is a static image, so when repositioning is necessary, there is additional manipulation of the infant and line. Each additional x-ray for placement exposes the infant to additional radiation. It is also not clear on a static image what the line is doing when the position

of the infant, particularly the arm, is manipulated. Should there be difficulty or discrepancy in identifying the line tip or line tip position, contrast or ultrasound could then be used to confirm placement. Generally, the risk of side effects is minimal with the small amount of contrast used in a PICC line, but it is still a consideration. Renal function should be evaluated prior to its administration, and it may be helpful to monitor thyroid function. Because most PICC lines are radiopaque, the concern is not visualizing the PICC tip, but accurately evaluating its position within the correct vessel and seeing where the infusate is flowing. Timing of the x-ray is important to evaluate line position to ensure the contrast has filled the line as well as not obscured the line tip.

When PICC lines are placed through the saphenous veins, the risk may justify performing both supine and lateral radiographs to confirm placement in the IVC. Complications of misplaced PICCs can be very serious, and every attempt to minimize them should be made.

CONCLUSION

This review found that there is a paucity of information available to answer the question: Are supine chest and abdominal radiographs the best way to confirm PICC placement in neonates? Although supine chest and abdominal radiographs are the most widely used method, data are available that support the use of ultrasound as a method to evaluate PICC placement, with added benefits of being able to adjust the PICC tip position while the line is being inserted, avoiding extra manipulation of the infant and line, and reducing exposure to radiation. However, the cost of equipment and training need to be considered when employing this method, and if there are problems viewing the line, a chest radiograph would have to be done to confirm placement. More studies need to be done to recommend this as the standard of care for PICC line placement. When confirming placement of a line placed in the lower extremities, a supine and lateral chest and abdominal radiograph would confirm appropriate position in the IVC and should be considered. Contrast is a widely used and accepted method of confirming line placement and may be used if there is any concern, discrepancy, or difficulty in visualizing the line tip. It is important to be aware of the potential side effects and risks associated with its use.

As PICC lines are becoming more common, it is important to be aware of all the methods available of confirming PICC placement and to be familiar with their uses and limitations. More studies are needed to evaluate cost-effective, safe, and reliable methods to confirm PICC placement to decrease the risks of complications. Also, more studies are needed to evaluate the changes in upper extremity PICC tip position related to position of the arm. It is important to evaluate not only the initial PICC tip position, but what is happening to the line after initial insertion as the infant changes position. Serial investigations of placement are also warranted to ensure the line has not migrated.

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