

## Ultrasound *vs.* standard radiography to determine peripherally-inserted central catheter tip location

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### Abstract

**Background** The use of a peripherally-inserted central catheter (PICC) has increased in preterm neonates to facilitate the administration of total parenteral nutrition. Standard radiography (thoracoabdominal X-ray) is the gold standard for determining the position of the PICC tip. However, radiography is not always accurate, influenced by the position of the extremities and anatomic variations, time-consuming procedural process, involves radiation, and is costly. Ultrasonography (USG) may serve as an easier, safer, less costly, and more real-time alternative in the neonatal intensive care unit (NICU) patients.

**Objective** To assess the accuracy of USG use in determining PICC tip position compared to that of standard radiography.

**Methods** This diagnostic study was conducted in the NICU at Dr. Cipto Mangunkusumo Hospital, Jakarta. The PICCs were placed using standard NICU procedure, then the tip position was evaluated using the USG immediately before standard radiography was performed. A 2x2 table was constructed to compare the diagnostic accuracy of the two modalities.

**Results** A total of 29 neonates were included in our study. Subjects' mean gestational age and weight were 31.7 weeks and 1,618.9 g, respectively. Concordance of PICC tip positioning between standard radiography and USG occurred in 27 neonates (93.1%). USG had 88.89% sensitivity, 95% specificity, and 93.1% diagnostic accuracy.

**Conclusion** USG has excellent diagnostic accuracy for confirmation of the PICC tip position. [Paediatr Indones. 2024;64:126-31; DOI: 10.14238/pi64.2.2024.119-24 ].

Inserting a peripherally-inserted central catheter (PICC) is a routine procedure that is performed in the NICU for full term and preterm neonates to provide total parenteral nutrition.<sup>1-6</sup> The use of PICCs in clinical practice has been associated with various complications if the catheter tip is incorrectly placed, such as obstruction, catheter rupture, infiltration, migrates following insertion, phlebitis, thrombosis, pleural effusion, pericardial effusion, sepsis caused by central line-associated blood infection (CLABSI), cholestasis, cardiac tamponade, and death.<sup>7-10</sup> The tip position for PICCs inserted in the upper extremities should be within the superior vena cava (SVC) above the right atrium. If the PICC is inserted through the lower extremities, the tip position should be in the inferior vena cava (IVC) below the right atrium. Often, catheters are not placed at the optimal position or within the heart, the necessitating repositioning and repeated X-rays.<sup>11,12</sup>

Ultrasonography (USG) is a safe and accurate supporting tool for diagnostic examinations and medical

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procedures in the NICU. Ultrasound-guided insertion of umbilical catheters can decrease evaluation time and ensure the catheter tip is in an optimal position compared to standard radiography line placement.<sup>13</sup> Experienced operators can detect the PICC tip using echocardiography better than novice operators, and the use of color Doppler provides better detection of the PICC tip.<sup>14</sup>

Evidence suggests that standard radiography alone is not entirely accurate for identifying catheter tip position. Additionally, it is often difficult to position the neonate for an optimum radiographic image without geometric or movement artifacts. Standard radiography also provides only a static image of the PICC position. The accuracy of the PICC tip on radiographic examination depends on the position of the extremity, and the compression of soft tissue around a catheter of fixed length, which could lead to catheter tip displacement.<sup>10</sup> If the PICC tip position is within the heart, it will increase the risk of serious complications, such as pericardial effusion and cardiac tamponade which can be fatal. Therefore, confirmation of the PICC tip placement should be performed immediately, and the PICC tip should be readily identifiable.<sup>8</sup>

In Indonesia, the performance of the USG in the NICU has become increased, following the development of the point of care ultrasound (POCUS) concept in neonatal care.<sup>15</sup> Confirmation of proper and safe PICC tip position is necessary for optimal NICU care. As the gold standard, radiographic examination is not always accurate and has radiation effects that are unsafe for neonates. As such, we aimed to assess the accuracy of USG in determining optimal PICC tip position compared to standard radiography.

## Methods

This diagnostic test study was conducted at Cipto Mangunkusumo Hospital, Jakarta, in April 2017 to May 2017 and was approved by the hospital Ethics Committee. Neonates who required PICC placement and who were hospitalized in the NICU were included. Neonates with contraindications for PICC insertion were excluded from the study.

The PICC line was placed by a certified doctor or nurse, using a *Premicath 28 G* or *Nutriline Twinflo 24 G*

*Vygon* catheter. In our unit, optimal positioning of the PICC tip was in the superior vena cava (SVC) above the right atrium for an upper extremity insertion, and in the inferior vena cava (IVC) below the right atrium for a lower extremity insertion. Confirmation of tip position was performed by a pediatrician trained in USG (Philips ultrasound type HD-11 XE with a 5-8 Hz micro convex probe). Results were confirmed, consulted, and recorded by an imaging consultant pediatrician. Immediately after the USG, the standard radiographic examination (thoracoabdominal X-ray) was performed by a radiographer using a *Philips* mobile X-ray of the *Practix* type 300. The X-ray results were reported and recorded by an imaging consultant pediatrician, regardless of the ultrasound results.

Quantitative data analysis was conducted using SPSS version 20.0 and OpenEpi ver 2.3 software. Diagnostic-test data were analyzed using a 2x2 table to assess the sensitivity, specificity, positive predictive value, negative predictive value, and diagnostic accuracy using Wilson's score.

## Results

During the study period, 29 patients met the inclusion criteria and enrolled in the study. All subjects with an indication for parenteral nutrition had a PICC placement. The characteristics of subjects are shown in **Table 1**. There were 11 males (37.9%) and 18 females (62.1%). Subjects' mean gestational age was 31.7 (SD 4.0) weeks, mean birth weight was 1,618.9 (SD 849.6) grams, and mean birth length was 39.5 (SD 5.9) cm. PICC lines were inserted in the upper extremities of 20/29 neonates and in the lower extremities in 9/29 neonates.

Standard radiography and USG confirmed PICC tip placement in 9/29 neonates with the correct PICC tip position and 20/29 neonates with PICC tip malposition (**Table 2**).

The suitability of USG for PICC tip examination compared to standard radiography was noted in 27/29 neonates: 8 neonates had the PICC tip in the appropriate position and 19 neonates had malpositioned PICC tips. Of the 8 neonates with appropriately positioned PICC tips, 6 neonates had PICC tips in SVC and 2 neonates had PICC tips in IVC. Of the 19 neonates with malpositioned PICC

tips, 17 neonates had PICC tips in the right atrium (**Figure 1**), one case had the tip in the aorta, and one case had the tip in the mid-clavicle (right subclavian artery). The estimated sensitivity and specificity for USG examination were 88.89% and 95%, respectively. The positive predictive value was 88.89%, the negative predictive value was 95% and the diagnostic accuracy value was 93.1%.

We noted 2 discrepant cases between USG and standard radiographs. In the first case, the USG showed the PICC tip in the right atrium, whereas the standard radiography showed the PICC tip inside the IVC at the thoracic vertebra 11 level (**Figure 2**). In the second case, USG revealed the PICC tip inside the SVC, while standard radiography revealed the PICC tip in the right atrium (**Figure 3**).

## Discussion

A total of 29 neonates with indications for parenteral nutrition received PICC placement. Four neonates were full term and 25 were preterm, with mean gestational age of 31.7 weeks and mean birth weight of 1,618.9 grams. A total of 4 full term neonates had PICCs placed due to sepsis and possible NEC. The high rate of the preterm neonates with indication for PICC insertion was similar to that reported in previous studies.<sup>4,11</sup>

The distribution of the PICC tip position was upper extremities in 20 and lower extremities in 9 neonates. This finding was in agreement with the PICC guidelines which stated that the priority for PICC positioning was through the upper extremities (Basilic vein) due to easier positioning, technique since the vein was large, easy to insert, had a shorter distance to SVC, and more accessible to fixation.<sup>16</sup>

USG and standard radiography were in agreement in confirming PICC tip location in 27/29 of subjects. Similarly, a previous study reported confirmity of

USG and standard radiography in 87% of subjects.<sup>17</sup> However, another study noted lower confirmity in 59% of subjects between echocardiography and standard radiography.<sup>18</sup> This difference could have been due to the transducer used in our study. We used a C5-8 micro-convex probe with this type of superficial examination, while two previous studies used a probe sector for echocardiographic examination.<sup>17,18</sup> Alternatively, differences may have been due to the position for the baby during the examination, as bone shadows, thymus shadows, heart shadows, thymus shadows, heart shadows, and bowel shadows can affect the perception in radiographic interpretations.

These study results indicate that USG is accurate in estimating optimal position of the PICC tips. Indeed, USG may be even better than standard radiography, such as in a study which showed standard radiographic sensitivity of 64% in indentifying incorrect PICC tip position, specificity of 55%, positive predictive value of 58%, negative predictive value of 60%.<sup>18</sup>

In cases where the PICC tip was within the heart, it was likely that the initial measurement were overestimated prior to PICC insertion. This should be

**Table 1.** Characteristics of subjects

Characteristics	N=29
Gestational age, weeks	
Mean (SD)	31.7 (4.0)
Median (range)	31 (26-41)
Birth weight, g	
Mean (SD)	1,618.9 (849.6)
Median (range)	1,350 (600-3750)
Birth length, cm	
Mean (SD)	39.5 (5.9)
Median (range)	41 (31-52)
Gender, n	
Male	11
Female	18
Place of insertion, n	
Upper extremity	20
Lower extremity	9

**Table 2.** PICC tip confirmation results

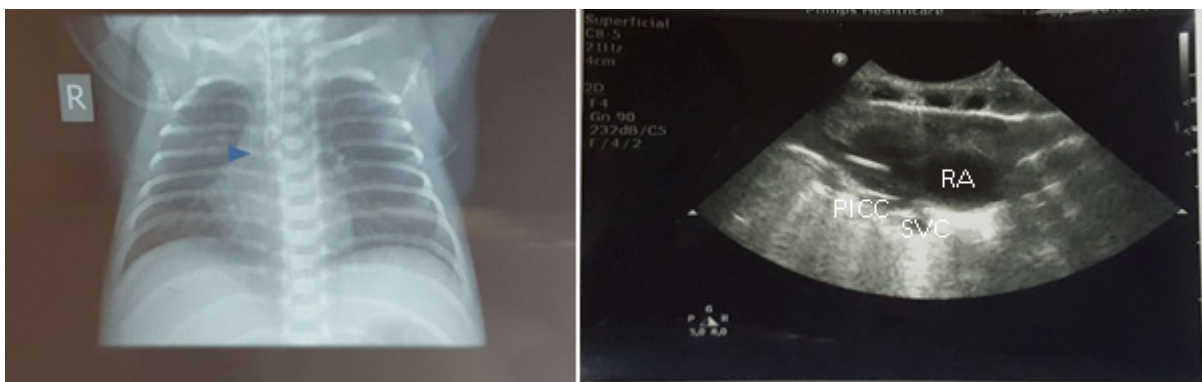
		Standard radiography		Total
		Appropriate	Malposition	
Ultrasound	Appropriate	8	1	9
	Malposition	1	19	20
	Total	9	20	29



**Figure 1.** An overview of the PICC tip within the heart (A) right parasternal view and, (B) subcostal view. (LA=left atrium; LV=left ventricle; PICC=peripherally inserted central catheter; RA=right atrium; RV=right ventricle)



**Figure 2.** (A) Standard radiographic and (B) USG (subcostal longitudinal) views of the same neonate. (IVC=inferior vena cava; PICC=peripherally inserted central catheter; RA=right atrium)



**Figure 3.** (A) Standard radiographic and (B) USG (right parasternal view) views of the same neonate.

an internal check for nurses to follow as part of the existing standard operating procedure (SOP). In the case of the PICC that was in the aorta, the PICC was

errantly inserted through the femoral artery, which was initially thought to be the femoral vein. It was difficult to see the undulation of arterial blood in the PICC.



Standard radiographs are also not very predictive of the PICC tip in the aorta.

In our study, there were 2 discrepant cases between USG and standard radiographs. Tauzin *et al.*<sup>19</sup> also noted different results, with a yield of 25% of the total PICCs inserted. We found that standard radiographic examinations to estimate PICC tip position are not always accurate, probably because standard radiographic examination is static and only displays one snapshot view in time. Accurate assessment of the PICC tip by standard radiographs requires that the forearm be maintained in an ideal position throughout the procedure, which is extremely difficult in neonates. In addition, assessment of the PICC tip is strongly influenced by the consulting physician who reads the standard radiographic examination. Determining SVC's upper and lower limits on the standard radiographic examination is challenging.

Our study demonstrates the advantages and disadvantages of USG. USG can be performed in real-time to estimate the PICC tip more accurately, especially when it has entered the heart. USG can provide a real-time picture of the PICC tip and its shifting when the baby's arm moves. USG has disadvantages such as, it should be performed by a trained doctor in USG.

In this study, the baby's shoulder was abducted and the arm extended at the time of standard radiography and USG. This position has become a standard in the NICU and can be used as a reference for further study to change the existing standards. Nadroo *et al.*<sup>20</sup> who found that the furthest shift was  $\pm 7-15$  mm towards the heart when the shoulder was adducted and the elbow was flexed. The location of the PICC tip is very important because serious complications can occur if it is within the heart. The PICC tip was within the heart, resulted in complications of pericardial effusion and cardiac tamponade, so it is recommended that the PICC tip position be in the SVC (1 cm above the right atrium for premature neonates, and 2 cm for term neonates).<sup>21</sup>

Ultrasound is less costly than the standard radiographic examination, Rp. 215.000,- in our facility, and it can be done directly by the patient's physician. A standard radiographic examination (thoracoabdominal X-ray) costs Rp. 325.000,- for one examination. In addition, USG reduces the effects

of additional radiation and manipulation measures to correct the PICC tip location if it is too deeply inserted.

A limitation of our study was that the initial estimation method for catheter length to be inserted was not the same or did not follow the established SOP, so many of catheter tips went too deep within the heart. Improvement of the SOP can be considered if further study is carried out. In conclusion, the use USG has better accuracy in assessing the optimal positioning of the PICC tip compared to standard radiography.

## Conflict of interest

None declared.

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