Original Article

Assessment of Central Catheter Tip Position in Neonates by Ultrasonography Versus X-ray

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Abstract

Central catheters are frequently inserted in neonatal intensive care units. The tip of these catheters should be in the correct position; otherwise, it may lead to life-threatening complications. X-ray has been universally used as a standard imaging modality to localize the position of central lines. Ultrasonography is an upcoming promising modality. We compared the catheter tip localization using ultrasonography versus X-ray.

Keywords

Birth weight, imaging and radiology, neonatal care, newborn

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Introduction

Central catheters are frequently inserted in neonates in neonatal intensive care units (NICU).[1] The commonly used central catheters in NICU are umbilical venous catheter (UVC), umbilical arterial catheter (UAC), and peripherally inserted central catheter (PICC). The common indications for insertion include administration of total parenteral nutrition, inotropes, high glucose infusion rate, and requirement of prolonged vascular access due to any cause (extremely low birth weight babies, prolonged antibiotics, surgical conditions), etc.[2–4] Malposition of the tip of these central catheters can lead to life-threatening complications, which include thrombosis, cardiac arrhythmias, cardiac tamponade, pleural as well as pericardial effusion, infective endocarditis, liver hematoma, diffuse liver injury, portal hypertension, phrenic nerve palsy, and infiltration into adjacent tissues including pericardial and pleural spaces.[1,5,6]

Various formulae have been used for the calculation of the central line length to be inserted, which are then confirmed by imaging modality.[3,6–9] Chest and abdominal X-rays are the standard practice for localization of the tip position. Although an X-ray is easy to interpret, exposure to radiation, longer time to confirm the position, and no direct visualization of large vessels to confirm the catheter tip position are some of its limitations. In recent years, ultrasonography (USG) has been increasingly used and can also provide real-time assessment of the tip position.[10–12] This study was done to evaluate the role of bedside ultrasound in confirming the central catheter tip position and its potential to become the preferred imaging modality for the same over X-ray assessment.

Materials and Methods

This prospective observational study was conducted in a level III NICU in North India over a six-month period from February to July 2023. The study was approved by the institutional ethics committee and a written informed consent was obtained from the guardians of all the consecutive neonates admitted to the NICU requiring central catheter (UVC, UAC, PICC) placement. Neonates with any surgical condition that could interfere with the path of insertion were excluded. For calculating the length, the Gomella formula was used for UVC insertion (distance from umbilicus to xiphisternum + 1 cm),[13,14] Dunn nomogram was used for UAC insertion based on the shoulder–umbilicus length,[7] and anatomical superficial landmarks were used for PICC insertion. For the upper limb PICC line, the length measured was from the punctured point along the vein to the right sternoclavicular joint and down to the second intercostal space. For the lower limb PICC line, the length measured was from the punctured point via the groin to the midpoint of the umbilicus and xiphoid.[6]

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After inserting the line under the sterile settings using standard techniques, USG and X-ray were done to confirm the position.

USG was done using a Sonosite M Turbo machine with a linear probe with a frequency of 4–8 MHz, by a neonatology resident, trained in USG for three months before the study. For localizing UVC, lower limb PICC line, and UAC, the probe was kept below the xiphoid process to scan the long axis of the inferior vena cava (IVC) and aorta, respectively.[15,16] Additional echocardiographic windows (apical, parasternal long axis view, or short axis view) were used if needed. UVC and lower limb PICC tips were considered well located if they were located at the right atrium-IVC (RA-IVC) junction or 0.5–1 cm proximal to the junction.[15,17] A catheter high up in the right atrium or below the specified position was considered malpositioned. Optimal UAC tip position was considered if the catheter passed the superior mesenteric artery (SMA) and celiac artery and was present in the thoracic aorta.[18] For the upper limb PICC line, the USG probe was kept in the left or right high parasternal area, the superior vena cava (SVC) was localized, and the PICC line tip was identified.[15,19] If the tip was located at the right atrium-SVC (RA-SVC) junction or 0.5–1 cm proximal to the junction, it was considered optimally positioned.[15] If the tip was inside the right atrium or higher than the specified position, it was considered malpositioned. During USG, if there was difficulty in visualizing any catheter tip, 0.5–1 ml of normal saline was flushed, to help in locating the tip better.

A bedside X-ray (supine antero-posterior chest/abdomen/trunk with limb view) was ordered soon after the placement of the central line to confirm the tip position. Radiography was done with a portable in-house digital X-ray machine to assess the catheter position. On X-ray, UVC and lower limb PICC lines were considered optimally placed if they were at the level of the diaphragm or between T8 and T10.[12,15,17,19] The UAC position was considered correct if it was between T6 and T10.[15,20] The upper limb PICC line was considered correctly placed if the tip was between T4 and T6.[12,19] Tip positions above or below the above-mentioned positions were considered malpositioned.

The primary outcome was to compare the rates of tip localization using ultrasonography and X-ray. Secondary outcomes were to compare the central catheter tip malposition rates based on ultrasonography and X-ray and to compare the time taken from insertion to tip localization using the two modalities.

Statistical Analysis

The minimum sample size was calculated as $n = Z_\alpha P(1-P)/d^2$, where p was .27,[17] $Z_\alpha = 1.64$ at 90% confidence level, and d = error taken at 10%. So, a minimum of 54 samples were included in our study. Data was described in terms of range, mean ± standard deviation, frequencies (number of cases), and relative frequencies (percentages) as appropriate. For comparing categorical data, a chi-square (χ^2) test was performed. The kappa value was calculated to see the agreement between the modalities. A probability value (p value) less than .05 was considered statistically significant. All statistical calculations were done using the Statistical Package for the Social Sciences (SPSS) version 21 (SPSS Inc., Chicago, IL, USA).

Results and Observation

Out of 44 neonates, 42 neonates were enrolled. Two were excluded in view of congenital malformations. In 42 neonates, 54 central lines were inserted. A PICC line was inserted in 20 (37%), UVC in 23 (42.6%) and UAC in 11 (20.4%) cases (Table 1).

The catheter tip could not be visualized in five cases (9.3%) by USG and in three cases (5.6%) by X-ray (kappa value 0.761, p value .001) (Table 2). The three upper limb PICC lines where the tip could not be visualized were common in both groups.

On USG, out of 49 visualized tips, 33 (67.3%) were optimally placed and 16 (32.7%) were malpositioned, compared to 26 (51%) (optimally placed) and 25 (49%) (malpositioned) in X-ray (Figure 1; Table 3). The time taken to assess the position by USG and X-ray was 19.4 and 168.3 minutes, respectively (p value .001) (Table 4).

Table 1. Baseline Demographic Details of the Enrolled Cases.

	***n* = 54#**
Gestation	
• <28 weeks	4
• 28–32 weeks	18
• 33–36 weeks	10
• ≥37 weeks	22
Central catheters	
• PICC	20 (37%)*
• UVC	23 (42.6%)
• UAC	11 (20.4%)

Note: #54 central lines were inserted in 42 neonates with a mean gestation age of 33.5 weeks.

*Upper limb PICC lines—6, lower limb PICC lines—14.

Abbreviations: PICC, peripherally inserted central catheter; SD, standard deviation; UAC, umbilical artery catheter; UVC, umbilical venous catheter.

Table 2. Tip Localization Rates on X-ray and USG.

	Non-visualization *n* (%)	**Visualization *n* (%)**	**Kappa Value**	***p* Value**
X-ray (n = 54)	3 (5.6%)*	51 (94.4%)	0.761	.001
USG (n = 54)	5 (9.3%)#	49 (90.7%)		

Note: *3 upper limb PICCs.
#4 upper limb PICCs, 1 lower limb PICC.

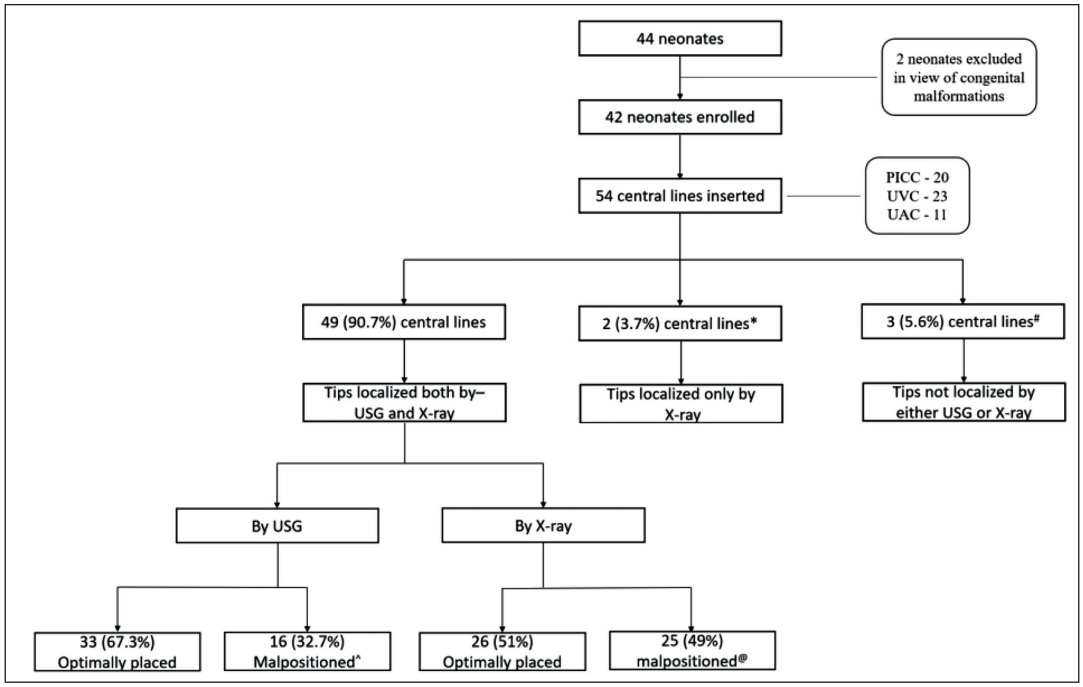

Figure 1. Visualization and Localization Rates of Central Lines by USG and X-ray.
Note: *1 upper limb PICC line, 1 lower limb PICC line; #3 upper limb PICC lines; ^9 UVCs, 1 UACs, 6 PICCs; @14 UVCs, 3 UACs, 8 PICCs.
Abbreviations: PICC, peripherally inserted central catheters; UAC, umbilical artery catheters; UVC, umbilical venous catheters; USG, ultrasonography.

Table 3. Malpositioned and Optimally Placed Catheter Tip Position by X-ray and USG.

Central Catheter Tip Position	X-ray (*n* = 51)	USG (*n* = 49)	Kappa Value	*p* Value
Malpositioned	25 (49.0%)*	16 (32.7%)#	0.374	.006
Optimally positioned	26 (51.0%)	33 (67.3%)		

Note: *8 PICCs, 3 UACs, 14 UVCs.
#6 PICCs, 1 UAC, 9 UVCs.

Table 4. Time Taken to Assess the Position by X-ray and USG.

	Minimum (Minutes)	Maximum (Minutes)	Mean (SD)	*p* Value
X-ray (*n* = 54)	60.00	270.00	168.3 (55.11)	.001
USG (*n* = 54)	13.00	60.00	19.4 (7.24)	

Discussion

Central catheterization is one of the common procedures in tertiary care NICUs. Incorrect position of the catheter tip may lead to serious complications.[1,6] Ensuring the correct position cannot be overemphasized. The primary outcome of the study was to compare tip localization rates using X- ray and USG.

On USG, 9.3% of the catheter tips could not be visualized, compared to 5.6% on X-ray (kappa value 0.761, *p* value.001), suggestive of good agreement. A strong agreement between the USG and X-ray in the visualization of the PICC line was also confirmed by Jiao et al.[19] In our study, most of the non-visualized catheter tips in the USG and X-ray group were upper limb PICC. In the X-ray, all the three upper limb PICCs could be traced up to the shoulder joint, but the tip could not be localized. The catheter tip overshadowed by the bone and poor exposure in the X-ray could have led to it. In the case of USG, non-localization could be due to the overexpanded lung obstructing the tip localization, inadequate experience due to a short training period of three months for the neonatology resident, and also, the PICC line not reaching the SVC.

In other two patients, where USG could not localize the tip, one was the upper limb PICC line, where the tip was in the shoulder joint, and one was the lower limb PICC line, where the catheter ended in the right hip joint. As only the SVC or IVC right atrium junction was visualized in the USG, these two PICC lines could not be visualized.

In a study by Thakur et al, the central catheter tip could be defined in 95% of the cases by USG.[15] The three catheter tips that could not be visualized were two PICCs and one UVC due to their presence in aberrant locations. In the study by Jiao et al, by USG, 98% of the PICC tip could be visualized.[19] One case where it was not visualized was due to lung fields.

On USG, 16 central lines (9 UVCs, 1 UAC, and 6 PICCs) were malpositioned, compared to 25 (14 UVCs, 3 UACs, and 8 PICCs) in X-ray. This showed poor agreement between the two modalities. Out of the 16 malpositioned tips on USG, 12 were also malpositioned on X-ray. Out of the 33 optimally placed tips on USG, 22 were also interpreted as well placed on X-ray. This difference may be due to variations in the anatomical landmarks. X-rays provide a two-dimensional image, which may not always accurately depict the actual catheter position in a three-dimensional space. X-ray gives an approximate position of the RA-SVC or RA-IVC junction or aorta, whereas on USG, real-time visualization of the vessels can be done. This limitation could lead to misinterpretation of the catheter tip location, resulting in higher malposition rates. Also, since there was a significant time lag between the two modalities, lines may have migrated in position. The position of the limbs while doing the imaging may also have caused the difference. This difference in the tip position was also documented by Michel et al, where the UVC tip position was accurately diagnosed by USG in 95.1% cases, compared to only 63.9% of cases by X-ray.[21] Similarly, concordance between X-ray and USG for PICC line localization was seen only in 59% of cases in a study by Jain et al.[22] Unlike our study, there was excellent agreement in the malpositioned rates of central catheters between X-ray and USG in a study by Thakur et al.[15] They showed 38.7% optimally placed catheters on X-ray, compared to 32.2% on USG. These variations in the studies could be due to factors such as the expertise level of the neonatologists performing USG and different types of central catheters compared in different studies. Varying gestation of neonates enrolled in different studies may also lead to the difference, as suggested by Michel et al.[21]

Point-of-care USG also has the benefit of reducing the time for confirming the position of central catheter tips. Our findings revealed a significant difference in the time taken from insertion to confirmation of the tip position by USG and X-ray with an average of 19.4 and 168.3 minutes, respectively. This result was consistent with other studies that show a significant decrease in the time by USG for confirmation of the catheter tip location.[10,23] USG also provides real-time visualization of the catheter during the procedure and can reduce the malposition rates, procedure time, and number of attempts of catheter manipulation.[16,17]

The strength of our study was the inclusion of the majority of central catheters inserted in the NICU. Ultrasound was done by a neonatology resident trained for three months, which is a true scenario in most of the tertiary care setups of low- and middle-income countries. Limitations include inadequate sample size for subgroup analysis for comparison between X-ray and USG in different gestation and weight of neonates, small or appropriate for gestation age neonates, and between different catheters. Difference in the visualization by either modality due to the size of the catheter was also not compared. Lateral view X-ray could provide better tip localization; however, to limit radiation exposure, as an NICU protocol, this was not done in our study. Further multicentric studies with larger sample sizes are needed to further increase the generalizability of the findings.

Conclusion

The visualization rate of central catheter tips was similar in USG and X-ray. There was poor agreement between malposition rates between the two modalities. With the actual visualization of the veins and aorta in USG, compared to the vertebra or diaphragm—the surrogate markers of large vessels in X-ray—ultrasonography is bound to be more accurate in predicting the actual location of the catheter tips. USG showing real-time imaging of the catheter with immediate feedback increases the probability of correct positioning and reduces the manipulations, thus enhancing the efficiency and accuracy of the procedure, leading to improved patient outcomes. Thus, USG has a potential to become a preferred modality over X-ray, for the assessment of the central catheter tip position in neonates.

Authors' Contribution

PP, CC, BS, VMJ, SP, and GG were involved in the management of patients. All authors were involved in writing the manuscript. CC, GG, and SP were involved in corrections of the manuscript and providing critical inputs.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical Approval

The study was approved by the institutional ethics committee (SRHU/HIMS/RC/2023/37).

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Informed Consent

A written informed consent was obtained from the guardians of all the consecutive neonates admitted to the NICU requiring central catheter placement.

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