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Review Article

Technologies for maintenance of Peripherally Inserted Central Catheter in neonates: an integrative review

Tecnologias para manutenção do Cateter Central de Inserção Periférica em neonatos: revisão integrativa

Tecnologías para el mantenimiento del Catéter Central de Inserción Periférica en neonatos: revisión integrativa

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Abstract

Objective: to analyze the scientific literature on technologies and care for positioning and repositioning of the peripherally inserted central catheter (PICC) in neonates. **Method:** integrative review, with search conducted in February 2022 in four databases. **Results:** 32 studies were included that address the use of technologies to verify the location of the PICC, procedures for its positioning and maneuvers for repositioning. For proper positioning should pay attention to the selection of the vessel, correct measurement of the device and maintenance of the well-being of the newborn. In the face of poor positioning, it is suggested limb movement, flush, catheter traction, and expectant management. The verification of the tip location is routine, by radiography, ultrasonography or electrocardiogram. **Conclusion:** the adoption of non-invasive technologies for the positioning and repositioning of PICC in neonates is recommended. The evidence points to professional competence in decision making for safe and quality care and prevention of adverse events.
Descriptors: Neonatology; Nursing; Catheters; Intensive Care, Neonatal; Technology

Resumo

Objetivo: analisar a literatura científica acerca das tecnologias e cuidados para posicionamento e reposicionamento do cateter central de inserção periférica (PICC) em neonatos. **Método:** revisão integrativa, com busca realizada em fevereiro de 2022 em quatro bases de dados. **Resultados:** incluíram-se 32 estudos que abordam uso de tecnologias para verificação da localização do PICC, procedimentos para seu posicionamento e manobras para reposicionamento. Para posicionamento adequado deve-se atentar para seleção do vaso, mensuração correta do dispositivo e manutenção do bem-estar do recém-nascido. Frente ao mal posicionamento sugere-se a movimentação do membro, *flush*, tração do cateter, e conduta expectante. A verificação da localização da ponta é rotineira, por meio de radiografia, ultrassonografia ou

eletrocardiograma. **Conclusão:** recomenda-se a adoção de tecnologias não invasivas para o posicionamento e reposicionamento do PICC em neonatos. As evidências apontam para competência profissional na tomada de decisão para o cuidado seguro e de qualidade, e prevenção de eventos adversos.
Descritores: Neonatologia; Enfermagem; Cateteres; Terapia Intensiva Neonatal; Tecnologia

Resumen

Objetivo: analizar la literatura científica acerca de las tecnologías y cuidados para posicionamiento y reposicionamiento del catéter central de inserción periférica (PICC) en neonatos. **Método:** revisión integrativa, con búsqueda realizada en febrero de 2022 en cuatro bases de datos. **Resultados:** se incluyeron 32 estudios que abordan el uso de tecnologías para verificar la localización del PICC, procedimientos para su posicionamiento y maniobras para reposicionamiento. Para un posicionamiento adecuado se debe prestar atención a la selección del recipiente, la medición correcta del dispositivo y el mantenimiento del bienestar del recién nacido. Frente al mal posicionamiento se sugiere el movimiento de la extremidad, color, tracción del catéter, y conducta expectante. La verificación de la localización de la punta es rutinaria, por medio de radiografía, ultrasonido o electrocardiograma. **Conclusión:** se recomienda la adopción de tecnologías no invasivas para el posicionamiento y reposicionamiento del PICC en neonatos. La evidencia apunta a la competencia profesional en la toma de decisiones para el cuidado seguro y de calidad, y la prevención de eventos adversos.
Descriptores: Neonatología; Enfermería; Catéteres; Cuidado Intensivo Neonatal; Tecnología

Introduction

The Peripherally Inserted Central Catheter (PICC) is often used in neonatology, once obtaining vascular access in neonates is challenging;[1] the fragility of the superficial venous network stands out, which contributes to the short duration of peripheral devices in this population.[2] PICC can be maintained for weeks, reducing the need for repeated punctures in newborns (NB).[3]

The optimal location of the tip of the PICC is central (vena cava); this positioning provides safety for the use of the device and allows the administration of irritating, vesicant and hyperosmolar solutions.[4] When mispositioned, infusion of solutions is performed in peripheral or intra-atrial veins, favoring the occurrence of complications.[2] Occlusion, leakage, infiltration, catheter-related infections and phlebitis are some of them, culminating in the non-elective removal of the device, reduction of their length of stay and interruption of drug therapy, and negatively interfere with neonate survival.[5-6] Evidence-based practices and trained staff on PICC care to reduce complications and infections are recommended.[1,7-11]

Anatomical abnormalities such as stenosis, thrombosis or lesions that compress the vein hinder the proper positioning of the PICC.[12] Catheter migration is the most common complication among neonates,[13] caused mainly by the action of physical and hemodynamic forces, position of

the patient and use of mechanical ventilation.[14] It should be noted that, eventually, there is movement of the tip of the catheter after its insertion.[4] Thus, it is imperative to check the central positioning of the PICC after its insertion and to ensure its location or determine the need for maneuvers for its repositioning.[15]

Malpositioning of PICC is approximately three times more common than with other central venous accesses,[12] especially among neonates who are under intensive care.[5] A study showed that after one hour and 24 hours of insertion, 23% and 11% of PICC, respectively, migrated to the cardiothymic silhouette.[16] In the same perspective, another investigation showed that 28% of PICC migrated, 60% of these between 12-24 hours and 23% between 24 hours and three days.[15]

The consequences of PICC misplacement depend on the location of its tip; when in peripheral vessels increases the risk of thrombosis or infiltration; in the right atrium there is a risk of arrhythmias and possibly lethal pericardial effusion and tamponade secondary to myocardial perforation; in the mediastinum may occur infiltration or extravasation; in the pleura causes hemothorax or pleural effusion; in the pericardium generates pericardial effusion and cardiac tamponade; and in the peritoneum causes intra-abdominal bleeding.[12,17-23]

The catheter tip is checked by means of ultrasonography, electrocardiography and chest radiography.[24-25] The resources that allow monitoring the catheter tip in real time facilitate its insertion in an ideal position; however, many health services do not have these technologies.[4]

Radiography is the conventional method for verifying the PICC positioning. It is suggested that ultrasonography (USG) has similar effectiveness in identifying the catheter tip compared to radiography, with the benefit of not exposing the patient to radiation, and allows the positioning verification at the bedside,[26-27] with greater sensitivity to identify misplacement.[28] Echocardiography (ECG) allows visualization of alteration of tracings to detect the entry of PICC into the right atrium, which prevents deep positioning into the heart.[29]

Upon finding the misplacement in clinical practice, it is necessary that the professional make an assertive decision to correct the PICC position. However, information is scarce, especially regarding device repositioning, ambiguous and not systematized. There are several technologies capable of moving the catheter, which prevent its removal and a new puncture; among these, the movement of the limbs in which the catheter is inserted stands out;[17] catheter traction when in the intracardiac position;[12,30-31] and the flush, which consists of washing the catheter that

generates a flow capable of moving it.[4,12,32]

This review aims to contribute to managers and health professionals through the presentation of evidence on technologies and care with PICC in neonates. It is intended to summarize the evidence to be implemented in clinical practice, provide systematic knowledge to health professionals and students, and contribute to research in the Brazilian and international reality. It is noteworthy that the theme is part of the international goal of patient safety in drug administration, and that systematic reviews or scope reviews on the subject were not located.

From the absence of studies that gather and compare the technologies for positioning and repositioning of PICC and the relevance of the theme, this integrative review aims to analyze the scientific literature on technologies and care for the positioning and repositioning of PICC in neonates.

Method

This is an Integrative Review developed in six steps: 1) identification of the theme and selection of the hypothesis or research question; 2) establishment of criteria for inclusion and exclusion of studies; 3) categorization of studies; 4) evaluation of included studies; 5) interpretation of results; and 6) synthesis of knowledge.[33]

For studies selection, the acronym PCC was used, in which the population (P) is neonates (up to 28 days) with PICC; the concept (C) technologies and care of positioning and repositioning of PICC; and the context (C) health services. The research question was: "What is addressed in the scientific literature about technologies and care for the positioning and repositioning of PICC in neonates?".

Controlled descriptors in Portuguese, English and Spanish were selected, identified in the Descriptors in Health Science (DeCS), Medical Subject Headings (MESH), and CINAHL Headings, as well as keywords, for the construction of the search strategy, which was combined with the aid of the Boolean operators "AND" and "OR" (Chart 1).

Chart 1 – Search strategy in databases, using DeCS descriptors and Boolean operators. Curitiba, Paraná, Brazil, 2022.

("Recém-Nascido" OR "Infant, Newborn" OR "Recién Nacido" OR "Criança Recém-Nascida" OR "Crianças Recém-Nascidas" OR "Lactente Recém-Nascido" OR "Lactentes Recém-Nascidos" OR "Neonato" OR "Neonatos" OR "Recém-Nascido (RN)" OR "Recém-Nascidos" OR "Infants, Newborn" OR "Neonate" OR "Neonates" OR "Newborn" OR "Newborn Infant" OR "Newborn Infants" OR "Newborns" OR "Lactante Recién Nacido" OR "Lactantes Recién Nacidos" OR "Niño Recién Nacido" OR "Niños Recién Nacidos" OR "Recién Nacidos" OR "Neonatologia" OR "Neonatology" OR "Neonatologia" OR "Neonatal") AND ("Catheterization, PICC Line" OR "Catheterizations, PICC Line" OR "PICC Line Catheterization" OR "PICC Line Catheterizations" OR "PICC Line Placement" OR "PICC Line Placements" OR "PICC Placement" OR "PICC Placements" OR "Peripherally Inserted Central Catheter Line Insertion" OR "Placement, PICC" OR "Placement, PICC Line" OR "Placements, PICC" OR "Placements, PICC Line" OR "Peripherally Inserted Central Catheters" OR "Cateter Central de Inserção Periférica" OR "Peripherally Inserted Central Catheter" OR "Catéter Central de Inserción Periférica" OR "PICC" OR "CCIP") AND ("Repositioning" OR "Reposition" OR "Reposicionamento" OR "Reposicionamiento" OR "Malposition" OR "Migration Tip" OR "Migration Line" OR "Migration" OR "Migração" OR "Migracion" OR "Replacement" OR "Recolocação" OR "Recolocación" OR "Relocation" OR "Tip Placement" OR "Tip Position" OR "Tip Location")

The search took place on February 23, 2022, on the following databases: Medical Literature Analysis and Retrieval System on-line - MEDLINE via PubMed. (178), Embase (176), Scopus (554) and Cumulative Index to Nursing and Allied Health Literature - CINAHL (66). The same search strategy was used in the searched databases.

References retrieved in the search were exported to *Mendeley*® reference management software, aiming identified and removed duplicates. Next, two reviewers selected the articles for inclusion in the review, independently, and the divergences were resolved by a third reviewer to define the final inclusion.

Inclusion criteria were: primary studies (randomized clinical trial (RCT)), quasi-experimental, cohort, case control, cross-sectional and case study) available in full, written in Portuguese, English or Spanish, without limitation of year of publication, technologies and/or care for positioning and repositioning of PICC in neonates (from zero to 28 days of life). The exclusion criteria were: articles that did not report separately the data of neonates, and those that simultaneously evaluated PICC and other catheters, without segregating the results by catheter type.

Data extraction was performed with an instrument was built in an Excel® sheet, with the synthesis of key information, as the method chosen guides.[33] The extracted data were: title, journal, year of publication, method, objective, number of participants and main results. Each study was evaluated in detail, critically, and the results of the analysis presented in a descriptive way.

The data extracted were organized according to the technologies used for the positioning and repositioning of the PICC, and are presented in a descriptive way.

Results

Of the 32 selected articles, 20 (62.5%) address the use of tests to verify the location of the PICC, five (15.6%) describe procedures or recommendations for the proper positioning of the PICC (catheter measurement and team expertise); five (15.6%) maneuvers for the repositioning of the poorly located catheter; and two (6.3%) mention the technologies for monitoring the catheter position. The flowchart shows the selection process of the articles (Figure 1).

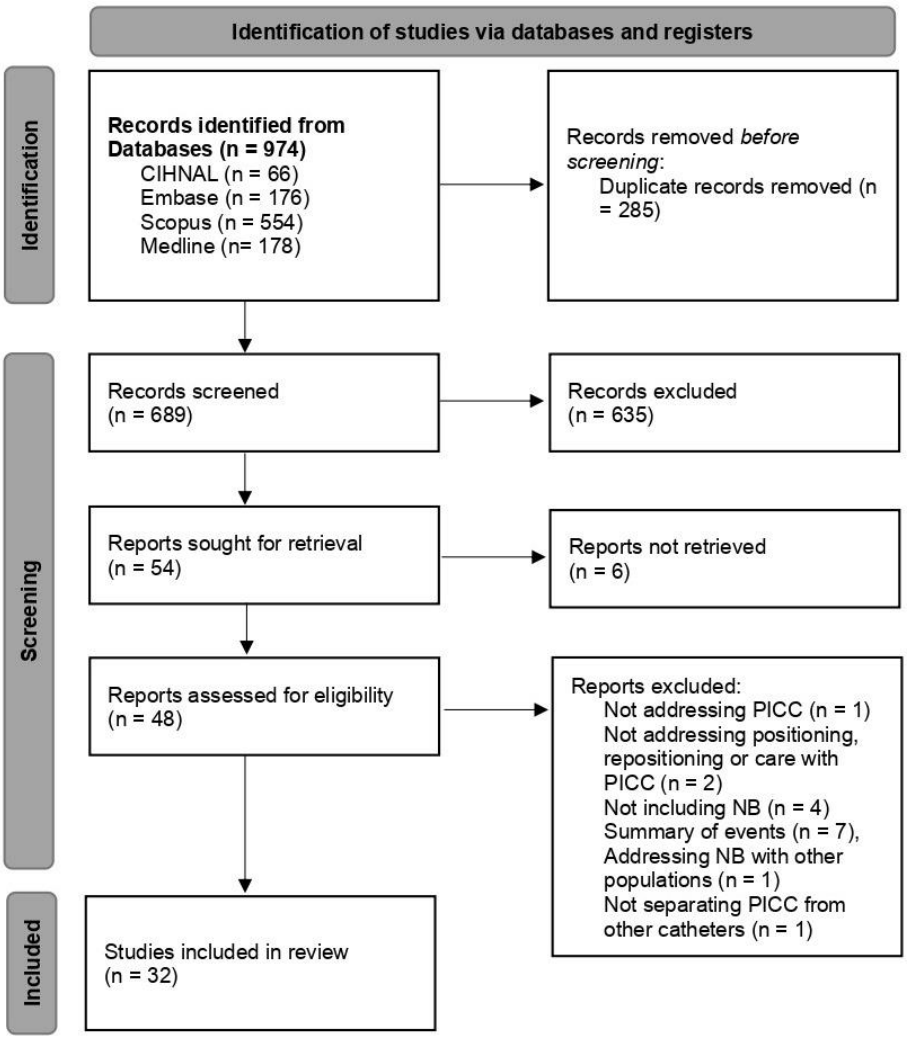

Figure 1 – Flowchart of identification, selection, eligibility and inclusion of studies in the review. Curitiba, Paraná, Brazil, 2022.

Regarding the period of publication, the articles were grouped into three periods: 2002 to

2010, with six publications (18.8%), 2012 to 2018 with 10 (31.3%), and 2019 to 2021 with sixteen (50%), with an increasing increase in publications on the subject over the years.

Charts 2 and 3 present the characteristics and results of the included studies, dividing the results between procedures and technologies used before and during or at the end of the puncture procedure (Chart 2) procedures and technologies used to reposition and monitor PICC after completion of the procedure (Chart 3).

Chart 2 - Characterization of included studies that used exams or measurements to position and/or verify the location of the PICC in neonates before, during or at the end of catheter puncture. Curitiba, Paraná, Brazil, 2022.

Author (Year) Country	Objective	Method/N	Results
Jain et al (2012)[34] Canada	To evaluate the accuracy of plain radiographs in determining the position of the PICC tip compared to TnECHO (echocardiography) .	*Quasi-Experimental N= 22 preterm NB	The agreement between the radiographs and the TnECHO was 59%. The sensitivity of radiography to determine catheter malposition was 64% with a specificity of 55%. Five NB had incorrect identification of the catheter tip with radiography. In 9 (41%) newborns, a second radiograph was avoided by the use of TnECHO, minimizing exposure to radiation.
Katheria et al (2013)[35] USA	To determine whether USG can be used to insert PICCs in less time, less manipulations and radiographs, and accurately.	*RCT N= 48 NB	Real-time USG compared to chest radiography reduces the time of PICC insertion by 30 minutes (69 vs. 99 minutes, p = 0.034), the number of manipulations (0 vs. 1, p = 0.032) and radiographs (1 vs. 2, p = 0.001). In the hands of experienced neonatologists in the US, real-time USG-guided PICC insertion is more efficient than the standard method.
Tauzin et al (2013)[36] France	To investigate the use of USG to determine catheter tip position compared to radiographs.	*Quasi-Experimental N= 89 NB (<1800 gr) (109 PICC)	Real-time USG compared to chest radiography reduces the time of PICC insertion by 30 minutes (69 vs. 99 minutes, p = 0.034), the number of manipulations (0 vs. 1, p = 0.032) and radiographs (1 vs. 2, p = 0.001). In the hands of experienced neonatologists in the US, real-time USG-guided PICC insertion is more efficient than the standard method.
Johnson et al (2016)[37] USA	To describe the technique for USG-guided PICC insertion in low and extremely low birth weight NBs.	*Retrospective cohort N= 10 NB	It describes a technique of PICC insertion in low and extremely low birth weight NBs using USG, after insertion by traditional method (non-USG guided puncture) had failed. The average weight of the patients was 968 gr. There was success in PICC insertion in all patients (n=10).

Telang et al (2017)[27] India	To compare the effectiveness of real-time USG with radiography in identifying the PICC tip after insertion, with radiography as the gold standard.	*Cross-sectional N= 31 NB (33 PICC)	The catheter tip was identified by US in 94% (31) of the cases. In one of the newborns, visualization was impaired due to abdominal distension, and in another it was located in the common iliac vein; in both cases the tip was located by abdominal radiography. The sensitivity of the US was 96.55 (95%CI: 82.17-99.42%); specificity of 100 (95%CI: 30.48-100.00%).
Oleti et al (2018)[26] Índia	To evaluate the incidence of malposition of the PICC when inserted under USG guidance compared to the conventional technique.	*RCT N= 80 NB	Use of US during insertion reduced the incidence of bad positioning by 52% when compared to the conventional technique (PICC measurement before insertion, according to NB landmarks) (67.5 vs. 32.5%; RR: 0.48; 95% CI: 0.29–0.79). PICC duration and incidence of catheter-related primary bloodstream infection did not differ between groups.
Ren et al (2019)[38] USA	To evaluate the feasibility of using US to confirm placement of PICC placement.	*Cross-sectional N= 186 NB	Successful placement occurred in 93.5% (174) of cases. The specificity and sensitivity of US was 100%. Advantages over radiography: no exposure to radiation, ease of operation, high accuracy, real-time evaluation and rapid identification of complications.
Zaghloul et al (2019)[39] USA	To assess the agreement between radiography and US to verify the position of the catheter tip and the rate of malposition.	*Cross-sectional N= 56 NB (22 PICC)	The concordance coefficient of radiography and bedside USG in the verification of the PICC position was 0.940. The rate of PICC malposition was low over the 6-day follow-up. The USG can be used for initial confirmation and tracking of the PICC position.
Huang et al (2021)[40] Taiwan	To analyze the role of USG in detecting the location of the PICC tip in the lower limbs.	*Prospective and retrospective cohort N= 166 PICC (USG) and 141 (radiography)	The group that used USG to position the PICC had a withdrawal rate of 10.8%, against 65.9% of those who did not use this technology ($p<0.001$). The time to confirm the location of the catheter tip was shorter in the group that used US (2-4.75 vs. 75-747.25 min., $p=0.001$).
Grasso et al (2022)[41] Italy	To assess the location of the PICC tip guided by US, after insertion in the upper limb.	*Prospective cohort N= 102 NB (118 PICC)	The feasibility of US-guided catheter tip location was 92.3% (109). Identification failures were associated with mechanical ventilation (OR 5.33; 95% CI 1.13-29.5; $p=0.038$). Agreement between US and radiography was found in 88 of 109 cases (80.7%).

Rossi et al (2022)[42] United Kingdom	To compare the number of radiographs performed for central catheter tip positioning when USG is used compared to radiography alone, and to assess the accuracy of position, irradiation, and cost.	*Retrospective cohort n= 142 PICC	The percentage of PICC in the correct position on the radiograph was higher in the group that used US than in the group without (79.1% vs. 45.5%, p=0.003). In the group without US, position accuracy was decreased when the catheter was inserted into the lower limbs (p=0.008). Position accuracy was high in the USG group. The USG group received less radiation compared to the non-USG group (p=0.001). The cost was lower in the group with US. Agreement in PICC placement was 0.8.
Upadhyay et al (2021)[43] India	To compare the safety and visibility of stirred saline with normal saline to identify the catheter tip.	†Experimental N= 40 PICC	The visibility of the PICC tip was significantly better with shaken saline compared to normal saline (75% vs. 30%, p=0.035). Agitated saline appears to increase the chance of detecting the PICC tip by 7-fold, in addition to reducing the time for USG tip visualization (13.5 min vs. 48.3 min, p<0.001).
Zhou et al (2017)[44] China	To analyze the accuracy of IC-ECG-guided PICC tip placement in neonates.	||Quasi-Experimental N= 115 NB	The accuracy of the method is better in the lower limb puncture (91.6%) compared to the upper limb (74.9%, p=0.035). The weight (greater) and the interval between P/R waves are risks for the accuracy of the positioning by the IC-ECG. The method is affordable and as reliable as radiographs.
Zhou et al (2017)[24] China	To assess the feasibility and safety of an improved IC-ECG technique to guide PICC placement in neonates.	1st stage: ||Cross-sectional N= 200 NB 2nd and 3rd stage: Quasi-Experimental N= 32 NB N= 49 NB	Study with three stages: the 1st analyzed data from the standard method for PICC positioning; the 2nd used IC-EEG as an adjuvant method to the traditional method; and the 3rd used only the IC-EEG for PICC positioning. NBs who received PICC guided by IC-ECG had higher success rates in positioning in the first attempt than those who used catheterization based on the surface reference point (93.9% vs. 62.5%, p<0.001).
Ling et al (2019)[45] China	To investigate the accuracy of the combined IC-ECG measurement in PICC insertion compared to the conventional technique.	||RCT N= 160 preterm NB	25% of the catheters entered the cardiac chamber, identified by the IC-ECG. The study demonstrated advantages of IC-ECG guidance for PICC placement in neonatal patients: higher first-attempt success rate (95% vs. 78.8%, p = 0.002), less medical time and cost, less exposure to radiation and fewer catheter-related complications.

Xiao et al (2019)[46] China	To assess the effectiveness and safety of IC-ECG guidance in placement and positioning of the PICC tip in premature infants.	||Quasi-Experimental n= 161 preterm NB	Pre-intervention (n=83) and post-intervention (n=78) group. The repositioning rate was higher before the intervention (19.3% vs. 3.8%) when nurses were trained to use the IC-ECG (OR=5.97, p=0.002). Success in positioning on the first attempt was higher in the IC-EEG group (93.6% vs. 73.5%, p=0.001). Complications were higher pre-intervention (14.5% vs. 3.8%, p=0.04).
Yang et al (2019)[47] China	To assess the accuracy of IC-ECG guidance for PICC placement in preterm infants, in relation to chest radiography.	||Quasi-Experimental n= 173 preterm NB	Changes in the P wave were observed in 90.75% (57) of the cases. Of these, the PICC tip of 85.55% (148) was well positioned. No alterations were observed in the P wave in 9.32% (16) of the cases; of these, half were adequate, according to radiography. The accuracy of the IC-ECG for positioning the PICC was 90.17%.
Zhu et al (2020)[48] China	To investigate P-wave changes on IC-ECG during PICC catheterization to guide accurate catheter tip location.	||RCT N= 106 NB	The P wave was observed in 53 NB. In 49 cases, wave amplitude was 60-80% of the R wave, and radiography revealed that the tip was in the correct location. In the other cases (4) the P wave was abnormal, and the catheter was poorly positioned on the radiograph. In the intervention group, the location was accurate in 100% of the cases. The sensitivity and specificity of PICC location were 100% and 92.5%, respectively. The procedure duration and cost were lower compared to the control group ($p<0.05$).
Coit et al (2005)[49] USA	To discuss two cases of unusual location of the catheter tip by radiography.	¶Case series N=2 NB with PICC	Proper placement of a PICC via the saphenous vein can be misleading with a single anteroposterior radiograph. Two views would ensure that the initial placement of the catheter tip was not outside the inferior vena cava.
Gupta et al (2016)[16] USA	To determine how often umbilical venous catheters and PICCs migrate into the cardiothymic silhouette after initial verification of correct placement.	¶Retrospective cohort N= 77 NB (41 UVC and 63 PICC)	Position verification was performed by means of radiography after insertion in the 1st hour, and between 12-24 hours after insertion. The incidence of migration from the tip of the PICC to the cardiothymic silhouette is 23%(15) and 11%(15) of PICCs, in the 1st and 24th hour, respectively. 33%(21) were repositioned within the first 24 hours. The PICCs inserted in the lower limbs migrated less compared to those in the upper limbs (p=0.004). After one week of insertion, all PICCs remained in the ideal position.
Chen et al (2018)[50] Taiwan	To determine an equation to estimate the ideal length of the PICC in RN.	**Retrospective cohort N= 214 NB	Four equations were defined to estimate the ideal length of PICCs before insertion. The repositioning rate after initial insertion was reduced from 73.5% to 53% after using the equation.

Kim et al (2021)[51] Korea	To verify the accuracy of a PICC insertion depth equation, using newborn weight and gestational age.	**Cross-sectional N= 790 NB	The equation was constructed based on logistic regression analysis of the data, considering the basilic, cephalic, cubital and saphenous veins, and body weight. The equation showed high predictive validity, with 90.8%, 94.1%, 96.2%, and 95.4% with ± 2.0 of standard deviation, for the cephalic, basilic, cubital and saphenous veins, respectively.
Tomazoni et al (2021)[52] Brazil	To evaluate the effectiveness of the modified PICC measurement method in NBs with regard to catheter tip positioning.	**RCT N= 88 PICC	Control group was 28.87 times more likely to have the tip in a peripheral position than the experimental group, and 44.80 times more likely to have intracardiac positioning. The chances of malpositioning were lower than in the traditional method and the number of traction interventions for catheter repositioning was reduced.
Tomazoni et al (2022)[53] Brazil	To analyze the results of PICC insertion procedures in NBs using two measurement methods.	**RCT N= 88 PICC	Experimental group had a higher occurrence of central placement (21 vs. 1), while the control group had more intracardiac (32 vs. 15) and peripheral (11 vs. 8) placements. Inadequate catheter progression occurred in 19 procedures (eight (18.2%) in the experimental group and 11 (25%) in the control group.

Note: *Addresses PICC positioning using ultrasound or echocardiography; †Addresses PICC positioning through infusion of agitated saline associated with ultrasound; ||Addresses PICC positioning through the use of intracavitary electrocardiography; ¶Addresses PICC positioning through chest radiography; **Addresses PICC positioning through catheter length measurement techniques.

Legend: ECG - Electrocardiogram; RCT – Randomized Clinical Study; USA - United States of America; IC-ECG - Intracavitary electrocardiogram; LL – Lower limbs; UL – Upper limbs; RUL – Right upper limb; LUL – Left upper limb; N - Number; PICC - Peripherally inserted central catheter; NB - Newborn; TnECHO - Targeted neonatal echocardiography; USG - Ultrasonography; UVC – Umbilical Central Catheter.

Chart 3 - Characterization of the included studies that address technologies for monitoring the position and maneuvers for repositioning the PICC after its puncture. Curitiba, Paraná, Brazil, 2022.

Author (Year) Country	Objective	Method/N	Results
Camargo et al (2007)[30] Brazil	Identify the initial positioning of the PICC tip and verify the prevalence of successful insertion.	*Cross-sectional N= 37 NB	Prevalence of successful catheter implantation was 72.3% (27); 25.9% (7) were centrally positioned, 48.2% (13) in the right atrium, 14.8% (4) in the axillary or innominate vein and 11.1% (3) in the jugular vein. After traction, 83.3% (20) of the catheters remained in the central position and 16.7% (4) in the peripheral position. The initial malposition of the catheter tip is related to the introduction of length beyond what is necessary.

Saul et al (2016)[54] USA	Evaluate the effectiveness of tracheal tubes, arterial and venous umbilical catheters and PICC by USG.	†Experimental N= 11 PICC in NB	Displays data from PICC and other devices separately. The objective was the direct visualization of the location of the vessel/cardiac chamber in the superior vena cava, right atrium or inferior vena cava, being possible in 91% (10) of the PICCs, taking an average of 7 min.
Motz et al (2019)[55] USA	To assess the feasibility and accuracy of USG in monitoring the PICC by non-radiologist physicians.	†Prospective Cohort N=30 NB	94% of the ultrasound exams corresponded to the radiographic report. The monitoring protocol had a sensitivity of 0.97, specificity of 0.66 and a positive predictive value of 0.98. Monitoring of PICC positioning by non-radiologist physicians is feasible.
Nadroo et al (2002)[17] USA	To examine the effects of arm movements on the position of PICCs placed in upper limb veins in 60 neonates.	||Retrospective Cohort N= 280 radiographs of 60 NB	Catheters inserted through the basilic or axillary vein migrated towards the heart with adduction of the arm, while those inserted through the cephalic vein were moved away from the heart. Elbow flexion shifted catheters inserted in the basilic and cephalic veins below the elbow towards the heart, but had no effect on catheters inserted in the axillary vein. Catheters inserted into the basilic vein were moved towards the heart with shoulder adduction and simultaneous elbow flexion. Repositioning was effective in 90% of attempts.
Tawil et al (2006)[56] Saudi Arabia	To study the incidence and location of misplaced PICCs, and their spontaneous correction over 12 months.	|| Prospective cohort N= 47 PICC in 41 NB	Five catheters (10.6%) had their tips misplaced and were treated as peripheral, with infusion of intravenous fluids for maintenance, except for hyperosmolar solutions. Radiographs taken 24 hours after insertion detected spontaneous correction of the tips to the ideal location.
Sharpe (2010)[14] USA	To describe three cases of patients with poorly positioned catheters guided to the appropriate position.	||Case series N= 3 NB with poorly positioned PICC	The three cases were successful in repositioning the catheter tip to the central location of the tip in the superior vena cava by implementing a combination of non-invasive catheter repositioning techniques.
Suell et al (2020)[57] USA	To present a case of PICC repositioning at the time of insertion, with the help of USG in real time.	||Case Study N=1 NB	The PICC was punctured in the left basilic vein; examinations demonstrated that the device was directed to the left internal jugular vein. The NB's left arm was abducted and extended at the elbow, aiming to move the catheter tip to the periphery; At the same time, USG was performed, which demonstrated migration to the superior vena cava.

Acun, et al (2021)[15] USA	To determine the incidence of PICC migration between 12–24 hours and >24 hours after insertion and during use; investigate risk factors for migration.	||Retrospective cohort N= 168 PICC (141 NB)	The overall incidence of PICC tip migration was 28% and the majority of PICC migration (83%) was detected within the first three days after insertion. Recommendations: obtaining periodic images from 12 to 24 hours and on the third day after PICC placement; thorough documentation of external catheter length before and during dressing changes and imaging after dressing change if measurement changes.

Note: *Addresses the success rate in implementing the PICC; †|Addresses the use of technologies for monitoring the PICC positioning; ||Addresses PICC repositioning technologies.

Legend: LL – Lower limbs; UL – Upper limbs; RUL – Right upper limb; LUL – Left upper limb; PICC - Peripherally inserted central catheter; NB - Newborn; USG - Ultrasonography.

There were 20 (62.5%) included articles that addressed the positioning of PICC in the newborn; eleven (34.4%) presented strategies of ideal catheter positioning through USG and echocardiography,[26-27,34-42] one (3.1%) the USG in association with infusion of agitated saline solution,[43] six (18.8%) to intracavitary electrocardiography,[24,44-48] and two (6.3%) to radiography.[16,49]

It was found that of the catheters considered well-positioned by radiography, 25% were in intracardiac position in the evaluation by USG. USG was effective in identifying PICC misplacement in real time, allowing corrections and avoiding adverse events.[26-27,34-36,38-42]

As for procedures and recommendations for proper positioning of PICC, seven articles,[30,50-55] of which four addressed catheter measurement procedures before insertion,[50-53] one addressed the success rate in catheter implantation,[30] and two strategies for monitoring catheter position after insertion.[54-55]

Five articles were identified and included regarding the repositioning maneuvers of poorly located PICC.[14-15,17,56-57]. The movement of the upper limbs affects catheter positioning.[14,17,57]

Discussion

The assertive PICC positioning PICC is central, since poorly positioned catheters eventually result in serious adverse events such as thrombosis or infiltration, arrhythmias, pericardial effusion, buffering secondary to myocardial perforation, mediastinal infiltration or extravasation, hemothorax or pleural effusion and intra-abdominal bleeding (peritoneum perforation).[12.17-23]

PICC placement guided by USG reduced the duration of catheter insertion by 30 minutes (69 min vs. 99 min with radiography, p = 0.034); the procedure was associated with a lower need

for manipulations[35] and radiographs when compared to the conventional confirmation method.[34-35,38,42] The time for positioning confirmation is also shorter when using USG compared to radiography (2-4.75 min vs. 75-747.25 min, p= 0.001), allowing the catheter to be used early.[40] Whether still the reduction in procedure costs when the USG is used compared to chest radiography.[42]

USG was used to confirm the PICC position during its insertion, resulting in successful positioning in more than 90% of cases.[27,37-38,41,58] It is noteworthy the non-exposure of patients to radiation, easy operation and its high precision.[34,38,42,58]

Use of real-time USG during PICC puncture is encouraged; real-time guidance during device insertion decreases the incidence of PICC misplacement in neonates when compared to measurement by anatomical landmarks,[26-27] in addition to presenting advantages in terms of accuracy, cost-effectiveness and safety.[59]

USG allowed precise detection of PICC tip location and allowed the observation of changes in position associated with limb movement in real time.[36,59] Use of USG in the Intensive Care Unit (ICU) neonatal is endorsed by specialists for various purposes, such as providing physiological and hemodynamic information in clinical decision-making in neonatal emergencies, as well as in the real-time positioning of devices.[20,54]

Quality of the USG depends on the operator, who must be properly trained to avoid clinical misinterpretation, resulting in erroneous diagnosis and inadequate management.[58] Teaching of PICC insertion guided by the USG is necessary in training programs, as it increases the success rate in the insertion of the device, reduces the time of confirmation of the positioning and allows the prompt use of the venous access.[40]

Among the advantages in the use of USG, it is mentioned: increased sensitivity, specificity, reduced exposure of the neonate to radiation, precision in the positioning of the catheter, visualization of the tip of the PICC in front of the neonate's movements and reduction of complications related to the procedure.

Infusion of agitated saline during USG at the time of insertion of PICC is higher than normal saline solution (75% vs. 30%, p= 0.035), increases tip detection by seven times and reduces time to visualization (13.5 vs. 48.3 min, p<0.001). The strategy was promising to improve the effectiveness of the PICC positioning.[43]

Six articles (18.8%) addressed the use of intracavitary electrocardiogram (IC-ECG) as a

technology in PICC positioning.[24,44-48] Intracavitary echocardiography verifies the PICC positioning in the vena cava by means of changes in the P wave when the catheter tip reaches the vena cava at the atrial junction.[60-61] The articles demonstrated success in ECG use for proper positioning of the PICC,[24,44-48] considered an accessible and reliable method, cheap[45,47-48] and faster compared to radiographs,[45,48] which reduces radiation exposure,[45,47] and the occurrence of associated complications.[45-46] It is a simple procedure, but it demands professional skills.[45]

Success in the first attempt with ECG is greater than with traditional PICC measurement, and confirms that the use of real-time evaluation technologies is relevant in terms of procedure success and patient safety.[24,45]

PICC insertion guided by ECG has greater precision when the device is inserted in the lower end than in the upper end (91.6% vs. 74.9%); this difference is related to the characteristics of the lower vena cava (more straight, less branched and less influenced by limb movement).[44] In heavier newborns the accuracy was lower; it is justified that premature and underweight babies have reduced mobility, and are easily calmed whith strategies such as nest bed, small doses of sedatives, pacifiers or glucose intake.[44]

In terms of efficacy, safety, viability and accuracy of the PICC guided by ECG, it was identified the reduction of the repositioning rate after the introduction of the ECG in the PICC positioning (from 19.28% to 3.85%). Success in positioning on the first attempt was higher in the ECG group (93.59% vs. 73.49%, p=0.001).[46]

ECG shows itself with a suitable technology for the guided placement of the PICC and for the positioning of the catheter tip, with 100% accuracy.[62] The procedure has as advantages: the accuracy of being in real time, avoid radiation, less time for insertion, being a simple procedure that requires the skill of the professional.

Even with all the advances, the technology most often available in hospital neonatology services for PICC tip positioning verification procedures is still chest radiography.[25]

A Brazilian study reported the initial positioning of the PICC tip and the prevalence of successful insertion in 37 neonates; 72.3% (27) catheters progressed, and 74.1% (20) of these were misplaced. Catheter traction maneuver was performed in the mispositioned devices, which resulted in central positioning in 83.3% (20) cases. In four cases, the catheter went to the atrium, suggesting oversizing of the measurement.[30]

Faced with the occurrence of measurement oversizing and failures in proper positioning,

a Chinese study developed four equations to estimate the ideal PICC insertion length for different puncture sites, as shown in Chart 4. After the equation application post-puncture adjustment rate decreased from 73.5% to 53% (p=0.003) and the complication rate decreased from 30.3% to 24.5%.[50]

Chart 4 - Equations to guide PICC length measurement according to puncture site.50 Curitiba, Paraná, Brazil.

Puncture site	Equation
Foot	16 + 4.27 x body weight (kg)
Femoral Vein	9.8 + 1.7 x body weight (kg)
Popliteal Vein	0.3 + 0.45 x body length (cm)
back of hand	4.46 + 0.32 x body length (cm)
Axillary Vein	1 + 0.18 x body length (cm)

Source: Information extracted from the article[50] and presented didactically by the authors.

Another equation to determine the ideal catheter measurement for PICC positioning was developed by Korean researchers, which considers the newborn's body weight. The equation: Insertion Depth = Section + (β1 Body Weight), in which "Section" will depend on the chosen vein (values tabulated for cephalic vein, basilica, cubital and saphenous), "β1" tabulated by vein, and "Body Weight" being the weight of RN every 100 gr (2000 gr = 20 gr. This equation demonstrated high predictive validity (90.8-95.4%).[51]

In Brazil, a measurement method was developed for the central positioning of PICC tip, with lower chances of intracardiac and peripheral location. The measurement was performed by extending the upper limb chosen at an angle of 90° and measuring the distance from the puncture site to the right sternal clavicular junction.[52] Success rate in positioning was 47.7% (n=21) in the experimental group and 2.3% (n=1) in the control group. Control group, that used the conventional measurement, had a higher risk of peripheral catheter positioning (OR=28.87), and 44.80 times more risk of intracardiac positioning. Inadequate catheter progression was identified in 19 procedures, eight (18.2%) of the experimental group and 11 (25%) of the control group.[53]

The approach of the included studies signals relevant aspects, such as the professional's ability to perform the procedure, which should establish the catheter measurement before the puncture, select the best vessel and ensure the general well-being of the neonate. It is essential to carefully select the best available access for PICC puncture.[3,63] The traditional measurement for

upper limbs (MMSS) recommends the positioning of the limb to be punctured in 90° relative to the thorax, followed by the measurement of the distance from the puncture point to the right sternal clavicular junction and from this to the third intercostal space.[12] There are a variety of methods for estimating the length of catheters,[12,50-53] however there is no recommendation on the most effective one that ensures the proper positioning of the PICC tip.

Two studies evaluated how limb movement influences catheter movement,[17,57] with movement and effect in Chart 5.

Chart 5 – Effect of upper limb movement on PICC movement according to the insertion vessel. Curitiba, Paraná, Brazil.

Vein	Movement	Effect
Basilica	Arm adduction Elbow flexion (PICC below the elbow) Shoulder adduction and elbow flexion (simultaneous)	Migrates towards the heart[17]
	Arm abducted and extended at elbow	Migrates towards the periphery[57]
Axillary	Arm adduction	Migrates towards the heart[17]
	Elbow flexion (PICC below the elbow)	None[17]
Cephalic	Arm adduction	Migrates towards the periphery[57]
	Elbow flexion (PICC below the elbow)	Migrates towards the heart[17]

Source: Information extracted from the article[17,57] and presented didactically by the authors

Repositioning by abduction and adduction movements of arm and elbow was effective in 9 out of 10 attempts.[17] Real-time USG is recommended concurrently with limb movement to confirm the effectiveness of the maneuver,[49,59] avoiding improper withdrawals, new punctures and adverse events.[57]

The movement of the patient's limb in an attempt to reposition the catheter involves abduction or adduction of the limb in which the PICC is inserted, and promotes retraction or advancement of the catheter, depending on the vein in which the catheter is inserted. When inserted into the UL elbow flexion helps the catheter to advance.[17] When inserted by the LL, if the leg is positioned relaxed and slightly flexed, the tip of the catheter may enter towards the heart.[40]

Knowledge of the effects of the upper extremity position on catheter tip movements can be used to reposition catheters without pulling them back to the insertion site or removing them in cases where the tip did not migrate to the appropriate position.[17] Corroborating with these findings, a Brazilian study evaluated the maneuver to promote the progression of the PICC inserted in the upper limb through elevation, protraction and lowering of the shoulder, and found the effectiveness of the strategy.[64] Through the influence of the movement of the members in the

positioning of the PICC, the USG is adopted for daily monitoring of the position of the device.[39]

A series of cases addressed the repositioning of the PICC through the movement of the MMSS, body positioning and flush administration: in the first case, the catheter wound and with poorly located tip migrated after washing with 1ml of saline, administered with the patient seated, with abducted limb and elbow extended, followed by extremity and elbow flexed; in the second case the catheter, initially intra-atrial, was pulled 1.5cm and was located in subclavian vein, then the patient was positioned on the same side of the catheter, with elevated headboard and catheter, washed with 1ml of saline solution, migrated; in the third case the catheter was located in jugular vein, the patient was positioned seated and the catheter washed with 1ml of saline solution and thus migrated.[14]

Spontaneous migration of the PICC is recognized by researchers.[15,56] It is estimated that 83% of catheters that migrate, do in up to three days after the puncture.[15] Not manipulating the PICC and maintaining expectant conduct showed good results in its repositioning.[56] A study conducted in Saudi Arabia reported that 10.6% (5) of the tips were misplaced, and catheters were treated as peripheral, receiving infusion of intravenous fluids not hyperosmolar for maintenance. After 24 hours of insertion, radiographs detected spontaneous correction of the five tips to the ideal location.[56]

In addition to performing periodic examinations (12-24 hours and in three days) to check the positioning of the catheter, it is recommended the rigorous measurement of the external portion of the PICC before and after the dressing change, as well as image examination at the end of the procedure, with a view to confirming the maintenance of proper positioning.[15]

Flush is a procedure adopted to position the catheter applied in isolation or combined. It is performed with saline solution, by means of pulsatile technique, creating a turbulent flow, capable of moving the distal tip of the PICC. The procedure prevents blood reflux and consequent catheter obstruction.[3,12]

Traction is useful in cases of long catheters located in the heart chambers. In these cases, the recommendation is to visualize the radiography and measure how much traction should be used for the catheter to be in vena cava or based on the ECG, and perform immediate traction to reposition the catheter.[12]

Despite the broad and comprehensive search, some study may not have been located. Among the limitations of the study, we highlight the reduced number of RCTs included, and that

no RCTs were found on the repositioning of PICC, only on the technologies for its positioning. It is suggested new studies especially on the repositioning of PICC in neonates.

This review contributes to the use of evidence-based practice in the positioning and repositioning of PICC in neonates, summarizing the effective technologies and strategies reported in the literature, contributing to safe and adverse event-free care. It emphasizes the importance of professional training for the use of hard technologies, such as USG and EEG, to position and monitor the catheter tip during its use.

Conclusion

The grouped evidence points to professional competence (knowledge and skills) for decision making in the care and use of technologies for the management of PICC in neonates, especially regarding the appropriate measurement of catheter length for its insertion, selection of vessels and maintenance of the general well-being of the newborn. This process involves the precise indication of the PICC, a puncture procedure that considers validated techniques for catheter measurement, the verification of the appropriate location through available technologies and their maintenance. These measures contribute to minimize the occurrence of adverse events and promotes patient safety.

This review summarizes strategies to reposition the catheter to the ideal location: movement in the catheter limb (adduction or abduction of the arm and flexion or extension of the elbow); flush with physiological solution combined with USG; manual catheter traction and expectant management. Applying non-invasive technologies for repositioning PICC in neonates is recommended, especially to avoid a new puncture, excessive manipulation, which contributes to the occurrence of infection and other complications.

It should be noted that for the safety of prolonged use of PICC, the verification of the location is routine, usually by radiography. There is a recommendation on the use of ultrasonography and electrocardiography, for confirmation in real time, avoiding exposure to radiation. It is relevant to include the handling of these technologies in PICC insertion training courses.

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