Review Article

Anatomical landmarks on radiography for peripheral central catheter in newborns: integrative review

Marcos anatômicos na radiografia para cateter central periférico em neonatos: revisão integrativa

Puntos anatómicos en la radiografía para catéter central periférico en neonatos: revisión integradora

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Abstract

Objective: To summarize the scientific evidence on anatomical landmarks on radiography used to evaluate the distal tip of the peripherally inserted central catheter in newborns.

Methods: This is an integrative literature review performed between 2017 and 2021 in Web of Science, National Library of Medicine (PubMed/MEDLINE) and Scopus databases.

Results: Thirteen out of 263 documents found in the databases met the eligibility criteria and were selected for analysis. Of these, 12 were observational studies and one was experimental. As for the country of origin, only one study was published in Brazil, five in China, two in the United States of America; and Italy, Germany, Canada, Iran and India with one study each. The evidence found demonstrated the existence of seven anatomical landmarks used in radiography to visualize the tip of the percutaneous catheter in newborns, and the vertebral body as the predominant guiding reference.

Conclusion: For catheters inserted in the upper limbs, the anatomical landmarks closer to the cavo-atrial junction are the fifth and seventh thoracic vertebrae, or two vertebral bodies below the level of the carina. For the lower limbs, the catheter tip should be positioned between the ninth and tenth thoracic vertebrae or above the fourth lumbar vertebra.

Resumo

Objetivo: Sumarizar as evidências científicas sobre os marcos anatômicos, na radiografia, utilizados para avaliar a ponta distal do cateter central de inserção periférica em recém-nascidos.

Métodos: Trata-se de uma revisão integrativa da literatura realizada nas bases de dados Web of Science, National Library of Medicine (PubMed/MEDLINE) e Scopus, entre os anos de 2017 e 2021.

Resultados: Dos 263 documentos encontrados nas bases, 13 preencheram os critérios de elegibilidade e foram selecionados para análise. Destes, 12 eram estudos observacionais e um experimental. Quanto ao país de origem, apenas um estudo foi publicado no Brasil, cinco na China, dois nos Estados Unidos da América e um estudo na Itália, Alemanha, Canadá, Irã e Índia. As evidências encontradas demonstraram a existência de sete marcos anatômicos utilizados na radiografia para visualização da ponta do cateter percutâneo em neonatos, sendo a unidade vertebral o referencial norteador predominante.

Conclusão: Para cateteres inseridos em membros superiores, os marcos anatômicos que mais se aproximam da junção cavo-atrial são a quinta e sétima vértebra torácica, ou duas unidades vertebrais abaixo da carina. Para os membros inferiores, o posicionamento da ponta do cateter deve estar entre a nona e décima vértebra torácica ou acima da quarta vértebra lombar.

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Resumen

Objetivo: Sintetizar las evidencias científicas sobre los puntos anatómicos, en radiografías, utilizados para evaluar el extremo distal del catéter central de inserción periférica en recién nacidos.

Métodos: Se trata de una revisión integradora de la literatura realizada en las bases de datos Web of Science, National Library of Medicine (PubMed/MEDLINE) y Scopus, entre los años 2017 y 2021.

Resultados: De los 263 documentos encontrados en las bases, 13 cumplieron con los criterios de elegibilidad y fueron seleccionados para análisis. Entre ellos, 12 eran estudios de observación y uno era experimental. Con relación al país de origen, únicamente un estudio fue publicado en Brasil, cinco en China, dos en Estados Unidos de América y un estudio en Italia, Alemania, Canadá, Irán e India. Las evidencias encontradas demostraron la existencia de siete puntos anatómicos utilizados en la radiografía para la visualización de la extremidad del catéter percutáneo en neonatos, y la unidad vertebral fue el referente orientador predominante.

Conclusión: Para catéteres insertados en miembros superiores, los puntos anatómicos que más se aproximaron a la unión cavoatrial son la quinta y la séptima vértebra torácica o dos unidades vertebrales por debajo de la carina. Para los miembros inferiores, la ubicación de la extremidad del catéter debe estar entre la novena y la décima vértebra torácica o sobre la cuarta vértebra lumbar.

Introduction

Peripherally inserted central catheters (PICCs) are lifesavers in the neonatal intensive care unit (NICU), as they are an indispensable treatment for the survival of critically ill newborns (NBs). Since they are an essential technology in the maintenance of vascular access in the long term and provide the survival of critically ill NBs, they have become popular and are being used more frequently.[1]

In Brazil, according to COFEN Resolution nº 258/2001, PICCs can be inserted by duly qualified nurses. The increase in the number of teams led by nurses in this procedure offered greater accessibility and convenience to the device in different contexts.[2]

As the safe use of central lines is strictly related to their correct placement, it is essential that nurses know how to recognize the ideal positioning to avoid complications.[3] One of the main guidelines in infusion therapy determines that placement of the tip of these catheters at the cavo-atrial junction has the highest safety profile.[4] Tip detection requires greater diligence in newborns, as the anatomical area corresponding to the cavo-atrial junction is very small and any oscillation outside the central vascular system is associated with a significant increase in complications. Furthermore, the intra-atrial positioning of the PICC can trigger arrhythmia, pericardial effusion, cardiac tamponade and death.[5,6]

More accurate technologies to determine the correct location of the PICC tip have been used in clinical practice, such as real-time ultrasound, which, although more reliable, is not always available. For this reason, radiography is the method commonly used in NICUs.[3,7] One of the justifications may be related to the high cost of that input for health care. Another barrier is the highly dependent nature of the professional performing the procedure. Therefore, radiography is still the standard method to assess PICC tip positioning in newborns.[8]

Some challenges in the use of radiography are accurate knowledge of the anatomy, problems in radiological identification of the cavo-atrial transition, and standardized assessment of the relationship between catheter tip position and outcome.[9] Misinterpretation of PICC positioning can be mitigated by the determination of anatomical landmarks on the radiograph that correspond to the cavo-atrial junction.[4] Therefore, an integrative review of the literature regarding the radiological interpretation of the distal tip of the PICC in NBs through anatomical landmarks is essential.

Given the above, the aim of this study is to summarize the scientific evidence on the anatomical landmarks on radiography used to evaluate the distal tip of the percutaneous catheter in newborns.

Methods

This is an integrative literature review guided by six recommended steps: definition of the guiding question, literature search, data collection, critical analysis of selected studies, presentation of results and discussion of the review.[10]

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist was used to organize the information.[11] The first

step was the construction of the PICO strategy (acronym for Population, Intervention, Comparison and Outcomes), a useful tool to formulate a focused clinical question and generate appropriate search terms to find the best evidence.[12] The descriptors selected with use of the acronym were organized as follows: P – newborn; I – PICC; C – does not apply; O – position of the catheter tip. The Boolean operators "OR" and "AND" were used vertically to compose the search strategy, resulting in the final search strategy Catheterization, Peripheral AND newborn OR neonate AND "tip position".

Based on the definition of descriptors by the acronym PICO, the guiding research question adopted in this review was: What is the scientific evidence available on anatomical landmarks used in radiography in newborns that corresponds to the cavo-atrial junction?

Searches were performed in Web of Science, National Library of Medicine (PubMed/MEDLINE) and Scopus databases.

The inclusion criteria were: online articles in Portuguese, English and Spanish, available in full, published between 2017 and 2021, and addressing the study theme. The time frame is justified by the aim to provide recent evidence to support clinical practice. Editorials, letters, abstracts of annals of events, dissertations and theses were excluded because they did not include the hierarchical levels of evidence considered for this review: I – at least one systematic review of multiple well-designed randomized controlled trials; II – at least one well-designed, randomized, controlled clinical trial; III – well-designed clinical trial without randomization of studies of only one group of the before-and-after type, cohort, time series or case-control studies; IV – non-experimental studies by more than one research center or group; V – evidence based opinions of respected authorities, descriptive studies or expert committee reports.[13]

The searches resulted in 263 publications, which were excluded after reading the title and abstract: 33 for being duplicated in other bases and 53 for not being related to the object of study, unavailable in full, published in another language and not contemplating the pyramid of evidence. Although 177 articles were read in full, 164 of these did not answer the guiding question and were excluded. In the end, the review sample consisted of 13 articles. The methodological flowchart with the steps of selection and exclusion process of studies is illustrated in Figure 1.

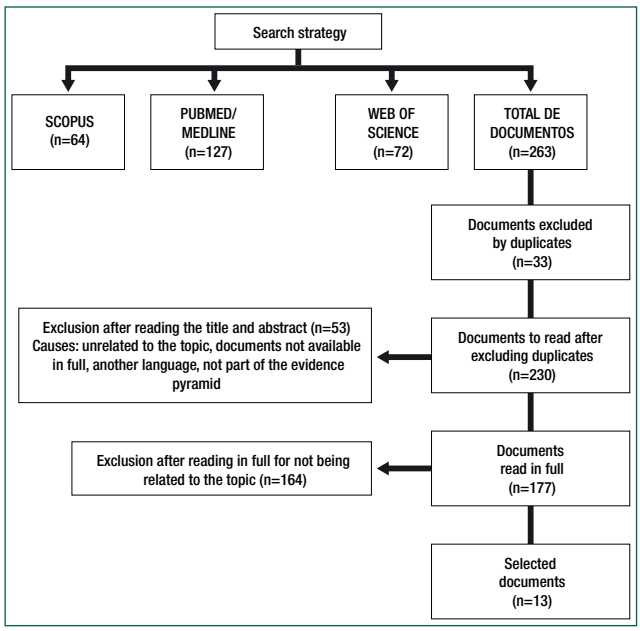

Figure 1. Methodological flowchart with the steps of the selection and exclusion process of published studies

The search took place in January 2022. Two researchers performed an exhaustive reading of titles and abstracts independently to ensure the texts addressed the guiding question of the review and met the established inclusion and exclusion criteria. In case of doubt about the selection, the publication was initially included and the decision on its selection was made only after reading its content in full. The next step involved the full reading of selected articles with the objective to identify evidence on the anatomical landmarks for assessment of the distal tip of the PICC in NBs on radiography. The definition of articles that would be part of the corpus of the review was made after agreement between researchers. Articles were organized into the following topics: authors, country and year of publication, title, anatomical landmarks on radiography and level of evidence.

Results

Of the total of 263 documents found, 13 met the eligibility criteria and were selected to compose this work. Chart 1 presents the characteristics of each study according to authors, country and year of publication, title, anatomical landmarks on radiography and level of evidence.

The first study dates from 2017[14] and the last from 2021.[26] Regarding the method, 12 were observational studies (one case-control,[22] two cross-sectional[19,21] and nine cohorts).[14-16,18,20,23-26] A randomized clinical trial was included.[17] Regarding the country of origin, 12 were international: five were conducted in China,[15,17,20,25,26] two in the United States of America[14,22] and one study in Italy,[16] one in Germany,[18] one in Canada,[21] one in Iran[23] and one in India.[24] Only one Brazilian publication was selected.[19]

Seven articles[15-17,20-22,26] described reference points used for PICC insertion in upper limbs, two[23,24] in lower limbs and four[14,18,19,25] provided guidance on the ideal location of the tip regardless of the member.

Seven reference points used in neonatology were reported, starting from the limb chosen for insertion. For puncture in upper limbs: brachiocephalic region[14] and ribs[21] (once); carina[16,20,22] (three times); cardiac silhouette/chambers[14,18,19,26] (four times) and vertebral bodies[15,17,21,25] (four times). For puncture in lower limbs: diaphragm[14] and iliac crest[23] (once), cardiac silhouette/chambers[18,19] (twice) and vertebral bodies[14,23-25] (four times). Thus, the most cited anatomical landmark was the vertebral body.

For devices placed in the upper limbs,[14-22,25,26] there was agreement on the position between the fifth and seventh thoracic vertebra,[15,17,25] or two vertebral bodies below the carina.[21] For lower limbs,[14,18,19,23-25] both the thoracic[24,25] and lumbar[14,23] vertebra were considered: the most used reference was between the ninth and tenth thoracic vertebra[24,25] or above the fourth lumbar vertebra.[23,24]

Table 1. Characterization of articles selected for analysis

Nº	Authors, country and year of publication	Title	Anatomical landmarks on radiography	Level of evidence
1	Goldwasser B; Baia C; Kim M; Taragin BH; Angert RM. United States, 2017.[14]	Non-central peripherally inserted central catheters in neonatal intensive care: complication rates and longevity of catheters relative to tip position.	For insertion in the upper limbs: between the brachiocephalic region to the cardiac silhouette. For insertion in lower limbs: between the fourth and fifth lumbar vertebra up to the level of the diaphragm.	III
2	Zhou L; Xu H; Liang J; Xu M; Yu J. China, 2017.[15]	Effectiveness of intracavitary eletrocardiogram guidance in peripherally inserted central catheter tip placement in neonates.	For insertion in upper limbs: between the fifth and sixth thoracic vertebra.	III
3	Capasso A; Mastroianni R; Passariello A; Palma M; Messina F; Ansalone A; et al. Italy, 2018.[16]	The intracavitary electrocardiography method for positioning the tip of epicutaneous cava catheter in neonates: pilot study.	For insertion in upper limbs: 1 cm above the carina up to a maximum of 2 cm from the carina.	III
4	Ling Q; Chen H; Tang M; Qu Y; Tang B. China, 2019.[17]	Accuracy and safety study of intracavitary eletrocardiographic guidance for peripherally inserted central catheter placement in neonates.	For insertion into upper limbs: between the fifth and seventh thoracic vertebra.	II
5	Hammon RA; Seuss H; Hammon M; Grillhösl C; Heiss R; Zeilinger M; et al. Germany, 2019.[18]	Improved visualization of peripherally inserted central catheters on chest radiographs of neonates using fractional multiscale image processing.	For insertion in upper and lower limbs: 0.5-1 cm outside the cardiac chambers in premature newborns and 1-2 cm in full term newborns.	III
6	Rangel RJM; Castro DS; Amorin MHC; Zandonade E; Christoffel MM; Primo CC. Brazil, 2019.[19]	Practice of insertion, maintenance and removal of peripheral inserted central catheter in neonates.	For insertion in upper and lower limbs: 0.5-1 cm outside the cardiac chambers.	III
7	Yang L; Bing X; Song L; Na C; Minghong D; Annuo L. China, 2019.[20]	Intracavitary electrocardiogram guidance for placement of peripherally inserted central catheters in premature infants.	For insertion in upper limbs: 3 cm below the carina.	III
8	Dhillon S; Connolly B; Shearkhani O; Brown M; Hamilton R. Canada, 2020.[21]	Arrhythmias in children with peripherally inserted central catheters (PICCs).	For insertion in upper limbs: on the sixth rib from top to bottom; or two vertebral bodies below the carina.	III
9	Hirschl JR; Gadepalli SK; Derstine BA; Holcombe SA; Smith EA; Wang SC; et al. United States, 2020.[22]	CT validation of SVC-RA junction for pediatric central line placement: is vertebral bodies below the carina accurate?	For insertion in the upper limbs: in children aged 0-1 years and weighing up to ten kilos, consider between 10.18-10.55 mm below the carina.	III
10	Kadivar M; Mosayebi Z; Ghaemi O; Sangsari R; Saeedi M; Shariat M; et al. Iran, 2020.[23]	Ultrasound and radiography evaluation of the tips of peripherally inserted central catheters in neonates admitted to the NICU.	For insertion in the lower limbs: above the fourth or fifth lumbar vertebra, or at the iliac crest.	III
11	Patil K; Dhaded SM; Bhandankar M. India, 2020.[24]	A 1-year study on association between peripherally inserted central catheter tip position and complications in neonates.	For insertion in the lower limbs: between the ninth thoracic vertebra and the fifth lumbar vertebra.	III
12	Yu X; Wang X; Fan L; Cao N; Yang F; Li J; et al. China, 2020.[25]	Iatrogenic pleural effusion due to extravasation of parenteral nutrition via an epicutaneo cava catheter in neonates: a prospective cohort study.	For insertion in the upper limbs: between the fifth and seventh thoracic vertebra. In lower limbs: between the ninth and tenth thoracic vertebra.	III
13	Ren X; Li H; Liu J; Chen Y; Wang M; Qiu R. China, 2021.[26]	Ultrasound to localize the peripherally inserted central catheter tip position in newborn infants.	For insertion in upper limbs: between 0.5 to 0.8 cm from the right atrium.	III

Discussion

The vertebral body was the main radiographic anatomical landmark corresponding to the cavo-atrial junction in newborns, regardless of the punctured limb. For devices placed in the upper limbs, the authors considered the fifth and seventh thoracic vertebra, or two vertebral bodies below the carina. For the lower limbs, between the ninth and tenth thoracic vertebra or above the fourth lumbar vertebra. The description of radiographic anatomical points in pediatrics was organized by Perin and Scarpa (2015) in a timeline.[27] In 2005, the carina was used as a reference for the correct placement of the catheter tip in children. In 2006 and 2007, in NB, it was observed that the carina was not always located above the pericardium and could not be considered a valid anatomical landmark. In 2008, researchers evaluated the use of vertebral bodies to define the position of central lines. They concluded that two vertebral bodies below the carina allow a reliable estimate of the cavo-atrial junction. Although this method does not consider the parallax effect, it still remains safe because the spine is minimally affected by geometric magnification and is adaptable to somatic growth.

The second most cited anatomical landmark was the cardiac silhouette/chamber. After analyzing a series of three cases of cardiac tamponade in newborns, researchers recommended that the catheter tip on radiography should be positioned outside the cardiac chambers at the junction of the superior or inferior vena cava with the right atrium, 0.5-1.0 cm for preterm infants and 1-2 cm for full term infants.[28]

In the hierarchical classification of evidence, observational cohort studies were predominant and there was a single randomized clinical trial. Authors described that robust scientific evidence on this topic to date are scarce, so most professionals rely on expert opinion, adult studies and their own experience to determine the PICC positioning in pediatrics.[9]

Regarding the country of origin of publications, the amount of international studies prevailed greatly, a fact that demonstrates the lack of Brazilian studies on the subject. The only national publication elected showed the lack of standardization to determine the correct positioning of the PICC tip in Brazilian NICUs, making this classification subjective.[19] Thus, research that aims to guide health professionals on the ideal positioning of this device through technologies available in the real environment of clinical practice is invaluable.

Most articles described the insertion of the PICC in the upper limbs. The literature describes that the basilic, cephalic and brachial veins are the first choice sites for placement of this catheter.[29] A Brazilian study revealed a higher prevalence of puncture in the basilic, cephalic and axillary veins, and a lower median number of puncture attempts in the basilic vein. These data evidence the priority choice of this vein for PICC insertion motivated by the advantages of easy catheter progression, optimized laminar flow, for being shorter and having fewer valves.[6]

Results from other studies have consolidated the preference for the upper limbs for central peripheral catheterization. A cohort that evaluated unscheduled PICC removals in NBs concluded that more catheters were non-electively removed from the lower limb compared to the upper limb.[30] A Korean study of 790 newborns justified the predilection for the upper limbs because the joints stretch more easily than joints of the lower limbs.[1]

A final hypothesis on the priority choice of upper limbs concerns the use of ultrasound in PICC insertion. Five out of the seven articles that described anatomical points for these limbs presented the use of this technology for PICC insertion. This technological modality determines a specific area for catheter insertion, called Zone Insertion Method (ZIM), with the aim of providing venipuncture in a safe and damage-free anatomical and musculoskeletal region.[31] This region comprises from the medial epicondyle to the line axillary, i.e., it is located in the upper limb.

Although other technologies coexist with radiography to assess the PICC positioning, articles related to this traditional imaging method were published in all years delimited by the time frame. This demonstrates a concern with the theme and suggests a predominant reliance on radiography to determine the catheter placement.[3] Recent re-

search reporting the use of ultrasound to identify the PICC tip in newborns concluded that the high cost of equipment and the longer learning curve of the professional operator may limit its application and popularity.[8,32] The Infusion Nurses Society (2021) declared that radiography remains an acceptable and necessary practice in the absence of superior technologies.[4]

Some articles compared the accuracy of real-time PICC placement with radiographs taken after the procedure. One of the studies concluded that the results of real-time PICC tip location were statistically similar to those of radiographs.[20] Authors demonstrated there was good concordance between ultrasound and radiography in the identification of misplaced catheter tips.[33] Therefore, radiography remains the gold standard until convincing evidence to change this standard is available to discontinue its use in care practice.[32]

Limitations of the present study were the scarcity of national publications on the subject, and the fact that most documents were published by the medical field. Percutaneous catheterization in critically ill NBs has become essential in clinical practice, where nurses are the professionals most involved in its execution. Thus, there is need for Brazilian scientific production in the field of pediatric nursing.

The results of this study contribute deeply to the clinical practice of neonatal nurses, considering that PICCs are indispensable intravenous devices for the treatment of critically ill NBs who need venous access for a long time. Furthermore, assessment of the tip of the PICC usually occurs through radiography and, in the absence of better technologies, the knowledge to determine its tip from the anatomy is essential to prevent complications.

Conclusion

The study summarized the national and international scientific evidence published on the anatomical landmarks used in newborns for assessment of the distal tip of the PICC through radiography. The productions show that the reference points closer to the cavo-atrial junction for insertion in the upper limbs are the fifth and seventh thoracic vertebra, or two vertebral bodies below the carina, and in lower limbs, the ninth and tenth thoracic vertebra or above the fourth lumbar vertebra.

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