e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(9); 1359-1365

Systematic Review

Neurological Complications following Paediatric Congenital Cardiac Surgery: A Systematic Review

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Received: 15-08-2023 / Revised: 05-09-2023 / Accepted: 14-09-2023

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Conflict of interest: Nil

Abstract:

Background: Neurological complications following paediatric congenital cardiac surgery constitute a significant concern that can have lasting effects on a child's development and quality of life. This systematic review is being conducted with the objectives of providing a comprehensive overview of postoperative neurological complications in paediatric congenital cardiac surgery, and to identify risk factors associated with the development of these complications.

Methods: The literature search encompassed an extensive database including PubMed, EMBASE, and Web of Science. Studies published after the year 2010 were included. The quality of included studies was assessed using appropriate tools tailored to the study design. The synthesis of data encompassed a narrative summary of study characteristics, outcomes, and findings.

Results: Sample sizes in the selected studies ranged widely from 75 to over 3,800 participants. The mean age at surgery varied from 3 months to 5.5 years. Mortality rates differed significantly, ranging from 0.004% to 33.33%. Various neurological complications were reported, including seizures, stroke, altered consciousness, and neurological deficits, with incidence rates ranging from 1.75% to 37%.

Conclusion: The study provides a comprehensive overview of the current state of knowledge regarding neurological complications following paediatric congenital cardiac surgery. Moreover, they emphasize the importance of standardized data collection and reporting practices to advance our understanding of this critical aspect of paediatric cardiac care.

Keywords: Congenital heart disease, surgical correction, neurological complications, paediatric age.

Introduction

Congenital heart defects (CHDs) are among the most common birth defects, affecting approximately 1% of live births worldwide [1]. The management of paediatric patients with CHDs often necessitates surgical intervention, with advancements in surgical techniques and perioperative care leading to improved survival rates over the past few decades. While the primary goal of paediatric congenital cardiac surgery is to correct or palliate the anatomical abnormalities and provide long-term functional benefit, these procedures are not without risks [2].

Postoperative complications in this vulnerable patient population can have significant implications for their overall health and quality of life. Understanding the spectrum of postoperative complications following paediatric congenital cardiac surgery is essential for healthcare providers, researchers, and families of affected children [3]. This systematic review aims to comprehensively assess the existing literature on postoperative neurological complications in paediatric patients undergoing congenital cardiac surgery. Such knowledge is pivotal in guiding clinical decision-making, optimizing patient care, and identifying areas where further research is needed.

Paediatric congenital cardiac surgery encompasses a wide range of procedures, from simple repairs to complex surgeries involving multiple cardiac anomalies. Common congenital heart defects include ventricular septal defects (VSDs), atrial septal defects (ASDs), tetralogy of Fallot, transposition of the great arteries, and hypoplastic left heart syndrome [1]. The surgical correction of these anomalies involves intricate techniques, often requiring the use of cardiopulmonary bypass and profound hypothermia. Despite the remarkable progress in the field, the inherent complexity of

these surgeries predisposes patients to various postoperative neurological complications [4].

Neurological complications following paediatric congenital cardiac surgery constitute a significant concern that can have lasting effects on a child's development and quality of life. Neurological complications following congenital cardiac surgery can range from subtle cognitive deficits to overt strokes. Identifying and addressing these complications are crucial given their potential long-term impact on a child's development [5].

The risk of stroke and ischemic events is heightened during cardiac surgery due to factors such as embolism, hypoperfusion, and thrombosis. Children who experience these events may exhibit motor deficits, cognitive impairment, and behavioural challenges, necessitating comprehensive rehabilitation and long-term care [6]. Postoperative seizures and neurological dysfunction can arise because of perioperative factors, including hypoxia, electrolyte imbalances, and metabolic derangements. These issues can disrupt a child's neurological development and may require ongoing management [7, 8].

Therefore, this systematic review is being conducted with the objectives of providing a comprehensive overview of postoperative neurological complications in paediatric congenital cardiac surgeries.By addressing these objectives, we aim to contribute to the body of knowledge surrounding postoperative complications in paediatric congenital cardiac surgery, ultimately improving the care and outcomes of these vulnerable patients.

Materials and Methods

Literature Search

The literature search encompassed an extensive database including PubMed, EMBASE, and Web of Science. By drawing from these diverse sources, we aim to minimize the risk of publication bias and capture a broad spectrum of relevant studies.

Keywords and Search Terms

To construct a precise search strategy, we employed a combination of controlled vocabulary terms (e.g., MeSH terms) and free-text keywords. The primary search terms were "congenital cardiac surgery," "paediatric age," and "neurological complications." These were linked with Boolean operators and refined using synonyms and related terms. The search strategy was designed with the assistance of an experienced medical librarian to maximize its sensitivity and specificity.

Study Selection

Studies published after the year 2010 were included. To ensure the reliability and credibility of the literature selection process, a pre-screening, or pilot literature review, was meticulously conducted. This pre-screening was performed by two independent researchers, and discrepancies were settled by a third reviewer. Each study's title and abstract were thoroughly examined to ascertain its relevance to the research objectives. From the identified papers, full text was obtained and scrutinized to extract the relevant outcome estimates reported in each study. By adopting this rigorous approach, we aimed to maintain a high standard of methodological integrity and accuracy throughout the data collection process, thus establishing a solid foundation for the subsequent analysis and synthesis of findings.

Inclusion Criteria

Clear and well-defined inclusion and exclusion criteria governed the selection of studies in our systematic review. Studies considered for inclusion met the following criteria: original research studies, including randomized controlled trials (RCTs), observational studies (cohort, case-control), and systematic reviews/meta-analyses, studies involving paediatric patients (age <18 years) who underwent cardiac surgeries, studies reporting complications following cardiac surgeries for CHD, and studies published in English.

Exclusion Criteria

Studies that do not meet these criteria or are of low methodological quality were excluded. We also excluded case reports, editorials, letters, and animal studies.

Process for Screening and Selecting Studies

The process of study selection adhered to a two-tiered screening process. In the initial phase, two independent reviewers screened titles and abstracts of retrieved articles against the inclusion and exclusion criteria. Subsequently, the full-text articles of potentially eligible studies were obtained and subjected to a detailed evaluation by the same reviewers.

Any discrepancies or disagreements between reviewers were resolved through discussion or consultation with a third reviewer if necessary.

Data Extraction

A standardized data extraction form was developed to systematically capture relevant information from selected studies. The following data points were extracted:

1. Study characteristics: Title, authors, publication year, study design.
2. Patient characteristics: Age, gender, sample size, inclusion/exclusion criteria.
3. Surgery type: The type of surgery done for congenital cardiac defect.

4. Outcome measures: Complications following surgeries: cardiac, respiratory, neurological, infectious, and hemodynamic.

Tools for Quality Assessment

The quality of included studies was assessed using appropriate tools tailored to the study design. For randomized controlled trials (RCTs), the Cochrane Risk of Bias tool [9] was employed to evaluate potential biases in various domains, including random sequence generation, allocation concealment, blinding, and attrition. Non-randomized studies were assessed using tools such as the Newcastle-Ottawa Scale for cohort studies and case-control studies [10]. Systematic reviews and meta-analyses underwent quality assessment using the AMSTAR-2 tool [11].

Data Synthesis

The synthesis of data encompassed a narrative summary of study characteristics, outcomes, and findings. This analysis will provide a qualitative measure of the postoperative complications of congenital cardiac surgeries.

Ethical Considerations: This study adhered to ethical guidelines and principles in accordance with international standards for research conduct. No individual patient data were collected, and the review relied solely on aggregated data from previously published studies. Ethical approval is not required for this systematic review as it does not involve direct interaction with human subjects or the conduct of new research.

Preferred Reporting Guidelines

This systematic review adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for transparent and comprehensive reporting [12].

Results

Study and patient characteristics

We began by identifying 248 studies. Following an assessment of the titles and abstracts, 36 papers were chosen for further consideration. Following that, 24 studies were eliminated failed to meet the laid down inclusion criteria, as they failed to meet the inclusion criteria and 1study was in a language other than English. Finally, we considered 11 studies [13-23]. The process of study selection is illustrated in the PRISMA study selection diagram (Figure 1).

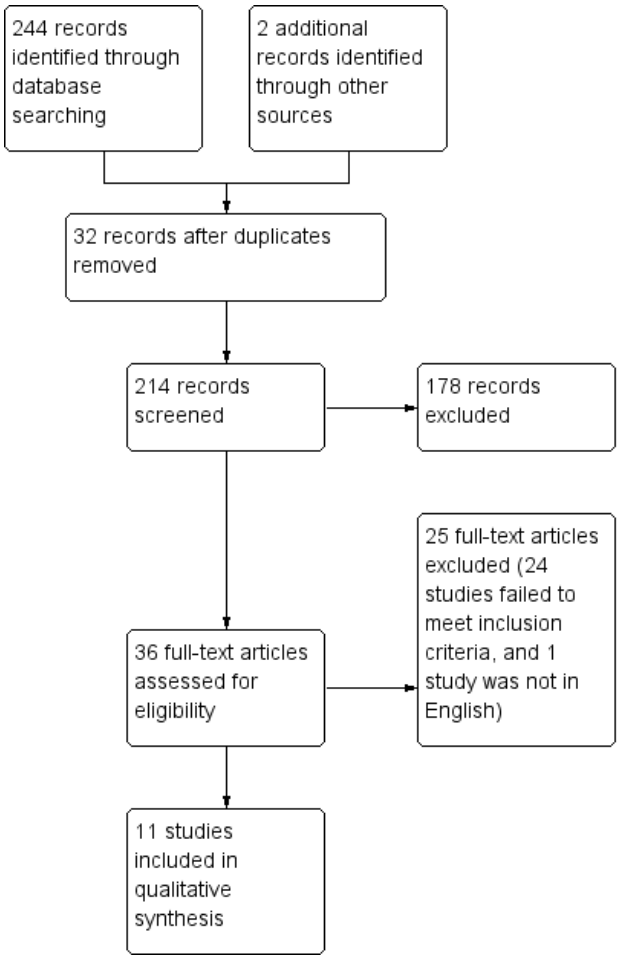

Figure 1: PRISMA study selection diagram

Salient features of the included studies

Our investigation comprised a total of 11 articles (Table 1). The publishing year spanned from 2010 to 2023. Five of the 11 investigations were prospective, while the other eleven were retrospective.

Table 1: Salient features of the included studies

Author, year	City, Country	Design of the study	Sample size	Mean age at operation	Mortality	Neurological complications reported	Incidence of neurological complications
Meyer, 2012 [13]	Saarland, Germany	Prospective	313	54.2 months	NA	Seizures, stroke, abnormal muscle tone	2.5
Agarwal, 2014 [14]	Nashville, USA	Retrospective	3253	6 months	7.5	Seizures	37
Jordan, 2015 [15]	North America	Prospective	204	18.6 months	25	Stroke and seizures	29
Jafri, 2017 [16]	Karachi, Pakistan	Retrospective	2000	19.5 months	0.004	Seizures, stroke, altered consciousness	1.75
Bar-Yosef, 2018 [17]	Tel Aviv, Israel	Retrospective	75	3 months	NA	Neurological deficit	26.67
Chung, 2019 [18]	Ohio, USA	Prospective	672	NA	7	Stroke	26
Arslanoglu, 2021 [19]	Istanbul, Turkey	Retrospective	3849	60.59 months	33.33	Seizures, stupor, confusion, hemiparesis	4.2
Agha, 2022 [20]	San Donato, Italy	Retrospective	63	12 months	19.05	Stroke	31.7
Abdshah, 2022 [21]	Tehran, Iran	Prospective	267	32 months	NA	Seizures and stroke	5.22
Rohde, 2022 [22]	Europe	Retrospective	230	24 months	24.5	Stroke	20
Elnagger, 2023 [23]	Cairo, Egypt	Prospective	105	9 months	14	Seizures and loss of consciousness	15.2

NA: Not available

The included studies employ a mix of prospective and retrospective designs. This diversity in study design enriches the research landscape by offering different perspectives on the subject. The sample sizes in these studies vary significantly, ranging from smaller cohorts of around 75 participants to much larger samples exceeding 3,800. The studies are conducted in various cities and countries, providing a global perspective on paediatric congenital cardiac surgery outcomes. However, the diverse geographic locations also introduce potential variations in healthcare practices, patient demographics, and access to medical resources.

Mean age at operation

The mean age at paediatric congenital cardiac surgery, as presented in Table 1, exhibits significant variability across the included studies, ranging from 3 months to approximately 5.5 years. This variation in age reflects the heterogeneity of the patient population undergoing these complex surgical procedures. The wide age range highlights the diversity of congenital heart defects and the timing of their diagnosis. The age at operation is a crucial factor in assessing the developmental impact of surgical interventions. Younger patients, such as infants, may be more vulnerable to potential neuro developmental complications due to the ongoing maturation of their central nervous system. Finally, variations in the mean age at surgery also underscore the importance of tailored treatment strategies for different age groups within the paediatric population.

Mortality

The mortality rates across the studies vary notably, ranging from as low as 0.004% to as high as 33.33%. Such variability may be attributed to

differences in patient populations, the complexity of surgical procedures, and the availability of advanced medical resources in various healthcare settings. Secondly, it is essential to assess whether the reported mortality rates account for the specific time frame under consideration, such as perioperative mortality or longer-term outcomes. Additionally, variations in data collection and reporting methods may influence the accuracy of mortality figures.

Neurological complications

Table 1 indicates a wide spectrum of neurological complications reported, including seizures, stroke, altered consciousness, abnormal muscle tone, neurological deficit, stupor, confusion, and hemiparesis. This diversity underscores the complexity of neurological issues that can arise postoperatively, reflecting the multifaceted nature of these surgeries.

The incidence rates of neurological complications also exhibit considerable variation, ranging from 1.75% to 37%. These discrepancies could be attributed to differences in patient populations, surgical techniques, and perioperative care protocols. A critical appraisal underscores the significance of standardized criteria for defining and reporting neurological complications to enhance consistency across studies. Additionally, a deeper exploration of the factors contributing to the incidence of such complications, such as risk factors and preventive measures, is essential to improve patient outcomes.

While the table 1 provides valuable insights into neurological complications following paediatric congenital cardiac surgery, careful consideration of the diversity in reported complications and incidence rates is crucial for a comprehensive understanding of this critical aspect of patient care.

Discussion

Our systematic review focused on the evaluation of neurological complications following paediatric congenital cardiac surgery, synthesizing data from 11 studies conducted between 2010 and 2023. The included studies encompassed a mix of prospective and retrospective designs, reflecting the diverse methodological approaches employed to investigate neurological complications in this patient population. The choice of study design can influence the types of data collected and the interpretation of results. Prospective studies offer real-time data collection but may be influenced by selection bias. In contrast, retrospective studies rely on existing data, which may limit control over variables. Sample sizes in the reviewed studies displayed substantial variability, ranging from relatively small cohorts to large-scale investigations. Larger samples offer improved statistical power but may pose logistical challenges in terms of data collection and management. Smaller samples, while more manageable, can limit the ability to detect rare complications, potentially impacting the accuracy of incidence rates.

Geographical diversity was a notable feature, with studies conducted in various cities and countries worldwide. This diversity is advantageous for gaining a global perspective on paediatric congenital cardiac surgery outcomes. However, it introduces potential variations in healthcare systems, patient demographics, and access to medical resources. These regional disparities may influence the prevalence of neurological complications and the associated mortality rates.

The wide variability in the mean age at paediatric congenital cardiac surgery across the included studies highlights the complex nature of these cases. Children undergoing these procedures span a broad age range, from infancy to early childhood. The age at which surgery is performed is influenced by factors such as the type and severity of the congenital heart defect, its timing of diagnosis, and the individualized treatment plan. Critically, the mean age at operation is a crucial determinant of the developmental impact of surgical interventions. Younger patients, particularly infants, may face increased vulnerability to neuro developmental complications due to the ongoing maturation of their central nervous system. This emphasizes the need for meticulous perioperative care, comprehensive neurologic assessments, and long-term follow-up for infants and younger children to detect and address potential cognitive and motor deficits.

The mortality rates reported in the reviewed studies exhibited substantial variation, ranging from exceedingly low percentages to alarmingly high figures. This wide range can be attributed to several factors, including differences in patient populations, the complexity of surgical procedures, and disparities in the availability of advanced medical resources in various healthcare settings. It is imperative to consider the specific time frame for which mortality rates are reported, as this can significantly impact the interpretation of findings. Variations in data collection methods and reporting practices may also influence the accuracy of mortality figures.

Neurological complications represent a critical aspect of this review. The diversity of complications reported, including seizures, stroke, altered consciousness, and muscle tone abnormalities, underscores the multifaceted nature of these surgeries and their potential impact on the central nervous system. Moreover, the incidence rates of neurological complications demonstrated considerable variability, reflecting the

heterogeneity of patient populations, surgical techniques, and perioperative care protocols.

Considering the observed heterogeneity in study designs, sample sizes, and geographical locations, future research in this field should prioritize standardization. The adoption of consistent criteria for defining and reporting neurological complications is essential to enhance the comparability of findings across studies. Furthermore, a deeper exploration of risk factors and preventive measures is warranted to mitigate the incidence of such complications and improve patient outcomes.

Conclusion

The study provides a comprehensive overview of the current state of knowledge regarding neurological complications following paediatric congenital cardiac surgery. The findings underscore the need for tailored treatment strategies, vigilant neurologic assessments, and long-term follow-up care, especially for infants and younger children. Moreover, they emphasize the importance of standardized data collection and reporting practices to advance our understanding of this critical aspect of paediatric cardiac care.

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