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Research Article

Artificial Intelligence in Pediatric Blood Transfusion during Anesthesia: A Scoping Review

Parisa Akbarpour[1], Parisa Moradimajd[1]*, Azam Saei[1,2], Maryam Aligholizadeh[1], Siavash Sangi[1]

[1]*Department of Anesthesia, Faculty of Paramedicine, Iran University of Medical Sciences, Tehran, Iran.*

[2]*Research Center for Trauma in Police Operations, Directorate of Health, Rescue & Treatment, Police Headquarter, Tehran, Iran.*

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ABSTRACT

Background: Transfusion is a vital process, but incorrect injection can cause harm. In the field of children's blood transfusion under anesthesia, the use of artificial intelligence (AI) and machine learning (ML) is regarded as innovative tools that enhance patient safety levels. This article examines and reviews the scoping literature on the use of artificial intelligence in pediatric blood transfusions during anesthesia, with the aim of identifying solutions, challenges, and future opportunities in this field.

Methods: The study, conducted from early 2024 to May 2024, aimed to evaluate the effectiveness of artificial intelligence (AI) and machine learning (ML) in predicting blood transfusion needs and bleeding risks in pediatric anesthesia. Relevant keywords, including artificial intelligence, machine learning, predictive model, neural network, predictive algorithm, blood transfusion, children, pediatric, neonates, anesthesia, surgery, and operation, were extracted from the Medical Subject Headings (MeSH). A comprehensive search strategy was independently implemented in Web of Science, PubMed, Scopus, and Google Scholar databases

Results: The search strategy initially identified 260 articles. After a systematic screening process, 60 duplicate articles were excluded. Subsequently, careful screening of titles, abstracts, and full texts eliminated an additional 195 articles, resulting in a final selection of 5 relevant English-language articles. Based on these studies, factors such as the type of surgery, the machine learning models used, decreases in hemoglobin and hematocrit levels before surgery, prolonged surgery, as well as the young age and low weight of pediatric patients, were identified as indicators of the increased risk of blood transfusion during surgery and anesthesia.

Conclusion: Based on the findings of the studies, artificial intelligence (AI) and machine learning (ML) have shown significant advancements in pediatric blood transfusion under anesthesia. This technology offers notable benefits, including high accuracy in predicting transfusion requirements and the ability to make timely decisions in critical situations. However, despite these advancements, further research is warranted to comprehensively understand the advantages and limitations of AI in the field of pediatric blood transfusion during anesthesia.

The authors declare no conflicts of interest.
*Corresponding author.
E-mail address: moradimajd.p@gmail.com

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Introduction

Blood transfusion is a common medical procedure, and although it is considered as a vital process , it may cause harm, especially in pediatric patients, in case of improper injection [1]. One of the important challenges of medical centers is the effective management of this vital resource. Deciding on the necessity of blood transfusion for a patient is one of the most difficult decisions in the field of medicine. Potential problems that arise in this context include underestimating or overestimating the volume of transfusion required [2]. So far, many efforts have been made to reduce the amount of unnecessary blood transfusions [3]. Most often, the preoperative hemoglobin level and the type of surgery are used as a basis for blood transfusion. But the lack of precise quantitative standards to determine the amount of blood transfusion has caused widespread problems in this field [4]. During surgery, the amount of unnecessary blood transfusions reaches 15-62.9% [5]. Improper blood transfusion requests impose the cost of conducting serology tests and reduce the amount of blood reserves for patients who urgently need blood transfusion [6]. Artificial intelligence (AI) and its sub-branches, which include machine learning (ML) and deep learning (DL) methods, are referred to as an emerging technological development that can play a significant role in the field of medicine [3]. Machine learning, a branch of artificial intelligence, utilizes computational models to collect and analyze data. Sophisticated machine learning algorithms have the capacity to recognize complex patterns in vast data sets, making them applicable to complex medical challenges. And it often leads to its superiority compared to conventional statistical methods [7]. Creating an efficient machine learning requires collaboration between doctors and computer engineers. The application of ML in healthcare mainly uses supervised learning methods, where models are trained using specified input features along with their corresponding labeled outputs, enabling the prediction of outcomes for new instances. Evaluation of model efficiency is usually related to performance measures, such as the area under the curve (AUROC). In addition, ML encompasses two other major paradigms: unsupervised learning, which recognizes inherent patterns in unlabeled data (eg, identifying clusters of similar patients), and reinforcement learning, a framework A cognitive methodology that requires learning optimal actions through repeated trials. For practical application, it is imperative that ML models undergo rigorous validation and seamless integration into clinical workflows, given the potential limitations in user capacity and responsiveness that can hamper the real-world effectiveness of even perfectly functioning models [1].

This study was conducted in beginning of 2024 to the end of May 2024. At present, there exists insufficient guidance regarding the selection between a systematic review and a scoping review in the process of synthesizing evidence, particularly when reviewing the literature. lacks support. Clear criteria have not yet been comprehensively established, and there are aspects that are considered important, complex or different, preventing a more detailed systematic review. Considering the lack of sufficient studies related to artificial intelligence (AI) or machine learning (ML) in diverse aspects of pediatric anesthesia and the process of blood transfusion, we decided to conduct a scoping review to review the minimum available resources.

Methods

Research question

How effective are artificial intelligence and machine learning for predicting blood transfusion and pediatric bleeding under anesthesia?

Search strategy

We first extracted keywords related to the main topic using the Utilized Medical Subject Heading (MeSH) terms and independently conducted initial searches in databases such as Web of Science, PubMed, Scopus, and Google Scholar using the following specified keywords: “artificial intelligence” OR“machine learning” OR “predictive model” OR “neural network “ OR “prediction algorithm” AND “blood transfusion” AND “children” OR “pediatrics” OR “infants’ AND "Anesthesia" OR “surgery” OR “Operation”.

All articles were reviewed by two researchers based on titles and abstracts, and irrelevant entries were removed. Any disagreements between the two researchers were reviewed by a third researcher and resolved through discussion between the researchers, resulting in unanimous consensus on the selection of articles for study inclusion. Data were extracted from all included studies, encompassing details such as author(s), objectives, participants, interventions, outcomes, and results. Articles found during each search process were limited to studies conducted between 2014 and 2024.

Study selection

Inclusion and exclusion criteria were determined for the studies pertinent to the research question, conducted in English, with a focus on the age group >18 years with the subject of estimating the amount of bleeding or blood transfusion under anesthesia using machine learning and artificial intelligence and without restrictions on the type of operation It was surgery. Exclusion criteria included systematic reviews, studies with no full text access, conference articles, case reports, book chapters, editorials, and animal studies. Duplicate studies were excluded. Next, the researchers assessed the articles against predefined inclusion and exclusion criteria and extracted data from them. The researchers evaluated the

articles based on predefined inclusion and exclusion criteria and extracted relevant data. The extracted data encompassed the following components: study details (including the principal author and year of publication), study characteristics (such as the objective, study location, and study population), and the impact of artificial intelligence or machine learning applications in the study. The collected data were then analyzed accordingly.

Results

The search strategy implemented resulted in the identification of 260 articles. Following a meticulous screening process, 60 duplicate articles were removed from consideration. Next, a thorough review of the titles and abstracts led to the exclusion of 130 articles that did not align with the research focus. Subsequently, the full texts of the remaining articles were examined in detail, resulting in the exclusion of an additional 65 articles due to their lack of relevance. Ultimately, the study included a final selection of 5 articles, all of which were in English. The article selection process is also illustrated in the PRISMA diagram (Figure 1). The articles are briefly discussed in (Table 1) [8-12].

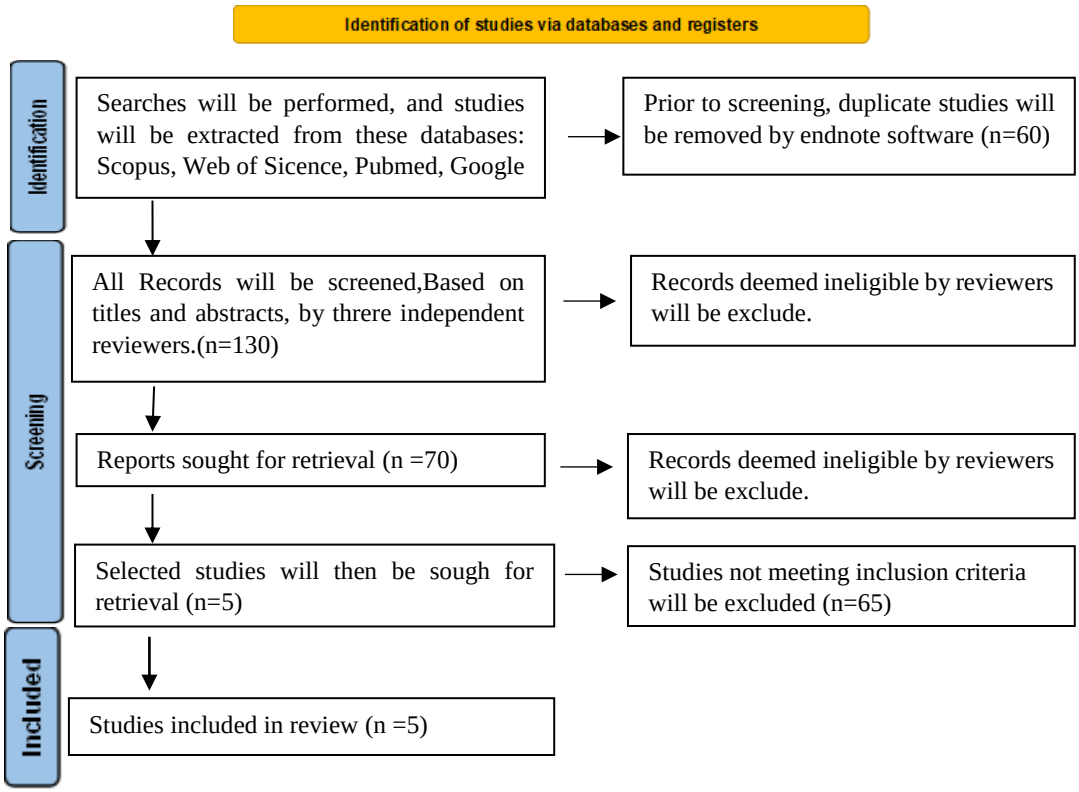

Figure 1- PRISMA diagram

Table 1- Selected articles in comprehensive review

Reference	Where	Objectives as stated	Sample size	Key findings as reported
Dupuis et.al. in 2015 [8]	France	Predictive factors for homologous transfusion during paediatric scoliosis surgery	147 children undergoing scoliosis surgery	The AUC value from ROC analysis was 0.9.
Vassal et. al. in 2016 [9]	France	Risk factors for intraoperative allogeneic blood transfusion during craniotomy for brain tumor removal in children	110 pediatric patients	The predictors of intraoperative ABT were determined using multivariate logistic regression.

Sherrod et. al. in 2018 [10]	England	Blood Transfusion Incidence, Risk Factors, and Associated Complications in Surgical Treatment of Hip Dysplasia	1184 children	ANOVA was performed to compare transfusion volumes between groups. Using binary logistic regression
Alassaf et. al. in 2019 [11]	Saudi Arabia	Development of a prediction model for allogenic blood transfusion in children undergoing surgery for developmental dysplasia of the hip	524 DDH patients	The AUC was 0.83, which indicates good discrimination.
Jalali et. al. in 2021 [12]	US state of pennsylvania	Machine Learning Applied to Registry Data:Development of a Patient-Specific Prediction Model for Blood Transfusion Requirements During Craniofacial Surgery Using the Pediatric Craniofacial Perioperative Registry Dataset	2143 Pediatrics under craniofacial surgery.	The GBM performed best in both domains, with an area under receiver operating characteristic curve of 0.87 ± 0.03 (95%confidence interval).

Discussion

Blood transfusions in pediatric patients must be tailored to the unique clinical circumstances and surgical needs of each child. While evaluating the risks and benefits of blood transfusion is important, the primary goal remains the same: maintain hemodynamic stability, ensure adequate oxygenation, support organ perfusion, avoid overtransfusion, and minimize adverse effects and associated complications of transfusions [13]. In this scoping review, we carefully reviewed the existing body of research on predicting transfusion requirements and bleeding events in pediatric patients under anesthesia. While the landscape of machine learning (ML) applications in transfusion is expanding, our review highlights a significant gap. Despite the vital importance of blood transfusion in children undergoing surgery and anesthesia, few studies have been conducted in this field. Our research sheds light on the potential benefits of using ML models in the context of transfusion prediction and clinical decision-making and can be a useful tool for clinicians (anaesthesiologists and surgeons). After a detailed examination of the results obtained from selected articles in comprehensive review (Table1), the separation of the type of surgery and the machine learning model used, factors such as the decrease in hemoglobin and hematocrit levels before surgery, the duration of surgery, as well as the low age and weight of pediatric patients as indicators of increased risk of transmission Blood is considered during surgery and anesthesia. A significant challenge in the adoption of machine learning is the scarcity of prospective studies. In response to this gap, researchers have suggested the adoption of a robust reporting framework [14] and the integration of detailed case reports [15] as potential solutions. One of the important obstacles in the use of artificial intelligence in the field of blood transfusion; It is suitable to build machine learning models with specific input data of the study group. Consequently, there is a potential risk of underestimating or overestimating transfusion requirements when extrapolating models to a different population. This is one of the reasons for reducing the external validity and generalizability of machine learning frameworks [16]. A scoping review conducted by Maynard et al in 2023 entitled Machine Learning in Transfusion Medicine. Its results were consistent with our study and the results pointed to the different models used and reduced external validity and generalizability of machine learning model [1]. In the field of predicting the amount of blood transfusion in pediatric anesthesia, machine learning and logistic regression methods are often used. However, definitive proof of the superiority of one over the other remains elusive. Increased model efficiency and broader generalizability are facilitated in both cases through iterative refinement techniques, including data-driven local adjustments and continuous monitoring of performance in clinical settings [16-17]. Our research has limitations, including that the found articles used different models and methods, which makes it difficult to integrate and interpret the results and creates obstacles for researchers to verify their validity and we also included only the articles written in English. We state that despite extensive efforts in citation review,some studies in this field may have been overlooked. The evolving landscape of machine learning in pediatric blood transfusion under anesthesia emphasizes the need for additional comprehensive studies to advance knowledge and practice in this growing field.

Conclusion

In the field of pediatric anesthesia and blood transfusion, the integration of artificial intelligence has attracted much attention as a new and effective tool to improve medical care during blood transfusion and improve patient safety. The advantages of this technology include exceptional accuracy in predicting blood transfusion needs and the ability to make optimal and quick decisions in critical scenarios. Nevertheless, for the

optimal use of artificial intelligence in pediatric blood transfusions under anesthesia, careful attention should be paid to aspects such as protecting data privacy, validating models, and ensuring alignment with medical standards. As a result, the integration of artificial intelligence for clinical decision-making in blood transfusion of children during anesthesia leads to an improvement in the quality of healthcare and treatment and as a result increases the safety of this group of patients.

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References

[1] Maynard S, Farrington J, Alimam S, Evans H, Li K, Wong WK, et al. Machine learning in transfusion medicine: A scoping review. Transfusion. 2024;64(1):162-84.

[2] Cifuentes J, Yao Y, Yan M, Zheng B. Blood transfusion prediction using restricted Boltzmann machines. Comput Methods Biomech Biomed Engin. 2020;23(9):510-7.

[3] Angthong C, Rungrattanawilai N, Pundee C. Artificial intelligence assistance in deciding management strategies for polytrauma and trauma patients. Pol Przegl Chir. 2023;96(0):114-7.

[4] Feng Y, Xu Z, Sun X, Wang D, Yu Y. Machine learning for predicting preoperative red blood cell demand. J Transfus Med. 2021;31(4):262-70.

[5] Tao J, Qian B, Zhang A, Liu X, Mao P. Investigation and analysis of rationality of 900 cases of clinical blood transfusion. Chin J Blood Transfus. 2017:805-7.

[6] Sadana D, Pratzer A, Scher LJ, Saag HS, Adler N, Volpicelli FM, et al. Promoting high-value practice by reducing unnecessary transfusions with a patient blood management program. JAMA Intern Med. 2018;178(1):116-22.

[7] Meier JM, Tschoellitsch T. Artificial intelligence and machine learning in patient blood management: a scoping review. Anesth Analg. 2022;135(3):524-31.

[8] Dupuis C, Michelet D, Hilly J, Diallo T, Vidal C, Delivet H, et al. Predictive factors for homologous transfusion during paediatric scoliosis surgery. Anaesth Crit Care Pain Med. 2015;34(6):327-32.

[9] Vassal O, Desgranges FP, Tosetti S, Burgal S, Dailler F, Javouhey E, et al. Risk factors for intraoperative allogeneic blood transfusion during craniotomy for brain tumor removal in children. Paediatr Anaesth. 2016;26(2):199-206.

[10] Sherrod BA, Baker DK, Gilbert SR. Blood transfusion incidence, risk factors, and associated complications in surgical treatment of hip dysplasia. J Pediatr Orthop. 2018;38(4):208-16.

[11] Alassaf N, Reitsma JB. Development of a prediction model for allogenic blood transfusion in children undergoing surgery for developmental dysplasia of the hip. Technol Health Care. 2019;27(3):327-34.

[12] Jalali A, Lonsdale H, Zamora LV, Ahumada L, Nguyen ATH, Rehman M, et al. Machine Learning Applied to Registry Data: Development of a Patient-Specific Prediction Model for Blood Transfusion Requirements During Craniofacial Surgery Using the Pediatric Craniofacial Perioperative Registry Dataset. Anesth Analg. 2021;132(1):160-71.

[13] Karišik M. Perioperative Blood Transfusion in Pediatrics. J Anesth. 2023;31.

[14] Wiens J, Saria S, Sendak M, Ghassemi M, Liu VX, Doshi-Velez F, et al. Do no harm: a roadmap for responsible machine learning for health care. Nat Med. 2019;25(9):1337-40.

[15] Sendak MP, D'Arcy J, Kashyap S, Gao M, Nichols M, Corey K, et al. A path for translation of machine learning products into healthcare delivery. EMJ Innov. 2020; 10:19-00172.

[16] Feng J, Phillips RV, Malenica I, Bishara A, Hubbard AE, Celi LA, et al. Clinical artificial intelligence quality improvement: towards continual monitoring and updating of AI algorithms in healthcare. NPJ digi Med. 2022;5(1):66.

[17] Amrollahi F, Shashikumar SP, Holder AL, Nemati S. Leveraging clinical data across healthcare institutions for continual learning of predictive risk models. Sci Rep. 2022;12(1):8380.