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INCIDENCE OF POSTOPERATIVE HYPOXIA IN CHILDREN FOLLOWING GENERAL ANESTHESIA FOR SURGICAL PROCEDURES: A SYSTEMATIC REVIEW

Systematic Review

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ABSTRACT

Background: Hypoxemia represents one of the most serious perioperative complications and is commonly encountered during intraoperative, postoperative, and recovery phases. Children are at particular risk due to reduced functional residual capacity, higher oxygen consumption, and immature airway structures. Despite advances in perioperative monitoring and anesthesia techniques, postoperative hypoxia remains frequent, even following minor procedures. Recognizing its burden and associated risk factors is essential for developing effective monitoring and preventive strategies to improve pediatric surgical outcomes.

Objective: The objective of this review was to determine the incidence of postoperative hypoxia in pediatric patients undergoing surgery under general anesthesia and to identify associated risk factors.

Methods: A systematic review was conducted by searching electronic databases including PubMed, Embase, MEDLINE, Cochrane Library, JAMA Network, Google Scholar, and ScienceDirect. Articles published from 2012 onwards were screened using keywords such as *hypoxemia*, *postoperative hypoxia*, *pediatric anesthesia*, *oxygen saturation*, and *recovery period*. Of 62 initially identified studies, 50 met the inclusion criteria, and 25 were selected for final analysis. Clinical trials, observational studies, and reviews involving children undergoing surgery under general anesthesia were included, while case reports, editorials, and pre-2012 publications were excluded.

Results: Analysis of included studies demonstrated that body weight, gender, and duration of surgery had no significant effect on the incidence of postoperative hypoxia. In contrast, age was a major determinant, with younger children experiencing higher rates of desaturation. One study reported 20% mild hypoxemia (SaO_2 86–90%), 2.66% moderate (81–85%), and 1.33% extreme (<76%) in patients without supplemental oxygen. Another study found desaturation in 21% of children transported under room air compared with only 3% in those given oxygen supplementation. Postoperative hypoxemia was most common in infants under six months and in children with pneumonia, where rates reached 42.7%.

Conclusion: Postoperative hypoxemia is a prevalent complication in pediatric patients, particularly in infants and those with comorbidities. Continuous pulse oximetry and provision of supplemental oxygen during transfer and recovery are essential preventive measures to reduce adverse outcomes.

Keywords: Anesthesia, General; Hypoxemia; Hypoxia; Oxygen Inhalation Therapy; Oxygen Saturation; Pediatrics; Postoperative Complications.

INTRODUCTION

Hypoxia refers to an insufficient supply of oxygen to body tissues required for normal cellular and organ function (1). When this deficit becomes significant, it compromises multiple physiological processes and may threaten survival (2). Hypoxemia, a measurable manifestation of hypoxia, is evident when arterial oxygen partial pressure (PaO_2) falls below 60 mmHg or oxygen saturation (SpO_2) decreases to 90% or less (3). It is further classified into mild (SpO_2 86–90%), moderate (81–85%), severe (76–80%), and extreme (<76%) stages (4). Hypoxemia is a frequent perioperative complication, particularly in pediatric populations, and has the potential to contribute to serious morbidity and mortality (5,6). The occurrence of postoperative hypoxia in children is of special concern because it can prolong wound healing and precipitate life-threatening complications, including arrhythmias, myocardial ischemia, neurological impairment, and even death (7). Globally, nearly two million deaths in children under five years of age are attributed to hypoxemia secondary to acute respiratory infections (8). Early recognition and treatment are therefore critical, particularly in surgical patients (9). Pulse oximetry has become an indispensable tool for detecting hypoxemia in clinical practice, as it allows continuous, non-invasive monitoring of oxygen saturation in the perioperative setting (10). Children are especially vulnerable to postoperative hypoxemia due to unique anatomical and physiological factors. Their reduced functional residual capacity, increased basal metabolic rate, and higher ventilation-to-FRC ratio contribute to a rapid decline in oxygen reserves when breathing room air (11). Infants and young children, particularly those under three years of age, are at greater risk compared to adults (12).

Transport from the operating room to recovery can itself precipitate oxygen desaturation, even in otherwise healthy patients (13). Clinical consequences of hypoxia in children include shortness of breath, bradycardia, loss of consciousness, and potentially cardiac arrest (11). Multiple factors predispose pediatric patients to hypoxemia in the postoperative period. These include patient-related risks such as obesity, anemia, and underlying cardiopulmonary disease, surgical procedures involving the thorax and lungs, and anesthetic factors including residual neuromuscular blockade, airway obstruction, laryngospasm, and opioid-induced respiratory depression (13,14). Children undergoing adenotonsillectomy for obstructive sleep apnea are particularly prone to postoperative respiratory complications (2,9). The presence of acute or upper respiratory infections further increases the likelihood of hypoxia (15). Environmental factors, such as high altitude, also exacerbate vulnerability due to reduced atmospheric oxygen pressure, necessitating lower opioid doses to minimize respiratory depression (12). Although the relationship between age and postoperative hypoxemia remains debated, younger children remain at greater risk for adverse outcomes than older patients or adults (12,13). Oxygen therapy, especially via face mask, is recommended as the primary treatment strategy in the postoperative care unit, as emphasized by the World Health Organization (10,14). Despite advancements in monitoring and management, the true burden and incidence of postoperative hypoxia in children remain insufficiently studied, particularly in resource-limited settings where timely recognition and intervention are challenging. Therefore, this study was designed to determine the incidence of postoperative hypoxia in children, addressing an important gap in perioperative pediatric care and contributing evidence for improved monitoring and management strategies in this high-risk population.

METHODS

This study was designed as a descriptive cross-sectional systematic review aimed at synthesizing available evidence on the incidence of early postoperative hypoxia in children. Electronic databases including Google Scholar, PubMed, Excerpta Medica Database (Embase), JAMA Network, Cochrane Library, ScienceDirect, and MEDLINE were systematically searched. Clinical studies and review articles published from 2012 onwards were considered eligible for inclusion, ensuring that only contemporary evidence was examined. The search strategy was developed using a combination of predefined keywords such as *hypoxemia*, *postoperative hypoxia*, *pediatric anesthesia*, *oxygen saturation*, and *recovery period*. To enhance the relevance of the findings, only those studies that addressed at least three or more of these keywords within their scope were retained for analysis. Both local and international studies were considered to provide a comprehensive overview. Inclusion criteria consisted of original research articles, observational studies, clinical trials, and systematic reviews that reported on the incidence, risk factors, or outcomes of postoperative hypoxia in pediatric populations. Exclusion criteria included case reports, editorials, conference abstracts, studies not involving children, and articles published prior to 2012 to avoid outdated clinical practices. The initial search yielded 62 articles, of which 50 were selected after preliminary screening of titles and abstracts. Following detailed review of the full texts, 25 studies were retained for final synthesis and analysis. The process of data

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extraction involved systematic evaluation of each study for methodology, sample size, diagnostic criteria for hypoxemia, and reported incidence rates. Information was tabulated and cross-compared to ensure reliability of interpretation. No quantitative meta-analysis was performed; instead, a narrative synthesis approach was applied due to heterogeneity in study designs, populations, and outcome measures. Where available, statistical methods and incidence estimates from the original studies were reported verbatim to maintain accuracy. Ethical considerations were acknowledged, although systematic reviews generally do not involve direct contact with human participants and therefore do not require individual informed consent. Nevertheless, all included studies were assumed to have obtained approval from their respective Institutional Review Boards (IRB) as per international publication standards. Since this review relied exclusively on published data, no new ethical approval was required for the present work.

RESULTS

The findings demonstrated that early postoperative hypoxia occurred more frequently in patients who were not provided with oxygen supplementation during transfer from the operating room to the recovery room. Among 150 patients studied, 20% developed mild hypoxemia with SaO_2 between 86–90%, 2.66% experienced moderate hypoxemia with SaO_2 between 85–81%, and 1.33% developed extreme hypoxemia with SaO_2 less than 76% in the non-supplemented group. Patient weight, gender, and duration of surgery did not show a significant association with the incidence of hypoxia (4). In high-altitude settings, children undergoing surgical procedures at facilities located at ≥3399 meters demonstrated a higher risk of postoperative hypoxia compared with those operated at low-altitude locations ≤150 meters (11). Postoperative desaturation was particularly evident in younger children. One study showed that desaturation occurred most commonly in patients aged 0–6 months, followed by those aged 7–12 months, despite 100% oxygenation for three minutes prior to transfer into the recovery room (15). In another study including 200 children aged between 2 months and 9 years, the incidence of desaturation was 21% in the group transferred under room air and 3% in the group provided with oxygen supplementation by face mask (16). A prospective non-randomized study of 110 pediatric surgeries involving patients with ASA physical status I and II reported desaturation rates of 27% in a group of 60 children compared to 8% in a group of 50 children. The risk was highest in children aged ≤2 years, where desaturation occurred in 50% of patients in one group and 17% in the other (17).

Children with comorbid conditions such as pneumonia were at particularly high risk. In a cohort of 150 children with pneumonia, postoperative hypoxemia defined as SpO_2 <90% was identified in 42.7% of patients, with a disproportionately higher incidence among younger children aged 2–12 months. Severe pneumonia was found to be a significant predictor of hypoxemia in this population (16,17). Risk factor analysis revealed several important predictors of postoperative hypoxia. Children with higher body mass index (25–60 kg/m²) had an adjusted odds ratio (OR) of 2.82 (95% CI: 1.30–6.11, p=0.009), while those with hyper-reactive airways had an OR of 2.50 (95% CI: 1.12–5.59, p=0.025). A probable difficult airway was strongly predictive of hypoxia with an OR of 4.99 (95% CI: 1.74–14.32, p=0.003). Higher ASA physical status was also associated with increased risk, with ASA III patients having an OR of 4.73 (95% CI: 2.43–9.18, p<0.001) compared to ASA I. Endotracheal intubation further elevated the risk with an OR of 6.64 (95% CI: 2.54–17.32, p=0.0001). The need for oxygen therapy varied considerably. The median duration of oxygen administration was 17 hours (IQR 9–22), with patients stratified into high (≥12), intermediate (8–11), and low (≤7) risk groups based on cumulative risk scores. Children undergoing thoracic surgery consistently required oxygen therapy and exhibited high-risk scores, whereas bronchospasm and upper airway obstruction contributed to intermediate scores. Difficult airway conditions and endotracheal intubation were strongly associated with prolonged oxygen requirement (18).

Table 1: Comparison of Patient Characteristics Between Control and Oxygen Therapy Groups

Factors	Control Group (No oxygen therapy) (n = 1152)	Cases Group (Oxygen therapy) (n = 288)	p value
Age (years)			0.99
<1	216 (18.8%)	84 (18.8%)	
1–6	552 (47.9%)	138 (47.9%)	
>6	384 (33.3%)	96 (33.3%)	

Factors	Control Group (No oxygen therapy) (n = 1152)	Cases Group (Oxygen therapy) (n = 288)	p value
Body Mass Index (kg/m²)			<0.001
5–14.9	479 (41.6%)	130 (45.1%)	
15–24.9	629 (54.6%)	128 (44.4%)	
25–60	44 (3.8%)	30 (10.4%)	
ASA Physical Status			<0.001
I	242 (21.0%)	21 (7.3%)	
II	742 (64.4%)	136 (47.2%)	
III	168 (14.6%)	131 (45.5%)	
Choice of Anesthesia			0.04
GA only	948 (82.3%)	252 (87.5%)	
GA with epidural/caudal	151 (13.1%)	31 (10.8%)	
GA with peripheral nerve block	53 (4.6%)	5 (1.7%)	
Airway Device			<0.001
Spontaneous breathing with mask	28 (2.4%)	4 (1.4%)	
Endotracheal tube intubation	713 (61.9%)	253 (87.8%)	

Table 2: Multivariate Analysis of Factors Associated with Postoperative Hypoxia

Factors	Coefficient	Adjusted OR (95% CI)	p value	Risk Score
Body Mass Index				
5–14.9	0.51	1.66 (1.07, 2.58)	0.024	1
25–60	1.04	2.82 (1.30, 6.11)	0.009	2
Hyper-reactive Airway (Ref: No/Yes)	0.92	2.50 (1.12, 5.59)	0.025	2
Probable Difficult Airway (Ref: No/Yes)	1.61	4.99 (1.74, 14.32)	0.003	3
ASA Physical Status (Ref: 1)				
2	0.31	1.36 (0.73, 2.53)	0.327	0
3	1.55	4.73 (2.43, 9.18)	<0.001	3
Airway Device (Ref: Facemask/LMA)				
Spontaneous breathing with non-rebreathing mask	1.38	3.98 (0.64, 24.88)	0.14	0
Endotracheal tube intubation	1.89	6.64 (2.54, 17.32)	0.0001	4

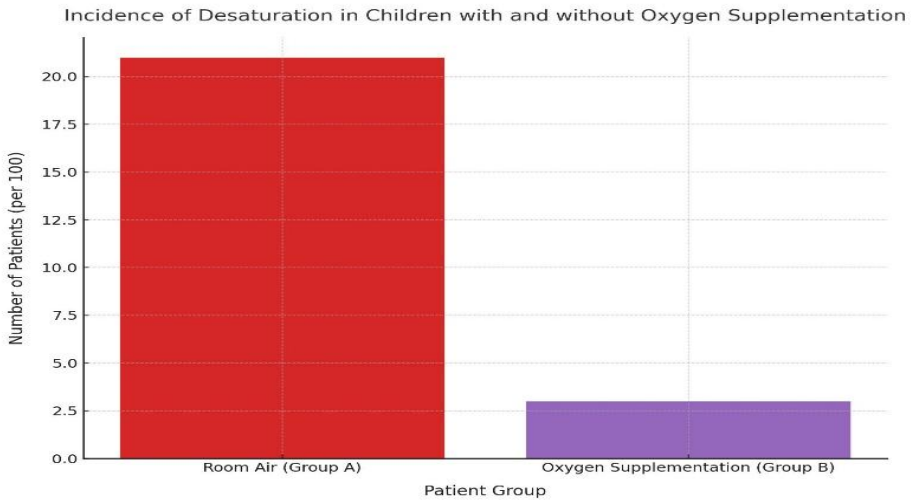

Figure 1 Incidence of Desaturation in Children with and Without Oxygen Supplementation

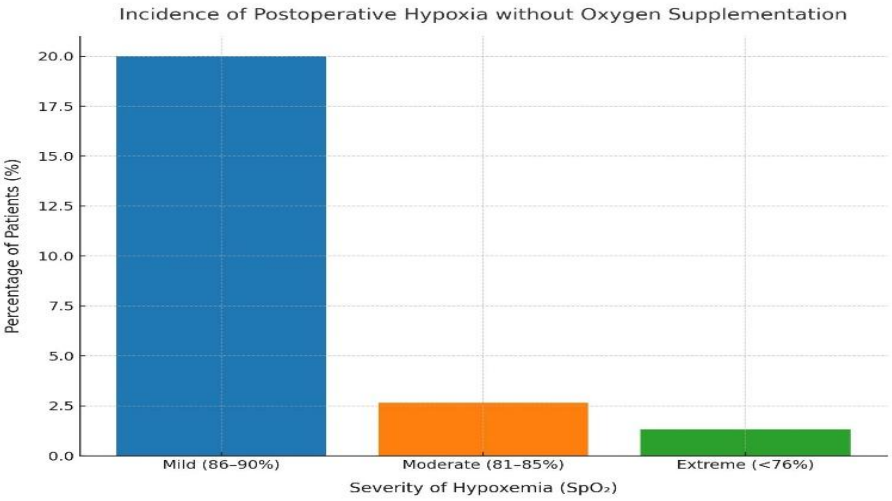

Figure 2 Incidence of Postoperative Hypoxia Without Oxygen Supplementation

DISCUSSION

The present review confirmed that postoperative hypoxemia is a frequent complication in children undergoing general anesthesia, aligning with previously reported findings in both local and international studies (14,15). The observed trend of higher susceptibility in infants and younger children reinforces the role of unique pediatric respiratory physiology, including reduced functional residual capacity, elevated oxygen consumption, and immature structural support of the airways, which predispose this age group to early desaturation (16-18). The current results are consistent with earlier studies demonstrating that the incidence of desaturation is most pronounced in children below six months of age and decreases gradually with advancing age, irrespective of the type of surgical procedure performed (19). The contribution of multiple mechanisms to postoperative hypoxemia, such as ventilation–perfusion mismatch, diffusion hypoxia, and anesthetic-induced respiratory depression, was highlighted. These mechanisms are well recognized in pediatric anesthesia literature and provide a rational explanation for the observed desaturation patterns (20). Additionally, external and

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patient-specific factors, such as residence at high altitude and conditions like obstructive sleep apnea, were shown to exacerbate the risk, which corroborates findings from studies conducted in populations exposed to environmental and physiological vulnerabilities (21).

The incidence of arterial desaturation during transport from the operating room to the recovery room was reported to range between 13% and 23%, which is consistent with the present synthesis of findings. Importantly, the risk was significantly higher when supplemental oxygen was not administered during transfer, underscoring the necessity of preventive strategies in the immediate postoperative period (21,22). These observations emphasize that perioperative care protocols should integrate supplemental oxygen delivery and continuous monitoring to mitigate preventable complications. The role of pulse oximetry as a reliable, non-invasive monitoring tool was further reaffirmed. Evidence consistently demonstrates that pulse oximetry detects up to 20–30% more cases of hypoxemia compared with reliance on clinical signs alone, thereby reducing the frequency of unrecognized desaturation events (23). Its portability and affordability also make it especially valuable in resource-limited settings, where early detection and timely intervention can be life-saving (15,24). The integration of continuous oximetry during transport and recovery has been shown to substantially decrease unmonitored periods and the occurrence of hypoxemic events, which is highly relevant in improving the quality of pediatric anesthesia care.

The strengths of this review included the inclusion of diverse studies conducted across different geographic and clinical settings, allowing for a broad understanding of postoperative hypoxemia in pediatric populations. The consistent findings across multiple data sources add robustness to the conclusion that supplemental oxygen and monitoring strategies remain indispensable. However, several limitations must be acknowledged. The heterogeneity of the included studies, in terms of design, patient selection, and outcome definitions, limited the ability to provide pooled incidence values. In some cases, key variables such as type of surgery, sex distribution, and anesthetic techniques were not uniformly reported, restricting the ability to conduct subgroup analyses. Furthermore, the lack of randomized controlled trials in certain subgroups reduced the strength of evidence regarding causality. Future research should focus on well-structured multicenter prospective studies with standardized protocols to better define risk factors, quantify benefits of oxygen supplementation, and assess the long-term impact of hypoxemia in children. Special emphasis should be placed on high-risk populations, such as neonates, infants with comorbidities, and children undergoing thoracic or upper airway procedures. Moreover, the development of risk stratification tools integrating clinical, demographic, and perioperative variables could allow clinicians to predict which patients would most benefit from aggressive monitoring and early oxygen supplementation. Overall, the findings reinforce that postoperative hypoxemia remains a clinically significant issue in pediatric anesthesia, with implications for morbidity and mortality if unrecognized. Supplemental oxygen administration during transport to the recovery room, combined with continuous monitoring through pulse oximetry, emerged as essential interventions. Strengthening perioperative safety protocols and addressing existing evidence gaps can improve outcomes and reduce the burden of hypoxemia in this vulnerable population.

CONCLUSION

This study concluded that early postoperative hypoxemia is a significant and frequent complication in children following general anesthesia, regardless of surgical duration, body weight, or gender. The findings highlighted that, younger children are particularly vulnerable, underscoring the importance of vigilant monitoring in this age group. Pulse oximetry emerged as a vital tool for timely detection of hypoxemia, and the provision of supplementary oxygen during transfer to the recovery room was emphasized as an essential preventive measure. The involvement of anesthetists in both transport and recovery care, along with the continued administration of oxygen by facemask until the child regains sufficient consciousness, represents a practical and effective strategy to minimize risks and improve postoperative safety in pediatric patients.

AUTHOR CONTRIBUTION

Author	Contribution
Shahid Hussain	Substantial Contribution to study design, analysis, acquisition of Data Manuscript Writing Has given Final Approval of the version to be published
Sajid Iqbal	Substantial Contribution to study design, acquisition and interpretation of Data Critical Review and Manuscript Writing Has given Final Approval of the version to be published
Jawad Ahmad Khan	Substantial Contribution to acquisition and interpretation of Data Has given Final Approval of the version to be published
Hikmat Yar	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Ahmad Ullah Khan	Contributed to Data Collection and Analysis Has given Final Approval of the version to be published
Niaz Ali*	Substantial Contribution to study design and Data Analysis Has given Final Approval of the version to be published
Ahmad Ullah	

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