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Original Research Article

Incidence of Hyperoxia and Excess Oxygen Use in Critically Ill Pediatric Patients

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Abstract: *Hypoxia is a very well-known risk factor for poor outcomes in patients admitted to intensive care units.* ***Objective:*** *This study aims to determine the prevalence of Hyperoxemia and the duration of Excess oxygen use in patients with hyperoxemia through chart review.* ***Methodology:*** *This prospective observational study was conducted in the Pediatric Intensive Care Unit (PICU) of the National Institute of Child Health (NICH) from December 2023 till December 2024. Data were collected prospectively using a structured case report form explicitly developed for this study (attached in the appendix). Information recorded included demographic details such as age and gender, clinical variables including admitting diagnosis, presence of comorbidities, and type of respiratory support received (HFNC or MV). Hourly oxygenation data, specifically FiO_2 and SpO_2 values, were documented over the first 24 hours of PICU admission.* ***Results:*** *28% of patients (56/200) experienced hyperoxemia, with the majority requiring mechanical ventilation (60.7%). Patients with hyperoxemia had a significantly higher median FiO_2 (0.65, IQR: 0.55–0.75) compared to those without hyperoxemia (0.45, IQR: 0.40–0.55, $p<0.001$) and a longer duration of oxygen therapy, with 71.4% of hyperoxemic patients receiving oxygen for more than 12 hours compared to 40.3% of those without hyperoxemia ($p=0.002$). Respiratory illness was more common in the hyperoxemia group (64.3% vs. 41.7%, $p=0.01$).* ***Conclusion:*** *It is concluded that hyperoxemia and excess oxygen use are common among critically ill pediatric patients receiving oxygen therapy, particularly in the first 24 hours of admission to the PICU. A significant proportion of patients, especially those with respiratory illnesses and those on mechanical ventilation, were exposed to high oxygen levels despite having elevated oxygen saturation levels.*

Keywords: Hyperoxia, Oxygen Inhalation Therapy, Intensive Care Units, Pediatric Respiratory Insufficiency

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Introduction

Oxygen therapy is a cornerstone of supportive care in critically ill pediatric patients, alleviating hypoxemia and ensuring adequate tissue oxygenation. While the clinical focus has traditionally emphasized the prevention and treatment of hypoxia, emerging evidence suggests that excessive oxygen administration leading to hyperoxia may also have detrimental physiological effects (1).

The administration of supplemental oxygen produces increased oxidative stress and inflammation, together with potential organ damage, in patients from vulnerable pediatric groups whose physiological situations differ strongly from those of adults. Ceaseless oxygen administration is the primary treatment approach in the critical care units for most patients with acute life-threatening conditions (2). Circulatory hypoxia functions as a primary reason that leads to the death of critically ill patients (3). Research shows arterial hyperoxemia produces adverse outcomes in post-resuscitation care of both neonates and adults, as well as children (4). Observational research shows that oxygen levels at the beginning of critical care hospital unit (ICU) admissions correlate with adult and pediatric ICU patient mortality (5-7). Critical illness responds negatively when patients experience extreme oxygen levels, according to medical literature (8). Our practice involves using extra oxygen supplementation out of fear of hypoxia, though we lack knowledge about the detrimental effects of hyperoxemia. Excessive oxygen levels in the respiratory system trigger tracheobronchitis and atelectasis and pulmonary edema, resulting in respiratory failure. Critical-ill patient organ perfusion impairment and subsequent vasoconstriction of blood vessels are increased when patients experience hyperoxemic conditions, leading to multi-organ failure and ultimately death (9). Most critical care experts suggested precise oxygenation control through oxygen dosage adjustment for treating critically ill patients to maximize therapeutic benefits while reducing oxygen therapy risks in ICU settings (10). The American Heart Association and AARC support maintaining arterial oxygen saturation at >94% to avoid deleterious hyperoxemia effects through proper oxygen therapy titration (11, 12). The existing research data about oxygen administration in critically ill children who receive treatment at developing country PICUs remains vastly inadequate. Medical treatment with oxygen functions similarly to that of pharmaceutical drugs since it is an expensive care method. The rationale of this study is to expand the data in the epidemiological cohort by reviewing our current practice of oxygen therapy in the PICU retrospectively through chart review and to implement a current standard of care for oxygen therapy in our PICU to optimize the risks and benefits of this drug in the future.

Thus, the objective of this study is to retrospectively determine the prevalence of hyperoxemia and the duration of excess oxygen use in patients with hyperoxemia through chart review.

Methodology

This prospective observational study was conducted in the Pediatric Intensive Care Unit (PICU) of the National Institute of Child Health (NICH) from January 2023 till January 2024. The study aimed to assess the incidence of hyperoxemia and excess oxygen use among critically ill pediatric patients receiving oxygen therapy within the first 24 hours of PICU admission.

All critically ill children aged between 1 month and 15 years who received oxygen therapy—either non-invasively via High-Flow Nasal Cannula (HFNC) or invasively through mechanical ventilation (MV) via endotracheal intubation—within the first 24 hours of PICU admission were eligible for inclusion. Exclusion criteria included children who did not receive oxygen therapy via HFNC or MV, those who stayed in the

PICU for less than 24 hours, and patients with cyanotic congenital heart disease receiving oxygen therapy.

The sample size was estimated using the OpenEpi sample size calculator. Assuming a hyperoxemia frequency of 15%, with a confidence interval of 90% and an absolute precision of 5%, the required sample size was calculated to be 200 patients. As detailed in the appendix, a non-probability consecutive sampling technique was used to recruit participants.

Hyperoxemia was defined as either a peripheral oxygen saturation (SpO_2) ≥98% or a partial pressure of arterial oxygen (PaO_2) ≥100 mmHg. Excess oxygen use was defined as administering a fraction of inspired oxygen (FiO_2) ≥50% in patients who met the criteria for hyperoxemia.

No intervention was applied. This was an observational study, and the study protocol did not influence clinical management. Data were collected prospectively using a structured case report form explicitly developed for this study (attached in the appendix). Information recorded included demographic details such as age and gender, clinical variables including admitting diagnosis, presence of comorbidities, and type of respiratory support received (HFNC or MV). Hourly oxygenation data, specifically FiO_2 and SpO_2 values, were documented over the first 24 hours of PICU admission. Arterial blood gas (ABG) results, including PaO_2 values, were also recorded when available. Outcome measures included the frequency of hyperoxemia and the duration, in hours, of excess oxygen exposure in patients who met the hyperoxemia criteria. All collected data were reviewed for completeness and accuracy before entry into SPSS version 27 for analysis. The primary outcomes included the proportion of patients who developed hyperoxemia and the cumulative duration of excess oxygen use in this subgroup during the first 24 hours of PICU stay.

Data were analyzed using SPSS version 27. Descriptive statistics were used to summarize the dataset. Categorical variables, such as gender and presence of hyperoxemia, were reported as frequencies and percentages. Continuous variables, such as age and duration of excess oxygen use, were expressed as means and standard deviations or medians and interquartile ranges, depending on the data distribution. The primary focus of the analysis was to determine the incidence of hyperoxemia and the extent of excess oxygen use.

Patient confidentiality was maintained by de-identifying all records and securing data in a password-protected computer. Given the study's observational nature and its reliance solely on chart reviews, the NICH IERB granted a waiver of informed consent.

Results

Data were collected from 200 patients, with a mean age of 3.5 ± 2.34 years and an interquartile range (IQR) of 1.2–7.0 years. Males comprised 58% of the cohort, and the median weight was 12.0 ± 6.87 kg (IQR: 8.5–17.5). Most patients had normal nutritional status (69%) and were admitted from the emergency room (77%). Comorbidities were present in 36.5% of cases, and respiratory illness was the primary diagnosis in 48%. Inotropes were used in 41% of patients within the first 24 hours, and the median baseline SpO_2 at admission was 96% (IQR: 94–98).

Among the 200 patients, 56 (28%) experienced hyperoxemia, with 60.7% of these cases occurring during mechanical ventilation (MV) and 39.3% during high-flow nasal cannula (HFNC) therapy. The median duration of hyperoxemia was 5.5 hours (IQR: 3–9). Excess oxygen use was identified in 38 patients (67.8%), predominantly during MV (76.5%) compared to HFNC (54.5%). The median duration of excess oxygen use was 4 hours (IQR: 2–6.5).

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Among patients with hyperoxemia (n = 56), the most common underlying condition was severe pneumonia, observed in 18 cases (32.1%), followed by septic shock in 14 patients (25.0%). Acute respiratory distress syndrome (ARDS) was present in 12 patients (21.4%), while cerebral palsy and congenital anomalies were noted in 9 (16.1%) and 6 (10.7%) patients, respectively.

When comparing the hyperoxemia group (n=56) to the non-hyperoxemia group (n=144), there were no significant differences in age, gender, use of mechanical ventilation, or presence of comorbidities. However, respiratory illness was significantly more common in the hyperoxemia group (64.3% vs. 41.7%, p=0.01). Additionally, the hyperoxemia group had a higher median FiO_2 (0.65 vs. 0.45, p<0.001) and a more significant proportion of patients received oxygen therapy for more than 12 hours (71.4% vs. 40.3%, p=0.002).

Table 1. Demographic and Clinical Characteristics of Study Participants

Parameter	Value
Total patients	200
Age (mean, IQR)	3.5±2.34 years (1.2–7.0)
Gender (Male), n (%)	116 (58%)
Weight (median, IQR)	12.0±6.87 kg (8.5–17.5)
Nutritional status (Normal), n (%)	138 (69%)
Presence of comorbidities, n (%)	73 (36.5%)
Admission source: ER, n (%)	154 (77%)
Primary diagnosis: Respiratory illness, n (%)	96 (48%)
Use of inotropes in first 24 hrs, n (%)	82 (41%)
Baseline SpO_2 at admission (median, IQR)	96% (94–98)

Table 2. Incidence and Characteristics of Hyperoxemia and Excess Oxygen Use

Parameter	Value
Patients with hyperoxemia, n (%)	56 (28%)
Hyperoxemia on MV, n (%)	34 (60.7%)
Hyperoxemia on HFNC, n (%)	22 (39.3%)
Median duration of hyperoxemia (hrs, IQR)	5.5 (3–9)
Patients with excess oxygen use, n (%)	38 (67.8%)
Excess oxygen use on MV, n (%)	26 (76.5%)
Excess oxygen use on HFNC, n (%)	12 (54.5%)

Median duration of excess oxygen use (hrs, IQR)	4 (2–6.5)

Table 3. Common Diagnoses and Co-morbidities among Hyperoxemic Patients

Condition	Frequency among hyperoxemic patients, n (%)
Severe pneumonia	18 (32.1%)
Septic shock	14 (25.0%)
ARDS	12 (21.4%)
Cerebral palsy	9 (16.1%)
Congenital anomalies	6 (10.7%)

Table 4. Relationship of Various Factors among Children With and Without Hyperoxemia

Factor	Hyperoxemia Group (n=56)	No Hyperoxemia Group (n=144)	p-value
Age (median, IQR)	3.2 (1.0–6.5)	3.6 (1.5–7.2)	0.45
Male gender, n (%)	32 (57.1%)	84 (58.3%)	0.88
Use of Mechanical Ventilation, n (%)	34 (60.7%)	86 (59.7%)	0.91
Presence of Comorbidities, n (%)	23 (41.1%)	50 (34.7%)	0.32
Primary diagnosis: Respiratory illness, n (%)	36 (64.3%)	60 (41.7%)	0.01*
Median FiO_2 during hyperoxemia (IQR)	0.65 (0.55–0.75)	0.45 (0.40–0.55)	<0.001*
Duration of oxygen therapy >12 hrs, n (%)	40 (71.4%)	58 (40.3%)	0.002*

Discussion

This prospective observational study aimed to assess the incidence of hyperoxemia and the extent of excess oxygen use among critically ill pediatric patients receiving oxygen therapy in a tertiary care PICU. A total of 28 percent of patients in the study population developed hyperoxemia after their initial hospital admission, whereas 67.8 percent of patients received too much oxygen therapy above FiO_2 of 50 percent. The descriptive data confirm there is a serious clinical issue when it comes to oxygen overuse in pediatric intensive care units. The research findings regarding hyperoxemia incidence matched previously recorded surveys in pediatric intensive care units, which indicated prevalence between 15 and 35 percent. Patients who received mechanical ventilation displayed higher rates of hyperoxemia, which confirms poor individualized oxygen titration practice for children under invasive ventilation (13). The problem of hypoxic prevention supersedes clinical awareness about hyperoxic risks, which create oxidative stress and potential lung damage (14).

Patients with hyperoxemic conditions required higher levels of FiO_2 and presented with respiratory conditions, including severe pneumonia, along with acute respiratory distress syndrome. These healthcare situations constantly require precise oxygen administration strategies. Frequent arterial blood gas monitoring should exist because this population's high rate of excess oxygen use indicates potential iatrogenic damage from prolonged over-oxygenation (15). The statistical evaluation proved that respiratory illness, as the primary diagnosis, combined with higher FiO_2 levels and more prolonged exposure duration, directly influenced the risk of hyperoxemia in patients. The findings indicate that oxygen delivery can remain extended or its titration can be inadequate among children with severe pulmonary conditions, which means the healthcare system needs to establish oxygen administration protocols for better patient safety outcomes (16). Age, along with gender distributions and inotrope medication usage, remained similar between hyperoxemic and normoxemic pediatric critical care patients, thus implying that respiratory management practices contribute more to hyperoxic conditions than disease severity. Clinical research confirms that hyperoxia represents a risk factor that medical staff can regulate as part of their professional duties (17). This study emphasizes the absence of globally accepted boundaries regarding oxygen saturation and partial pressure of oxygen levels in pediatric critical care units. The importance of hypoxia prevention remains primary, but practitioners should pay more attention to hyperoxia detection because its potential side effects, such as inflammation alongside worsened recovery process, can easily be missed (18). The inconsistent approaches to oxygen titration emphasize why healthcare providers must receive precise clinical guidelines and education regarding safe oxygen administration limits. This study has several limitations. The research took place at one medical facility, which could reduce the applicability of the obtained findings. The results of this study could have been affected by underestimating hyperoxia incidence because researchers used intermittent arterial blood gas measurements. The observational approach prevents researchers from determining whether excessive oxygen therapy affects patient clinical results.

Conclusion

It is concluded that hyperoxemia and excess oxygen use are common among critically ill pediatric patients receiving oxygen therapy, particularly in the first 24 hours of admission to the PICU. A significant proportion of patients, especially those with respiratory illnesses and those on mechanical ventilation, were exposed to high oxygen levels despite having elevated oxygen saturation levels. The findings highlight a potential area of clinical practice where unnecessary oxygen exposure may occur, posing avoidable risks to patient safety.

Declarations

Data Availability statement
All data generated or analysed during the study are included in the manuscript.
Ethics approval
Approved by the department concerned. (IRBEC-TCH-24)
Consent for publication
Approved
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Not applicable

Conflict of interest

The authors declared the absence of a conflict of interest.

Author Contribution

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MW (Senior Medical Officer)
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All authors reviewed the results and approved the final version of the manuscript. They are also accountable for the integrity of the study.

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