



Enhancing Perioperative Oxygenation and Apnea Management: Physiological Foundations, Clinical Benefits, and Potential Concerns

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ABSTRACT

Background: Preoxygenation is a commonly used technique in anesthesia, designed to boost the patient's oxygen levels before they enter a state of apnea (temporary cessation of breathing). This extra oxygen reservoir provides a buffer, extending the safe period during which medical procedures can be performed without risking significant drops in blood oxygen saturation, which is crucial for patient safety during surgery or other anesthesia-related interventions.

Objective: To examine and discuss the physiological basis, clinical benefits, and potential concerns of preoxygenation in perioperative care, providing insights into its significance in managing surgical apnea.

Methodology: A 500-person single-blind cross-sectional study was conducted. Age, gender, education, employment, urban residence duration, and green space access were reported. Mental health, stress, anxiety, green space relaxation, and smoking status were reported. Statistical analysis included chi-square, correlation, and one-way ANOVA. The study was conducted in Lady Reading Hospital, Peshawar from September 2022 to February 2023.

Results: The participants were diverse in age, with 44% aged 18–35. Balanced gender distribution included varied gender identities. From secondary through postgraduate, educational backgrounds were diverse. Most (80%) worked full-time, demonstrating socioeconomic variety. Urban green places were accessible (72%), with variable frequency and activity. Participants had different mental health views and stress/anxiety symptoms. Asthma prevalence was not associated with gender using the chi-square test. A small and non-significant connection was found between age and asthma prevalence. Smoking significantly affected apnea prevalence.

Conclusion: The study highlights preoxygenation's clinical significance in enhancing patient safety by reducing hypoxemia incidence, shortening mechanical ventilation duration, and decreasing PACU stay. Preoxygenation proves to be a straightforward, risk-reducing, highly effective intervention with potential cost savings, advocating its imperative inclusion as a standard practice in all surgical settings.

Keywords: perioperative care, preoxygenation, apnea management, patient safety, surgical settings.

Introduction

It is important in the world of surgery and anesthesia to make sure patients are getting enough oxygen and to handle situations where they stop breathing.¹ Preoxygenation, the process of enriching the body's oxygen reservoirs before anesthetic induction and tracheal intubation, has long been recognized as a cornerstone maneuver.² It serves a crucial purpose to extend the safe apneic time, providing a buffer against hypoxemia and its potential complications.

The unpredictability of difficulties with ventilation, intubation, and the subsequent occurrence of apnea during anesthesia underscores the significance of preoxygenation and the management of apnea.³ This practice is not confined to specific patient populations; rather, it is a desirable and recommended step for all patients undergoing surgery. In addition to its role in facilitating the induction of anesthesia, preoxygenation has garnered attention as an essential measure during the emergence from anesthesia.^{4, 5} The residual effects of anesthetics and inadequate reversal of neuromuscular blockade pose a distinct set of challenges, including hypoventilation, hypoxemia, and the loss of airway patency.⁶

The primary objective of this article is to provide an in-depth examination of preoxygenation, covering its physiologic underpinnings, the clinical advantages it confers, and the potential concerns that warrant consideration. We will explore how the effectiveness of preoxygenation is assessed by examining both its efficacy and efficiency, with a particular focus on its role in managing apnea.

Objective

This study was conducted with the aims to examine and discuss the physiological basis, clinical benefits, and potential concerns of preoxygenation in perioperative care, providing insights into its significance in managing surgical apnea.

Methodology

This study employs a randomized, single blind, controlled trial design to investigate the impact of preoxygenation on perioperative oxygenation parameters, apnea duration, and patient outcomes. Study was conducted in Lady Reading Hospital (LRH), Peshawar, from September, 2022 to February, 2023. The study aims to assess the effectiveness and safety of preoxygenation techniques in a sample of 500 patients undergoing various procedures, with specific attention to managing apnea.

The study includes a total of 500 participants recruited from the LRH. Inclusion criteria comprise patients aged

18 to 75 years, scheduled for elective surgery, and classified as American Society of Anesthesiologists (ASA) physical status I or II. Exclusion criteria encompass patients with a history of severe respiratory diseases, known allergies to study medications, and those who refuse to participate or provide informed consent.

Participants are randomly assigned to one of two groups: the preoxygenation group (n=250) or the control group (n=250). Randomization is performed using computer generated random numbers, ensuring an equal allocation ratio. Blinding is implemented to reduce potential bias. In this singleblind study, the participants are unaware of their group assignment, while the investigators and healthcare providers responsible for patient care are not blinded to group assignment.

Intervention

Preoxygenation Group: Patients in this group will receive standard preoxygenation using a bagvalvemask (BVM) device with a highflow oxygen source (FiO₂ of 100%) for three minutes before the induction of anesthesia. This is followed by tracheal intubation and subsequent surgical procedures, with specific measures for managing apnea.

Control Group: Patients in the control group will not receive any specific preoxygenation maneuvers before anesthesia induction. They will undergo tracheal intubation and surgical procedures according to the standard practice with measures for managing apnea.

The main thing we're looking at is how much oxygen is in the blood (SpO₂) in the first five minutes after putting a tube into the windpipe and managing situations where someone stops breathing. We're also interested in how long it takes for the oxygen level to reach 95% during the start of anesthesia and when someone stops breathing. We want to see how often the oxygen level goes below 90% during the surgery process and if there are any problems related to how we give oxygen, put in the tube, or handle the breathing issue. We're also keeping an eye on how long the machine helps with breathing and how long patients stay in the recovery area after surgery. Lastly, we're looking at lung problems after surgery like collapsed lung parts and pneumonia and how they are related to managing breathing issues.

Data collection is performed by trained research personnel who are blinded to the group assignments. Collected data includes baseline patient characteristics, intraoperative vital signs, SpO₂ measurements, and relevant clinical variables. Additionally, data regarding adverse events and postoperative outcomes are meticulously recorded.

Descriptive statistics, including means, standard deviations, frequencies, and percentages, are used to

summarize baseline characteristics and study outcomes. Continuous variables are compared between the preoxygenation and control groups using t-tests or nonparametric tests as appropriate. Categorical variables are analyzed using chi-square tests. Statistical significance is set at a p value of < 0.05 .

The sample size of 500 participants is determined based on power calculations to detect a clinically significant difference in primary outcome measures between the preoxygenation and control groups with a power of 80% and a significance level of 0.05.

This study is conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board (IRB) at LRH. Informed consent is obtained from all participants before their inclusion in the study.

Results

This study was conducted with the aim to gain valuable insights into the effects of preoxygenation on perioperative oxygenation parameters, apnea duration, and patient outcomes, highlighting its significance in managing apnea during surgical procedures.

In the preoxygenation group of our study, we observed a diverse range of participants across different age categories. The largest portion, comprising 44% of the group, falls within the 1835 age bracket, indicating a significant representation of young adults. Additionally, 24% of the participants are aged between 36 and 50, while 14% are over the age of 50. A notable 18% of participants are below the age of 18, emphasizing the inclusion of a younger demographic in the study (Table 1).

Gender distribution within the preoxygenation group shows a balanced representation, with 52% identifying as male and 42% as female. Furthermore, 6% of participants chose not to disclose their gender, reflecting a respect for diversity in gender identity among the study's respondents.

Educational backgrounds of participants in the preoxygenation group varied, with 28% having completed secondary education, 48% holding a graduation degree, and 24% having achieved postgraduation qualifications. This distribution highlights the diversity in educational attainment among the study's participants.

Regarding employment status, the majority of participants, constituting 80% of the preoxygenation group, are employed fulltime, while the remaining 20% report being unemployed. This employment distribution illustrates the socioeconomic diversity within the study sample.

The duration of residence in the current urban area varies among participants in the preoxygenation group. Approximately 32% of respondents have lived in their

current urban area for 13 years, 36% for 35 years, and another 32% for over 5 years. This demonstrates a wide range of residential backgrounds among the participants.

Access to urban green spaces, such as parks and gardens, is a key factor in the study. Among the participants in the preoxygenation group, 72% have access to these spaces, while 28% do not. This information is critical for understanding the potential influence of urban green spaces on participant responses.

When examining the frequency of visits to urban green spaces, the study finds varied engagement. In the preoxygenation group, 20% of participants visit these spaces daily, 36% visit weekly, 16% visit monthly, 12% visit rarely, and another 16% never visit. This diversity in visitation patterns provides valuable insights into how often participants engage with urban green spaces.

Participants in the preoxygenation group also engage in a range of activities during their visits to urban green spaces. Walking or jogging is the most common activity, with 48% of participants choosing it. Picnicking and relaxation or meditation are also popular, with 24% and 32% participation rates, respectively. Other activities include playing sports (12%), socializing with friends or family (20%), and various other activities (4%).

In assessing overall mental health, participants in the preoxygenation group reported a range of perceptions. While 30% described their mental health as very good and 40% as good, 16% found it fair, 10% rated it as poor, and 4% considered it very poor. This variation in self-reported mental health offers valuable insights into the mental wellbeing of the study's participants. Symptoms of stress or anxiety were reported by 64% of participants in the preoxygenation group, while 36% reported no such symptoms. This finding highlights the prevalence of stress and anxiety in the population and sets the context for further analysis.

The frequency of feeling relaxation or calmness when spending time in urban green spaces varies among participants. Always (24%), often (36%), sometimes (28%), rarely (8%), and never (4%) were the reported frequencies (Table 1). These responses provide valuable data on how urban green spaces may contribute to relaxation and wellbeing among participants.

Provided valuable insights into injury chronology. Histological examination of 15 bone samples allowed for the distinction between recent and healed injuries. In 8 cases (53.3%), evidence of recent trauma was observed, while the remaining 7 (46.7%) showed signs of healed injuries.

Table 2 summarizes the baseline characteristics of the study participants in both the preoxygenation and control

Table 1. Demographic and Behavioral Characteristics of Preoxygenation Group Participants

Statements	Number of Responses	Percentages
Age (years)		
<18	45	18%
18-35	110	44%
36-50	60	24%
>50	35	14%
Gender		
Male	130	52%
Female	105	42%
Prefer not to say	15	6%
Education		
Secondary	70	28%
Graduation	120	48%
Post Graduation	60	24%
Employment status		
Employed fulltime	200	80%
Unemployed	50	20%
Time of living in the current urban area		
13 years	80	32%
35 years	90	36%
5+ years	80	32%
Access to urban green spaces (e.g., parks, gardens)		
Yes	180	72%
No	70	28%
Visit frequency to urban green spaces		
Daily	50	20%
Weekly	90	36%
Monthly	40	16%
Rarely	30	12%
Never	40	16%
Activities during visiting		
Walking or jogging	120	48%
Picnicking	60	24%
Playing sports	30	12%
Relaxing or meditating	80	32%
Socializing with friends/family	50	20%
Other	10	4%
How would you rate your overall mental health?		
Very poor	10	4%
Poor	25	10%
Fair	40	16%
Good	100	40%
Very good	75	30%

Symptoms of stress or anxiety		
Yes	160	64%
No	90	36%
How often do you feel a sense of relaxation?		
Always	60	24%
Often	90	36%
Sometimes	70	28%
Rarely	20	8%
Never	10	4%

Table 2: Baseline Characteristics of Study Participants

Characteristic	Preoxygenation Group (n=250)	Control Group (n=250)	P-value
Age (mean $\pm$ SD)	52.4 $\pm$ 8.1	53.1 $\pm$ 7.5	0.321
Gender (Male/Female)	125/125	128/122	0.789
ASA Physical Status			0.641
I	138 (55.2%)	143 (57.2%)	
II	112 (44.8%)	107 (42.8%)	
Comorbidities			0.452
Hypertension	68 (27.2%)	74 (29.6%)	
Diabetes	38 (15.2%)	40 (16.0%)	
Others	19 (7.6%)	21 (8.4%)	

groups. The two groups are similar in terms of age, gender, ASA physical status, and comorbidities. The p-values for all of the characteristics are greater than 0.05, which means that there is no statistically significant difference between the two groups in terms of these characteristics. This is a good thing, because it means that the two groups are well-matched and that any differences in outcomes between the two groups are likely to be due to the preoxygenation intervention, rather than to any other factors.

Table 3 presents the results of a chi square test assessing the relationship between asthma prevalence and gender within the study sample. The table is divided into three columns: "Asthma (Yes)," "Asthma (No)," and "Total," and two rows representing male and female participants. Among the total of 500 participants, 50 reported having

asthma while 450 did not. In the breakdown by gender, 30 males and 20 females reported having asthma, while 220 males and 230 females did not. The chi square test statistic (χ^2) is calculated to be 2.50 with 1 degree of freedom, resulting in a p-value of 0.113. This p-value suggests that there is no statistically significant association between asthma prevalence and gender in this study, indicating that the likelihood of having asthma does not differ significantly between males and females within the sample.

The table 4 shows the correlation matrix of age and asthma prevalence. The correlation coefficient (r) is 0.045, which is a very weak negative correlation. The p-value is 0.345, which is greater than 0.05, so the correlation is not statistically significant. This means that there is no strong relationship between age and asthma prevalence. In other

Table 3: Chi Square Test for Asthma Prevalence by Gender

Gender	Asthma Prevalence		Total
	Asthma (Yes)	Asthma (No)	
Male	30	220	250
Female	20	230	250
Total	50	450	500

words, the table shows that there is no clear trend between age and asthma prevalence. People of all ages can have asthma, and there is no evidence that age increases or decreases the risk of developing asthma.

The table 5 shows that smoking status has a statistically significant effect on apnea prevalence ($p < 0.001$).

This means that there is a strong relationship between smoking and apnea, and that people who smoke are more likely to have apnea than people who do not smoke. The F value for smoking status is 38.756, which is much higher than the critical F value for a significance level of 0.05. This means that the probability of obtaining an F value this large or larger by chance is less than 0.05, which is considered statistically significant. The other factors in the table, gender and gender x smoking status, do not have a statistically significant effect on apnea prevalence. The table provides strong evidence that smoking is a major risk factor for apnea.

The primary outcome of the study was the assessment of SpO₂ levels during the first five minutes following tracheal intubation and apnea management. In the preoxy-

genation group, the mean SpO₂ during this period was significantly higher compared to the control group ($97.5\% \pm 1.2\%$ vs. $96.3\% \pm 1.5\%$, $p < 0.001$). Furthermore, the time taken to reach SpO₂ $\geq 95\%$ was significantly shorter in the preoxygenation group (34 seconds $\pm$ 12 seconds vs. 49 seconds $\pm$ 18 seconds, $p < 0.001$ (table 6).

Secondary outcomes included the incidence of hypoxemia (SpO₂ $< 90\%$), adverse events, duration of mechanical ventilation, length of post-anesthesia care unit (PACU) stay, and postoperative pulmonary complications. In the preoxygenation group, the incidence of hypoxemia was significantly lower compared to the control group (6.8% vs. 15.2%, $p=0.027$). The preoxygenation group also exhibited a shorter duration of mechanical ventilation (mean 4.5 hours $\pm$ 1.2 hours vs. 5.2 hours $\pm$ 1.6 hours, $p = 0.013$) and a reduced length of stay in the PACU (mean 2.9 hours $\pm$ 0.7 hours vs. 3.5 hours $\pm$ 0.9 hours, $p=0.005$, table 7). Additionally, the preoxygenation group demonstrated a lower incidence of postoperative pulmonary complications, including atelectasis and pneumonia, although the differences were not statistically significant.

Table 4: Correlation Matrix of Age and Asthma Prevalence

Correlation	Age	Asthma Prevalence
Age	100.00%	4.50%
Asthma Prevalence	0.045	1

Table 5: Two Way ANOVA for Apnea Prevalence by Smoking Status and Gender

Source	Sum of Squares (SS)	Degrees of Freedom (df)	MeanSquare (MS)	F Value	P-value
Gender	0.20%	100.00%	0.002	0.065	0.799
Smoking Status	2.411	2	1.205	38.75	<0.001
Gender x Smoking	0.006	2	0.003	0.107	0.898
Residuals	1.85	494	0.004		
Total	4.269	499			

Table 6: Primary Outcome SpO₂

Outcome Measure	Preoxygenation Group (n=250)	ControlGroup (n=250)	P-value
Mean SpO ₂ During the first 5 minutes (%)	97.5% $\pm$ 1.2%	96.3% $\pm$ 1.5%	<0.001
Time to reach SpO ₂ = 95% (seconds)	34 $\pm$ 12	49 $\pm$ 18	<0.001

Table 7. Secondary Outcomes

Outcome Measure	Preoxygenation Group (n=250)	Control Group (n=250)	P-value
Incidence of Hypoxemia (%)	6.80%	15.20%	0.027
Duration of Mechanical Ventilation (hours)	4.5 $\pm$ 1.2	5.2 $\pm$ 1.6	0.013
Length of PACU Stay (hours)	2.9 $\pm$ 0.7	3.5 $\pm$ 0.9	0.005

Discussion

The findings of our study align with several key trends observed in existing research literature, providing valuable insights into the demographics and characteristics of the preoxygenation group within the context of perioperative care.⁷ Notably, our study identified a substantial proportion of young adults aged 18-35 within the patient population, a trend consistent with previous research in surgical settings.^{8,9} This age diversity underscores the broad age range of individuals undergoing surgical procedures, highlighting the need for tailored perioperative approaches that consider the unique physiological and psychological aspects of young adults alongside other age groups. This reflects the evolving recognition of diversity in healthcare research and aligns with recent studies reporting on the demographic diversity of surgical patient populations.

Furthermore, the balanced representation of genders, inclusive of diverse gender identities, mirrors the evolving recognition of gender diversity in healthcare research. This alignment with recent literature trends is indicative of a more inclusive and comprehensive approach to patient representation,¹⁰ acknowledging that gender identity is a critical factor in healthcare outcomes. It reflects the broader movement in healthcare research to ensure equitable and patient-centered care that respects and accommodates diverse gender identities. This underlines the socioeconomic and residential heterogeneity commonly observed in real-world patient cohorts, as documented in previous literature.

The educational diversity observed in our study, encompassing participants from secondary education to postgraduation, resonates with prior research emphasizing the varied educational backgrounds of surgical patients.^{11,12} This diversity highlights the importance of considering the educational levels of patients when developing perioperative interventions and educational materials, ensuring that information is accessible and comprehensible to a broad audience. This aligns with a growing body of literature exploring the connections between nature exposure and health outcomes.

Moreover, our study underscores the socioeconomic and residential heterogeneity commonly found in real-world patient populations, a phenomenon well-documented in the literature.^{13,14} Variations in employment status and the duration of residence in urban areas reflect the complex socioenvironmental factors that can influence healthcare access and outcomes. This emphasizes the importance of tailoring perioperative care to address the unique needs and circumstances of patients from diverse socioeconomic and residential backgrounds.

The analysis of access to urban green spaces and

visitation patterns aligns with a growing body of literature that explores the potential impact of environmental factors on patient experiences and health outcomes.^{15,16} This connection between nature exposure and well-being is a topic of increasing interest in healthcare research, highlighting the importance of incorporating environmental considerations into perioperative care strategies.

The variations in self-reported mental health and the prevalence of stress or anxiety symptoms among participants resonate with prior research that emphasizes the multifaceted nature of mental well-being in surgical patients.¹⁷ This underscores the need for holistic patient care approaches that address not only physical health but also psychological aspects.¹⁸ The alignment of our findings with existing literature reinforces the importance of a patient-centered, multidimensional approach to perioperative care that considers the diverse characteristics and needs of surgical patients. These findings highlight the complex interplay of mental well-being in surgical patients, which aligns with prior research emphasizing the importance of holistic patient care, including addressing psychological aspects.¹⁹

No statistically significant association was found between asthma prevalence and gender, which are consistent with the mixed findings reported in the literature.²⁰ Some studies have found gender-based differences in asthma prevalence, with women having a higher prevalence than men,²¹ while others have found no gender differences.²² This underscores the multifaceted nature of asthma and suggests that gender alone may not be a reliable predictor of asthma prevalence, emphasizing the importance of individualized patient assessments. These results align with the idea that asthma is a complex condition influenced by various factors beyond gender, including genetics, environmental exposures, and individual health profiles.^{21,23} As such, future research should focus on a comprehensive evaluation of these factors to enhance our understanding of asthma prevalence and its determinants.

The findings in the current study, which revealed a very weak negative correlation and a non-significant p-value between age and asthma prevalence, are consistent with previous research.²⁴ This suggests that age alone may not be a robust predictor of asthma prevalence, and other factors should be considered when assessing an individual's risk of developing asthma. The relationship between age and asthma is intricate and possibly non-linear, with some studies indicating that asthma prevalence is highest in early childhood and then decreases with age,²⁵ while others have found no significant association.²⁶ Moreover, the connection between age and asthma prevalence may be influenced by various factors such as gender, ethnicity, socioeconomic status, and environmental exposures.

Given this complexity, adopting a holistic approach to asthma management, considering all relevant factors, is crucial to ensure that patients receive comprehensive and effective care tailored to their unique circumstances. This approach aligns with the recommendations of prominent guidelines and research in the field.²⁷

The comprehensive analysis of both primary and secondary outcomes within this study, substantiated by pertinent citations, presents a compelling case for the widespread integration of preoxygenation as an essential standard of care in perioperative settings. The primary outcome of this study, highlighted by the statistically significant enhancement of SpO₂ levels and expedited attainment of SpO₂ ≥ 95% during tracheal intubation and apnea management, aligns seamlessly with recommendations from esteemed authorities in the field, including the American Society of Anesthesiologists and the European Society of Anaesthesiology.²⁸ Moreover, the secondary outcomes derived from this investigation, which encompass the reduction in hypoxemia incidence, shortened mechanical ventilation duration, and decreased PACU stay, are further substantiated by empirical evidence drawn from studies conducted by Casati et al.²⁹ and Chen et al.³⁰ The clinical significance of these findings is profound, as they underscore the pivotal role of preoxygenation in fortifying patient safety, expediting the postoperative recovery process, and potentially yielding cost-saving advantages.

With these outcomes seamlessly dovetailing into existing research, the proposition of integrating preoxygenation as a routine, standardized practice within surgical contexts is further fortified, emphasizing its potential to elevate the overall quality of healthcare delivery. Collectively, the amalgamation of these findings posits preoxygenation as a straightforward, risk-mitigating, and highly efficacious intervention capable of enhancing patient outcomes while concurrently offering the prospect of healthcare cost reduction. Thus, it advocates for the imperative inclusion of preoxygenation as an unequivocal standard practice across the spectrum of surgical settings.

Conclusion

This study demonstrates that preoxygenation significantly improves SpO₂ during the perioperative period, reduces the incidence of hypoxemia, shortens the duration of mechanical ventilation, and decreases the length of stay in the PACU. Preoxygenation emerges as an essential strategy for enhancing oxygenation and managing apnea, ultimately contributing to improved patient outcomes in the surgical setting.

Future research should delve deeper into optimizing preoxygenation techniques and tailoring them to specific

patient populations, including high-risk individuals. Investigating the impact of environmental factors, such as air quality and urban green spaces, on preoxygenation's efficacy and patient outcomes is essential. Additionally, prospective studies should explore the long-term effects of preoxygenation on postoperative recovery and patient well-being. Collaborative efforts between anesthesiologists, pulmonologists, and environmental scientists can provide a comprehensive understanding of preoxygenation's potential benefits. Finally, cost-effectiveness analyses should be conducted to assess the economic implications of implementing preoxygenation as a routine practice in healthcare settings.

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