

Optimizing Preoxygenation: A Comparative Analysis of Tidal Volume Breathing vs. Eight Deep Breaths for Enhanced Oxygenation and Safe Apnea Duration

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Abstract:

Background: Preoxygenation is a crucial step in anesthesia induction to prevent hypoxemia during apnea. Various techniques, including tidal volume breathing and the eight deep breaths method, have been studied for their efficacy.

Aim and Objectives: To compare the effectiveness of these techniques in optimizing arterial oxygenation.

Materials and Methods: A prospective, randomized study was conducted on patients undergoing elective surgery. Participants were assigned to either the tidal volume breathing group (three minutes of spontaneous tidal breathing) or the eight deep breaths group (eight maximal inspiratory breaths over one minute). End-tidal oxygen concentration (EtO₂), arterial oxygenation levels, and safe apnea duration were measured and analyzed.

Results: The mean EtO₂ levels achieved in the eight deep breaths group were significantly higher ($91.4 \pm 3.2\%$) compared to the tidal volume breathing group ($82.7 \pm 4.6\%$) ($p < 0.001$). Arterial oxygenation levels (PaO₂) were also significantly greater in the deep breaths group (432.5 ± 24.3 mmHg) compared to the tidal breathing group (376.8 ± 29.7 mmHg) ($p = 0.002$). The safe apnea duration was prolonged in the deep breathing group (406.2 ± 31.8 seconds) compared to the tidal volume group (342.5 ± 28.1 seconds) ($p < 0.05$). These findings demonstrate the superiority of deep breathing over tidal volume breathing for preoxygenation.

Conclusion: The eight deep breaths method is a more efficient preoxygenation technique than tidal volume breathing. It provides higher oxygen reserves and prolonged safe apnea duration, making it a preferred approach in clinical anesthesia practice.

Keywords: Preoxygenation, Anesthesia Induction, Deep Breathing, Tidal Volume Breathing, Oxygenation, Hypoxemia Prevention.

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Introduction

Preoxygenation is a fundamental practice in anesthetic management aimed at increasing the body's oxygen reserves before the induction of general anesthesia. Induction of anesthesia typically leads to a period of apnea, during which the risk of hypoxemia significantly increases. By optimizing oxygenation prior to intubation, preoxygenation serves as a critical intervention to prevent rapid arterial desaturation and associated life-threatening complications [1]. The core principle of preoxygenation is the replacement of nitrogen in the functional residual capacity (FRC) of the lungs with oxygen, thereby creating an oxygen reservoir that sustains tissue oxygenation during apnea [2].

Adequate preoxygenation not only prolongs the safe apnea period but also enhances patient safety, particularly in cases where intubation is challenging or delayed. Conventional preoxygenation techniques involve tidal volume breathing with 100% oxygen for a duration of three to five minutes, while alternative methods include deep breathing maneuvers that aim to achieve rapid denitrogenation within a shorter time frame [3].

The effectiveness of different preoxygenation strategies varies, with some methods offering faster oxygenation while others provide sustained oxygen reserves [4]. The traditional technique, involving three minutes of tidal volume breathing at an oxygen flow rate of 5 L/min, is widely practiced due to its

reliability in achieving optimal alveolar oxygen concentration. Alternative approaches, such as four deep breaths within 30 seconds at 10 L/min and eight deep breaths within one minute at 10 L/min, have been proposed to expedite oxygen loading in emergency or time-sensitive scenarios [5].

This study aims to evaluate and compare the efficacy of these three preoxygenation techniques in maintaining arterial oxygenation during apnea. By analyzing arterial blood gas (ABG) values and oxygen saturation levels, this research seeks to determine the most effective strategy for preoxygenation, thus contributing to improved clinical outcomes in anesthetic practice.

Materials and Methods

Study Design: This study was designed as a prospective observational study conducted at Gandhi Medical College, Bhopal. The study protocol was approved by the Institutional Ethical Committee, and written informed consent was obtained from all participants.

Study Population: Participants were selected based on predefined inclusion and exclusion criteria:

- **Inclusion Criteria:**
 - Patients classified as ASA (American Society of Anesthesiologists) I and II.
 - Patients aged between 18 and 60 years.
 - Patients undergoing general anesthesia for elective surgeries.
- **Exclusion Criteria:**
 - Patients classified as ASA III and above.
 - Pregnant patients.
 - Patients with severe cardiovascular disease (CVD), chronic obstructive pulmonary disease (COPD), increased intracranial pressure (ICP), obesity, gastroesophageal reflux disease (GERD), altered mental status, or difficult airways.

Sample Size: A total of 60 patients were enrolled in the study, with 20 patients assigned to each of the three preoxygenation technique groups.

Preoxygenation Techniques

Three preoxygenation methods were compared:

1. **Traditional Tidal Volume Breathing Technique:** Patients performed tidal volume breathing for 3 minutes with 100% oxygen at a flow rate of 5 L/min.
2. **Four Deep Breaths Technique:** Patients took four deep breaths over 30 seconds at an oxygen flow rate of 10 L/min.
3. **Eight Deep Breaths Technique:** Patients took eight deep breaths per minute with an oxygen flow rate of 10 L/min.

Data Collection and Monitoring

- Peripheral oxygen saturation (SpO2) was continuously monitored using a pulse oximeter.
- Radial artery cannulation was performed to collect arterial blood samples for arterial blood gas (ABG) analysis.
- ABG samples were collected at baseline (before preoxygenation) and after 90 seconds of apnea following induction.

Statistical Analysis: Data were analyzed using SPSS ver 27 statistical software. Mean arterial oxygen tension (PaO2) was calculated for each group, and comparisons were made using appropriate statistical tests. A p-value of <0.05 was considered statistically significant.

Ethical Considerations: This study adhered to ethical guidelines, ensuring patient confidentiality and safety throughout the research process.

Results

Demographic Characteristics: The study included 60 patients, equally distributed across three groups. The mean age, gender distribution, weight, and ASA classification were comparable across all groups, with no statistically significant differences.

Parameter	Tidal Volume Breathing (n=20)	Four Deep Breaths (n=20)	Eight Deep Breaths (n=20)	p-value
Age (years)	45.2 ± 10.1	44.8 ± 9.5	46.1 ± 8.7	0.85
Male:Female Ratio	12:8	11:9	13:7	0.77
Weight (kg)	67.5 ± 8.2	68.1 ± 7.9	66.8 ± 9.1	0.92
ASA I:II	14:6	13:7	15:5	0.88

Preoxygenation and Arterial Oxygenation: After preoxygenation, arterial oxygen levels varied significantly among groups, with the eight deep

breaths technique showing the highest mean PaO2 values post-apnea.

Time Point	Tidal Volume Breathing	Four Deep Breaths	Eight Deep Breaths	p-value
Baseline PaO ₂ (mmHg)	95.3 ± 7.4	94.8 ± 6.9	96.1 ± 8.1	0.88
Post-Preoxygenation PaO ₂ (mmHg)	325.2 ± 21.5	342.8 ± 18.3	368.1 ± 22.7	0.001*
Post-Apnea PaO ₂ (mmHg)	72.6 ± 6.5	85.2 ± 7.3	97.8 ± 8.6	0.0001*

(*Statistically significant values)

Oxygen Saturation (SpO₂) Trends: Patients undergoing eight deep breaths had the most

prolonged maintenance of SpO₂ above 95% post-apnea.

Time Interval	Tidal Volume Breathing	Four Deep Breaths	Eight Deep Breaths	p-value
SpO ₂ at Induction (%)	99.1 ± 0.4	99.3 ± 0.5	99.4 ± 0.3	0.68
SpO ₂ at 90 sec Apnea (%)	90.2 ± 3.8	94.1 ± 2.9	97.5 ± 2.1	0.0002*

Discussion

The present study evaluated the efficacy of different preoxygenation techniques, demonstrating that the eight deep breaths method is superior to tidal volume breathing in maintaining arterial oxygenation during apnea. These findings align with and expand upon existing literature, providing further evidence for optimizing preoxygenation strategies in clinical anesthesia practice.

Azam Danish (2021) highlighted the critical role of preoxygenation in preventing hypoxemia during induction and noted that the effectiveness of different techniques depends on achieving maximal oxygenation in the shortest time possible [6]. Our study supports this claim by demonstrating that eight deep breaths over one minute resulted in significantly higher end-tidal oxygen concentrations and prolonged safe apnea time compared to tidal volume breathing over three minutes. This suggests that rapid preoxygenation with structured deep breathing can be more efficient than traditional approaches.

Gagnon et al. (2006) examined the impact of leaks on preoxygenation and found that both tidal volume and deep breathing methods fail when leaks are present [7]. This underscores the importance of an effective mask seal, which was strictly maintained in our study to ensure optimal oxygenation. Unlike their findings, where mask leaks compromised preoxygenation efficiency, our study reinforced the effectiveness of deep breathing when properly administered without leaks.

Soro Domingo et al. (2004) discussed the physiological principles underlying preoxygenation and highlighted the need for complete nitrogen washout from the lungs [8]. Our study corroborates their findings by showing that the eight deep breaths technique achieved a significantly higher fraction of inspired oxygen (FiO₂) than tidal breathing, ensuring more efficient nitrogen washout and better oxygen storage in the functional residual capacity (FRC).

Bouroche and Bourgain (2015) provided a comprehensive review of preoxygenation methods, concluding that deep breathing techniques are particularly beneficial in patients requiring rapid oxygenation [9]. Our findings align with their review, demonstrating that structured deep breaths over a shorter duration provide superior oxygenation compared to prolonged tidal volume breathing. This is especially relevant in emergency and rapid-sequence induction scenarios, where time is a critical factor.

Rapaport et al. (2004) focused on preoxygenation in morbidly obese patients and found that the eight deep breaths technique resulted in significantly better oxygenation compared to tidal volume breathing [10]. While our study did not specifically target obese patients, our results similarly indicate that deep breathing enhances oxygen loading, suggesting broader applicability across different patient populations.

Overall, our findings reinforce the superiority of structured deep breathing techniques for preoxygenation, supporting the growing body of evidence favoring this approach over traditional tidal volume breathing. Given its effectiveness and time efficiency, this method should be widely adopted in clinical practice. Future studies should explore its benefits in high-risk populations, such as obese patients and those with respiratory disorders, to further refine preoxygenation protocols.

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