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Mini Review

# Apneic Oxygenation and Anesthesia: Mini Review

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**Abstract**

Preoxygenation and apneic oxygenation (AO) are essential in airway management and prevention of low saturation during anesthesia and are very important for patient safety and quality. Preventing and reducing severe complications in airway management is a challenging and essential task for anesthesiologists. Good quality and preoxygenation are critical in airway management and vital prerequisites in AO. At the same time, preoxygenation increases "the safe apnea time" before desaturation, and AO significantly reduces the incidence of hypoxemia during endotracheal intubation. Inappropriate and inadequate preoxygenation, obesity, pregnancy, airway obstruction, pulmonary shunt, pediatric patients, and critical illness are important risk factors for short apnea windows. Face mask, bag-valve mask, venturi mask, nasal cannula, nasopharyngeal catheter, double blade laryngoscopes, transtracheal endobronchial catheters, and high-flow nasal cannula (HFNC) oxygenation by applying low-flow oxygen, or high-flow oxygen are the most commonly used systems in preoxygenation. Regardless of the method in anesthesia practice, preoxygenation and AO are very important in reducing hypoxemia, mortality, and morbidity. Herein, our aim in this review is to emphasize the importance of preoxygenation and AO in our anesthesia practice.

## INTRODUCTION

Preoxygenation and AO are critical in airway management and prevention of desaturation and are essential for patient safety. Preventing and minimizing serious complications in difficult airway management are challenging and vital goals for anesthesiologists [1-3]. Preoxygenation increases "the safe apnea time" before desaturation, and AO significantly reduces the incidence of hypoxemia during endotracheal intubation [4]. The tolerance of short-term apnea is generally good in patients undergoing general anesthesia with endotracheal intubation. This concept was first applied in the operating room [5], and then its use in airway management in the emergency department (ED) and intensive care ünit (ICU) was rapidly adopted [6,7]. The physiology of AO is based on increasing the physiological capacity of continuous oxygen ($O_2$) capture and $O_2$ reserves by the alveoli through a passive process without ventilation [6,8]. AO can be achieved by administering continuous $O_2$ during intubation with a face mask, bag-valve mask, venturi mask, nasal cannula, nasopharyngeal catheter, double blade laryngoscopes, transtracheal endobronchial catheters, and low-flow $O_2$ or HFNC oxygenation systems during laryngoscopy. The basis of all these methods is to delay the development of hypoxemia and prolong the apnea period. Anesthesiologists, emergency physicians, and intensivists usually perform airway management. In the operating room, most intubations are performed under ideal conditions and control. However, non-operating room intubations often have more serious complication rates as they are performed as an emergency (28%) [3,4,7,9].

Hypoxemia is a significant complication that may occur in airway management and during intubation [3,4,10]. If arterial oxyhemoglobin saturation ($SaO_2$) falls below 70%, patients are at increased risk of arrhythmia, hemoglobin decompensation, hypoxic brain damage, and death. Regardless of the method, preoxygenation and AO are crucial in reducing hypoxemia, mortality, and morbidity in anesthesia practice [1-4].

Herein, our aim in this review is to emphasize the importance of preoxygenation and AO in our anesthesia practice.

## PHYSIOLOGY OF PREOXYGENATION AND APNEIC OXYGENATION

Preoxygenation is a widely practiced maneuver based on using a high rate of inspiratory oxygen fraction ($FiO_2$) before anesthesia induction and endotracheal intubation and increasing the body's $O_2$ stores, ultimately preventing $SaO_2$ desaturation during apnea, intubation to extend ''the safe apnoea time", and providing denitrogenation. Adequate and high-quality preoxygenation must be applied to all patients since difficulties are sometimes unpredictable during airway management. There are three stages of preoxygenation (First, second, and third phase)(Figure 1) [11].

Correct and adequate preoxygenation provides safe airway management by keeping the $SaO_2$ level at 88-90% and prolonging "the safe apnea time" [1-3]. 1 If $SaO_2$ goes below this level, it enters the steeper part of the oxyhemoglobin dissociation curve

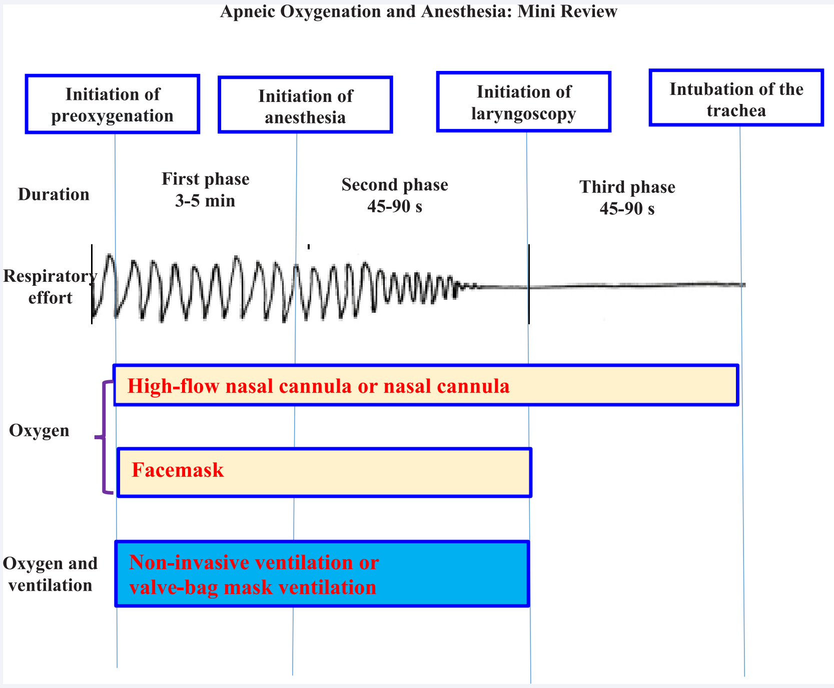


**Figure 1** Stages of preoxygenation (First, second, and third phase).

and can drop to a critical <70% of $SaO_2$ within seconds [1-3,6]. Duration of apnea after preoxygenation showed in Figure 2 [12].

Oxygen consumption ($VO_2$) rate and carbon dioxide ($CO_2$) production rate during apnea in healthy adults are 250 mL/min and 200 mL/min, respectively. After denitrogenation and when a patient develops apnea, $O_2$ is transferred from the alveoli to the blood circulation at approximately 250 mL/min [1,3,6,11,13]. During an apnea, the elimination of $CO_2$ nearly stops and diffuses into the alveolar space at a rate of about 10 mL/min. A 240 mL/min pressure difference from the alveoli to the blood creates an inverse pressure gradient. As the $O_2$ continues to propagate and bring down the gradient, the negative pressure causes ambient gases to enter the lungs from the pharynx, providing the phenomenon of ventilator mass flow. ''The safe apnea time'' is the time from cessation of ventilation to $SaO_2$ <88-90%. Anesthesiologists have limited time to maintain a safe airway when patients are unconscious, and this phase is known as "the apnea window"[1,2,6,11,12]. In the patient's breathing room air before endotracheal intubation, $PaO_2$ is ≈ 90-100 mmHg, but $SaO_2$ may decrease 45-60 seconds after a sedative/paralytic [6,11,12].

- In-room air: a healthy person may have a " safe apnea period of ≈ 1 minute.
- At high $FiO_2$: a healthy person may have a " safe apnea period of ≈ 8 minutes. [5,6,11,12].

Denitrogenation involves using $O_2$ to flush nitrogen from the lungs after breathing room air, thus providing a more extensive alveolar $O_2$ reservoir. While an average healthy adult breathes room air (79% nitrogen, 21% $O_2$), his lungs have 450 mL of $O_2$. When inhales 100% $O_2$, it washes out the nitrogen and increases the $O_2$ in the lungs to 3,000 mL. In summary, the primary purposes of preoxygenation are as follows [13].

- To extend ''the safe apnoea time'',

- To provide denitrogenation of the lungs,

- To allow the lungs to act as a great reservoir of $O_2$ during apnea,

- To achieve as much $SaO_2$ to 100% as possible,

- To increase functional residual capacity (FRC) [1-3,5,6,11,12].

## FACTORS AFFECTING OF PREOXYGENATION

Factors affecting the effectiveness and efficiency of preoxygenation include $FiO_2$ concentration, preoxygenation time and technique, alveolar ventilation/FRC ratio, cardiac output (CO), fresh gas flow (FGF), and leakage in circuits (Table 1) [3,6,14]. Adequate and accurate pre-oxygenation techniques provide a " the safe apnea time" of 4-8 minutes in an adult patient without obesity and lung disease [15]. The applied preoxygenation technique is also essential, and many different preoxygenation techniques have been described (Table 2) [3,6,14].

Despite the clinical effectiveness of preoxygenation and AO, there is no algorithm, consensus, or guideline for AO. In our clinic, we apply AO techniques in line with the information stated in the literature. In our clinic, we usually use 100% $FiO_2$ with four deep breaths (4 inspiratory capacity breaths) in preoxygenation or the eight deep breaths (8 inspiratory capacity breaths) method. We also sometimes use the HFNC method in obese and critically ill pediatric patients.

## MONITORING OF PREOXYGENATION

There are three ideal monitoring methods in the follow-up of preoxygenation.

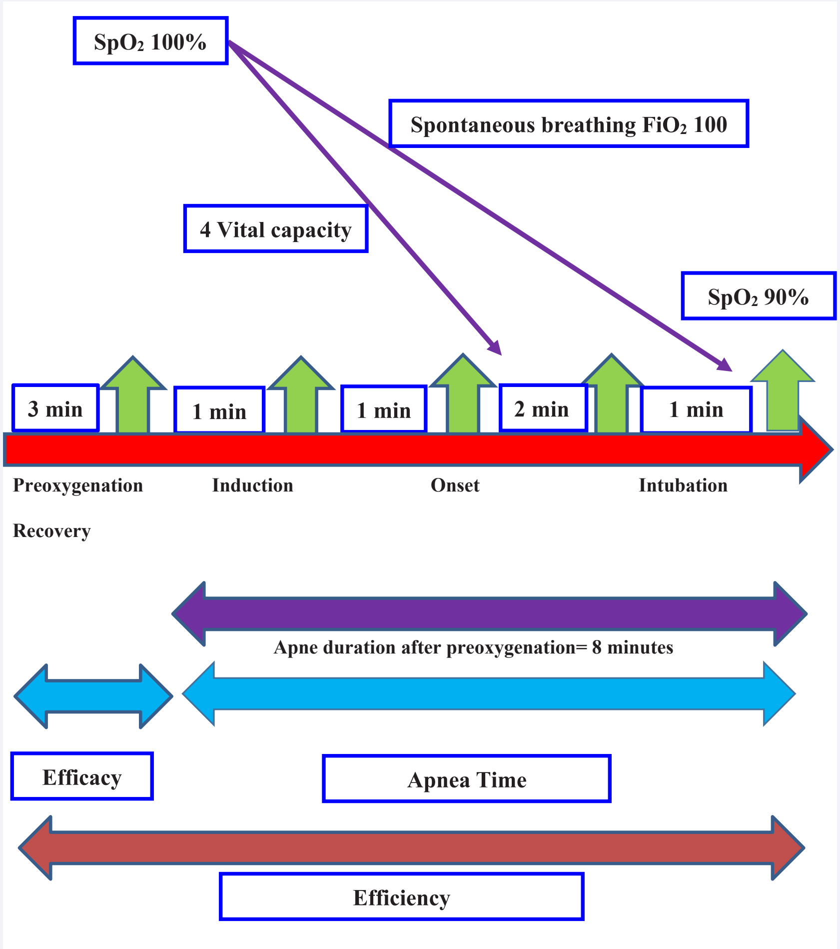


**Figure 2** Duration of apnea after preoxygenation.

**Table 1:** Factors affecting preoxygenation and apneic oxygenation.

| Effectiveness | Efficiency |
|---|---|
| -$FiO_2$<br>• Presence of leak<br>• Anesthetic system used<br>• Level of FGF<br>• Type of breathing (TV or deep breathing)<br>- VA/FRC ratio<br>- Duration of breathing | - Oxygen volume in lungs<br>• Alveolar oxygen tension<br>• FRC<br>- Systemic oxygen supply versus demand balance<br>• Arterial oxygen content<br>• CO<br>• Whole body $VO_2$ |

**$FiO_2$,** fraction inspired oxygen concentration; **FGF,** fresh gas flow; **TV,** tidal volume; **VA,** alveolar ventilation; **FRC,** functional residual capacity; **CO,** cardiac output; **$VO_2$,** oxygen consumption;

**Table 2:** Techniques and devices of preoxygenation and apneic oxygenation.

| Techniques | Devices |
|---|---|
| • TV breathing<br>• One VC breath followed by TV breathing<br>• Single VC breathing<br>• Four deep breaths (4 inspiratory capacity breaths)<br>• Eight deep breaths (8 inspiratory capacity breaths)<br>• Extended deep breathing (12-16 inspiratory capacity breaths) | **Unsupported ventilation**<br>• Face-mask with reservoir<br>• Bag-valve mask (- insufflation)<br>• Non-rebreather +/- nasal cannula<br>**Supported ventilation**<br>• Continuous positive airway pressure<br>• Bilevel-positive airway pressure<br>• High-flow nasal cannula |

**TV,** tidal volume; **VC,** vital capacity;

1- Capnography: Continuous end-tidal carbon dioxide ($EtCO_2$) monitoring should be used. The primary purposes are:

- To demonstrate ventilation before intubation,
- To confirm the endotracheal tube location,
- To identify leaks/poor face seals,
- To help detect insufficient ventilation, perfusion, and shunt.

2- Oxygen gas analyzer: Monitoring of end-tidal $O_2$ ($ETO_2$) is the standard gold test for evaluating denitrogenation of the lungs in clinical practice during preoxygenation:

- $EtO_2$ is generally used in the operating room,
- Primary goal $EtO_2$ should be >90% for optimal preoxygenation.

3-Pulse oximetry: Frequently used in daily practice.

- Peripheral oxygen saturation ($SpO_2$) of 100% does not designate optimum preoxygenation,
- Hemoglobin becomes 100% saturated in $PaO_2$, slightly above what room air provides,
- It does not designate the effectiveness of denitrogenizing/oxygen-filling the lungs,
- It should be noted that $SpO_2$ has a natural latency time and should not be monitored based on this parameter alone. In critically ill patients, this time may exceed 90 seconds due to the delay time in the redistribution of oxygenated blood from the central to the periphery and prolonged signal averaging times [1-3,6,16].

## COMPLICATIONS OF APNOEIC OXYGENATION

It should be kept in mind that some complications may develop in preoxygenation and AO applications, and great care should be taken to prevent these complications. This complication includes;

- Hyperoxia (e.g., stroke, post-arrest ICU),
- Minor hemodynamic effects due to high $O_2$ use,
  - Heart rate and CO ↓,
  - Systemic vascular resistance ↑,
  - Hyperventilation and hypocapnia may develop if 8 deep breaths are used in 60 seconds during preoxygenation,
  - Atelectasis due to excessive absorption of $O_2$,
  - Side effects due to devices used during preoxygenation (for example, pressure sores due to continuous positive airway pressure (CPAP) mask or aspiration due to vomiting) [17,18].

## CONCLUSIONS

Preoxygenation and AO are widely accepted and frequently used methods before anesthesia induction and endotracheal intubation. Preventing and reducing severe complications in airway management is a challenging and essential task for anesthesiologists. Good quality and preoxygenation are critical in airway management and vital prerequisites in AO. The physiology of preoxygenation and AO is based on increasing the physiological capacity of continuous $O_2$ capture and $O_2$ reserves by the alveoli through a passive process without ventilation. Regardless of the method in anesthesia practice, preoxygenation and AO are very important in reducing hypoxemia, mortality, and morbidity. In the preoperative period, a multidisciplinary approach, detailed evaluation, and optimization are very important, especially in obesity, pregnancy, pediatric, and critically ill patients. For this reason, it will be more effective for anesthesiologists in terms of patient safety and quality if they have substantial knowledge about preoxygenation and AO and closely follow related algorithms, protocols and guidelines.

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