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A Practical Approach to Apneic Oxygenation during Endotracheal Intubation

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Abstract

Patients undergoing general anesthesia with endotracheal intubation are exposed to a brief apnea period that is usually well tolerated. Conventional preoxygenation techniques may not provide adequate time for safe airway management in patients at high risk for desaturation or when an unanticipated difficult airway arises. Continuous oxygen administration during the apnea period, termed apneic oxygenation, can be used in conjunction with traditional pre-oxygenation techniques to prolong the time to patient desaturation when tracheal intubation is attempted. Clinical studies have evaluated the efficacy of apneic oxygenation using multiple techniques, nasopharyngeal catheters, nasal prongs, modified laryngoscopes, and buccal oxygen administration, all proved to be effective at prolonging the duration of apnea, by delaying the onset of hypoxemia.

Keywords: Apneic oxygenation; Passive oxygen insufflation; Airway management

Introduction

Patients undergoing general anesthesia with endotracheal intubation are exposed to a brief apnea period that is usually well tolerated. Conventional preoxygenation techniques may not be adequate in providing a safe apnea period in patients at high risk for desaturation or when an unanticipated difficult airway arises [1]. Obese, obstetric, and pediatric patients are considered to be at high risk for rapid desaturation, because they have increased oxygen consumption and reduced functional residual capacity (FRC), which hastens the development of hypoxemia [2-4].

Apneic oxygenation (AO) has been researched for over a century [3]. In 1956, Holmdahl [5] first described the concept in humans, during bronchoscopies AO was used to prevent desaturation while permitting the endoscopist to work without the need for ventilations. It has since been utilized for brain death testing, otolaryngeal procedures, and laryngoscopy [3]. Clinical studies have evaluated the efficacy of AO during the induction of anesthesia using nasopharyngeal catheters, nasal prongs, modified laryngoscopes, and buccal oxygen administration. Research shows that AO in conjunction with traditional pre-oxygenation techniques can extend the safe apnea period by prolonging the time to patient desaturation [6-9]. Despite the evidence supporting the clinical efficacy of AO, there are currently no available consensus guidelines and many anesthetists may not be familiar with all of the AO techniques.

Physiology of Apneic Oxygenation

The primary objective of airway management is ensuring adequate oxygenation and ventilation, thus, prior to induction patients are pre-oxygenated with 100% oxygen (O_2) via facemask. Denitrogenation of the lungs creates an alveolar oxygen reservoir that helps reduce the frequency and severity of desaturation. Conventional pre-oxygenation techniques provide 4-8 minutes of safe apnea in a non-obese adult patient without pulmonary disease [4]. In the adult human body weighing approximately 70 kg, metabolic O_2 consumption is approximately 250 mL/min. After denitrogenation of the FRC, O_2 diffuses from the alveolus into the bloodstream at a rate of about 250 mL/min [4,5]. During apnea, the elimination of carbon dioxide (CO_2) is almost completely halted and diffuses into the alveolar space at a rate of approximately 10 mL/min. There is a pressure difference of 240 mL/min from the alveoli into the blood, which generates a negative pressure gradient. As O_2 continues to diffuse down its gradient, the negative pressure that is created causes entrainment of ambient gases from the pharynx into the lungs, describing the phenomenon of aventilatory mass flow (AVMF). Generally, room air gases (79% nitrogen and 21% O_2) are entrained from the pharynx into the lungs, when nitrogen accumulates desaturation ensues. If O_2 is insufflated to the pharynx while a patent air passage is maintained from the pharynx to the lungs, this results in AVMF of O_2 and extends the alveolar reservoir (Figure 1) [1,5]. The clinical application of this procedure, termed apneic oxygenation, allows for persistent oxygenation in the absence of ventilation.

Nasal Prongs

Nasal prongs necessitate upper airway patency to permit delivery of O_2 to the pharynx. Induction may compromise nasopharyngeal patency in a number of patients, e.g., people who are edentulous, obese, or have obstructive sleep apnea [1,6,9]. Ramachandran et al. [6] evaluated AO utilizing nasal prongs in a simulated difficult laryngoscopy situation with obese patients. After preoxygenation and induction, O_2 was administered to the study group via nasal prongs at 5 L/min *vs.* no O_2 to the control group. Study cut off time was 6 minutes or until SpO_2 decreased below 95%. Mean apnea time for the AO group was 5.29 minutes compared to 3.49 minutes in the control group. A method proposed by Weingart and Levitan [3] is insufflation of O_2 at flows of 15 L/min through nasal prongs, suggesting higher flows may enhance nasopharyngeal patency.

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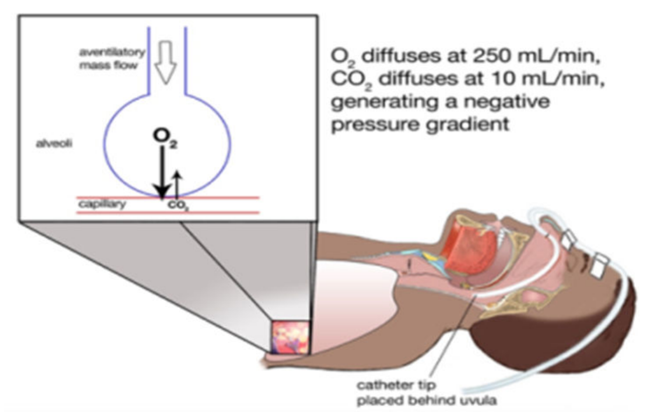

Figure 1: Mechanics of Apneic Oxygenation. Pressure difference between oxygen (O_2) diffusion from the alveoli and carbon dioxide (CO_2) excretion from the capillary generates a negative pressure gradient, resulting in aventilatory mass flow (AVMF) of gases into the lungs [5]. Insufflation of O_2 into the pharynx via nasopharyngeal catheter allows for AVMF of O_2 into the lungs. Image reprinted from AANA Journal, 2016 [1].

Insufflation of O_2 via nasal prongs appears to be one of the more popular routes; however, several studies have disputed its efficacy. Riyapan and Lubin [10] conducted a study on AO during prehospital rapid sequence intubation (RSI). Utilizing nasal prongs, O_2 was insufflated at 15 L/min *vs.* no O_2 in the control group. Results showed no significant difference in the rate of severe hypoxemia between the control group and patients receiving AO. Upon evaluation of the demographic data, there are several possible explanations for these results. First, among the patients in the two groups, there was a high rate of severe hypoxemia ($SpO_2 < 90\%$) prior to airway management (14% in the AO group *vs.* 17% in the control group) [10]. Severe hypoxemia is reported as an independent risk factor for severe desaturation during endotracheal intubation of critically ill patients [11].

Additionally, providers utilized two different methods for preoxygenation. In the control group 50% of patients were preoxygenated with a bag valve mask and 46% preoxygenated via nonrebreathing mask, as compared to 24% and 65% in the AO group, respectively. Furthermore, the protocol used lacked a SpO_2 end point for preoxygenation, thus there was no way to evaluate the efficacy of preoxygenation [10]. The principle of AO relies heavily on adequate denitrogenation of the FRC, as this allows for greater entrainment of O_2 from the pharynx to the lungs [3,5]. Clinicians should consider the potential patient populations; as AO may provide very little benefit if any in critically ill patients or those with a ventilation/perfusion mismatch [12,13].

Nasopharyngeal Catheter

The AO technique with the most research and strongest evidence is utilization of a nasopharyngeal catheter. This method allows for direct delivery of O_2 to the pharynx during apnea. Achar et al. [9] conducted a study comparing the effectiveness of nasal prongs *vs.* nasopharyngeal catheter in a difficult intubation scenario. Following preoxygenation and induction, O_2 was insufflated at 5 L/min via nasopharyngeal catheter or nasal prongs. The apneic period was maintained for 10 minutes or until SpO_2 dropped below 95%, whichever came first. Among the nasopharyngeal catheter group, no patients desaturated, as opposed to 32% in the nasal prongs group. This study suggests that AO is better achieved with a nasopharyngeal catheter rather than nasal prongs [9]. A benefit of utilizing a nasopharyngeal catheter is that O_2 is distributed close to the trachea, thereby circumventing potential problems associated with nasal prongs when airway patency is not maintained.

One commercially available product is the Naso-Flo nasopharyngeal airway (Medis Medical Co Ltd, Ashton-under-Lyne, United Kingdom). This catheter features an O_2 port that allows for direct insufflation of O_2 to the pharynx (Figure 2). Based on clinical experience and review of the research, this author recommends utilizing a nasopharyngeal catheter and insufflating O_2 at 6 L/min during the apneic period. Though practitioners should be reminded that nasopharyngeal catheter insertion may be contraindicated with certain patient groups, e.g., taking anticoagulants or head trauma [7].

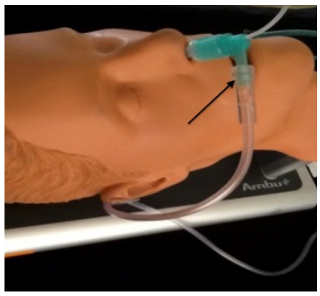

Figure 2: Naso-Flo nasopharyngeal airway (Medis Medical Co Ltd) in mannequin's right naris. Arrow indicates oxygen insufflation port of the Naso-Flo airway connected to auxiliary oxygen tubing. (Image courtesy of Medis Medical).

Buccal Oxygen Insufflation

Heard et al. [7] has introduced a new method for providing AO, which involves the use of a modified Ring-Adair-Elwyn (RAE) tube to provide buccal oxygenation. Utilizing a RAE tube with a 3.5 mm internal diameter, the tube was cut on the distal end above the Murphy eye. The cut end was then connected to standard oxygen tubing, the tube connector was removed and the blunt proximal end was placed in the left buccal space (Figure 3) [7]. The modified tube is easily secured to the cheek to prevent dislodgement.

In a prolonged laryngoscopy situation with obese patients, buccal oxygenation was employed during the apneic period. Study end point time was 12.5 minutes or until the SpO_2 concentration decreased to less than 95%, whichever occurred first. Following preoxygenation and induction, buccal oxygen was insufflated at 10 L/min. All patients in the control group desaturated and median apnea time was 296 seconds. In comparison, 65% of the patients in the buccal oxygenation group maintained their SpO_2 above 95% for the duration of the apneic period [7]. Evaluating the efficacy of AO for 12.5 minutes marks the longest study undertaken in the obese population [7].

Figure 3: Modified 3.5 mm Ring-Adair-Elwyn (RAE) tube for insufflation of buccal oxygen. Image from left to right demonstrates: intact RAE tube; connector removed from tube and distal end cut above the Murphy eye; modified RAE tube with oxygen tubing attached to cut end.

Positioning the RAE tube in the left buccal space allows for the use of normal oropharyngeal and laryngeal airways [7]. When comparing buccal oxygenation to the nasopharyngeal catheter, it takes longer to assemble and some anesthetists may not have RAE tubes readily available in their operating room. Additionally, the tube length may need to be altered to prevent obstruction and allow for effective O_2 delivery [7]. Despite the concerns of airway patency, buccal oxygenation is a practical alternative and should be considered when the nasal route is contraindicated.

Laryngeal Oxygen Insufflation

Another technique for performing AO, combines a laryngoscope blade with an internal lumen for the insufflation of O_2 during laryngoscopy [8]. Steiner et al. [8] researched the efficacy of laryngeal oxygen insufflation in 457 pediatric patients undergoing nasotracheal intubation. Children age 1-17 years were randomly assigned to one of three groups: standard direct laryngoscopy (DL); laryngoscopy with the Trueview PCD video laryngoscope (Truphatek International Ltd., Netanya, Israel), delivering O_2 through the oxygen port (VLO_2); or direct laryngoscopy, combined with insufflation of O_2 through a catheter attached to the side of a laryngoscope blade (DLO_2) [8].

Following induction, subjects were mask ventilated for 3 minutes with 70% N_2O and 30% O_2. In an effort to simulate a prolonged intubation scenario with limited O_2 supply, a starting O_2 concentration of 30% was utilized. Nasotracheal intubation was then performed with DL, VLO_2, or DLO_2, providing O_2 at 2 L/min or 3 L/min to the study groups. The study was stopped when the trachea was intubated or SpO_2 decreased to 90%. In the DL group not receiving supplemental O_2, SpO_2 fell below 90% in 49% of the subjects compared with 11% in the deep laryngeal O_2 groups (DLO_2 and VLO_2). Mean time to 1% saturation reduction was twice as long for the laryngeal O_2 insufflation groups, 70 seconds *vs.* 30 seconds in the standard DL group [8].

SunMed produces a dual-use laryngoscope blade, the Miller Port American Profile Conventional Blade (SunMed, Grand Rapids, Michigan, United States), which contains an internal lumen within the blade that allows for laryngeal O_2 insufflation. A cost effective alternative involves attaching a 14 fr suction catheter to the side of a laryngoscope blade. The proximal end is then connected to oxygen tubing and O_2 is insufflated at 2-6 L/min (Figure 4). Use of laryngeal O_2 insufflation provides similar benefits, as compared to the nasopharyngeal catheter method by allowing direct delivery of O_2 to the pharynx and maintenance of oropharyngeal patency. Although laryngeal O_2 insufflation is an effective AO technique, O_2 is only insufflated when DL is performed and there is a potential concern for gastric distension if O_2 is insufflated into the esophagus.

Figure 4: Adapted macintosh laryngoscope blade for laryngeal oxygen insufflation. A 14 fr suction catheter is secured to the blade. Proximal end of the catheter is connected to secondary oxygen tubing.

Summary

Oxygen insufflation is a technically easy skill that can be performed utilizing devices that are readily available in the operating room. Empirical evidence supports the efficacy of AO in delaying desaturation and prolonging the safe apnea period in pediatric and adult patients. Although it is unlikely that pharyngeal oxygen insufflation will provide much value in the typical 15-second intubation, clinicians should consider the potential benefit in patients at high risk of desaturation or when an unanticipated difficult airway arises.

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