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REVIEW ARTICLE

Apneic Oxygenation and High Flow

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Abstract

Prevention and minimizing serious complications during difficult airway management is an important goal for anesthesia providers. Using the high flow cannula oxygenation systems it is possible to improve the clinical outcomes, increase patient safety and reduce the rate of complications. A possible mechanism of this method can be explain by 'Aventilatory Mass Flow' which is a physilogical phenomenon. Several methods can be used to implement apneic oxygenation such as nasopharyngeal catheter, nasal cannula, face mask, Venturi mask, transtracheal endobronchial catheters, dual blade laryngoscopes and High Flow Nasal Cannula Oxygenation (HFNCO) systems. However each method has some restrictions. In this review we aim to focus on the important features of HFNCO systems including the indications, contraindications and possible complications.

Keywords

Apneic oxygenation, Aventilatory mass flow, High flow

Introduction

Cardiovascular collapse, anoxic brain injury or death are some of the results of serious complications that may occur during difficult airway management. Minimizing the risk of these complications is only possible by improving airway management strategies. Apneic oxygenation is a beneficial method adopted incrementally for this purpose. Actually this is historically an old method, first defined by German Anesthesiologists in 1905 [1]. Holmdahl [2] defined apneic diffusion oxygenation during bronchoscopies in 1956. Frumin, et al. [3] demonstrated that it was possible to maintain high levels of oxygen saturation for 18 to 55 minutes without ventilation. Following these reports, Weingart and Levitan [4] introduced apneic oxygenation to prevent desaturation. And popularity of this method has been peaking in this century. Fick principle explains uptake and consumption of O_2 by peripheral tissues. Cardiac output and oxygen rates in arterial and venous compartments play major role in this equation. A normothermic adult human consumes 3 mL/kg oxygen. Critical threshold of oxygen consumption is 250 mL/min. Oxygen consumption increases with increased alveolar ventilation in parturients [5].

During apnea, PaO_2 decreases as O_2 gets removed from lungs. As long as hemoglobin keeps being oxygenated in lungs, saturation levels remain over 90%. When oxygen the level in lungs start decreasing, PaO_2 is around 45-50 mmHg at this point. Denitrogenation of functional residual capacity (FRC) may increase oxygen capacity of lungs. This is possible by increasing oxygen percentage in breathing gas (FiO_2). Also applying continuous positive airway pressure (CPAP) and elevating patient's head to 25-30 degrees prevents atelectasia and improves FRC respectively.

Safe apnea period is the time from discontinuation of ventilation to the beginning of desaturation (SpO_2 < 90%). Anesthesiologists have limited time to provide safe airway when patients are unconscious. This period is called "apneic window". Decrease in PaO_2 levels causes rapid deceleration in SaO_2 below this level. Inappropriate preoxygenation, airway occlusion, pulmonary shunt, critical diseases, obesity, pregnancy and pediatric patients are some risk factors of short apneic win-

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dow. Time from succinylcholine administration to desaturation (SpO_2 < 90%) has been found as 8 min, 5 min, and 2.7 min in normal adults, moderately ill patients and obese patients respectively [6]. Recommended preoxygenation techniques include tidal volume ventilation with high FiO_2 for 3 min or 8 deep breaths with 100% FiO_2 [7].

Aventilatory Mass Flow

This is a physilogical phenomenon. Metabolic O_2 consumption rate and CO_2 production rate in an adult patient are 250 mL/min and 200 mL/min respectively. Following denitrogenation of FRC, O_2 diffuses to the capillary blood with 250 mL/min rate. During apnea, CO_2 production does not change, but elimination of CO_2 is almost paused and diffusion slows down to only 10-20 mL/min [8,9]. As a result of this negative pressure gradient, a mass flow of gas from pharynx to alveoli occur. CO_2 levels keep increasing. This causes a decrease in pH and respiratory acidosis. A high O_2 flow of > 15 L/min through nasal cannula washes dead space in lungs, thus restricts CO_2 increase. This also creates a "stent effect" via better gas washout. In several studies, patients were able to tolerate long apnea periods [9,10]. Average apnea duration changes between 5-45 minutes. CO_2 increase has been found between 1.1 to 3.4 mmHg/min during this application. CO_2 levels may increase up to 160 mmHg. Complications like seizures, cardiovascular collapse, and arrythmias related to hypercapnia have not been reported.

The Canadian Airway Focus Group and Difficult Airway Society proposes this method in patients with anticipated difficult airway [4,11]. Additionally, Obstetric Anaesthetists' Association also supports this method in obstetric patients with a possibility of failed airway management. Nasopharyngeal catheter, nasal cannula, face mask, Venturi mask, transtracheal endobronchial catheters, dual blade laryngoscopes and low flow oxygen or High Flow Nasal Cannula Oxygenation (HFNCO) systems are also usable for this method by applying high flow oxygen. However efficiency of oxygen flow applied by conventional methods are limited, because, these methods doesn't provide enough warming and humidifying. This also causes a decrease in inspired oxygen concentration. Low flow systems have no effect on ventilation and CO_2 removal. Oxygen entrance port of nasopharyngeal airway permits oxygen insufflation. Nasopharyngeal catheter helps oxygen delivery to pharynx very effectively. If oxygen flow is between 1-8 L/min, this increases FiO_2 to 24-44%. But this method also removes humidity in mucosa, and may be disturbing for awake patients. That's why high flow rates over 15 L/min is usually preferred in patients under general anesthesia.

Venturi mask is able to deliver 100% oxygen. This method increases FiO_2 up to 50%. Re-breathless masks has an oxygen reservoir and two valves. One of the valves is placed in exhalation port and the other is located between reservoir and face mask. This prevents air slip in. This increases FiO_2 up to 60-70% for flow rates over 15 L/min. Oxygenation is also possible through cricothyrotomi or a cannula inserted through endotracheal tube. Endotracheal catheters placed in right or left bronchi is another method of apneic oxygenation. Another technique is dual-use laryngoscope. Oxygen is applicable through a canal inside the blade. This makes insufflation of oxygen up to 15 L/min possible.

In recent years, high levels of humidified oxygen therapy through nasal cannula has been possible with advanced devices and it is possible to apply up to 70 L/min O_2 flow. Atelectasia risk following denitrogenation due to application of 100% oxygen is partially prevented by forming positive pharyngeal pressure. This method also makes application of positive pressure in low levels with nasal interface possible and provides controlled oxygen concentrations. Utilizing an oxygen/air blender, it is possible to obtain FiO_2 0.21-1 with 60-70 L/min flow.

Gases are actively ventilated, humidified and inspired to the patient through a one-way circuit. High flow is 2-8 L/min for neonatal patients, 5-20 L/min for pediatric patients and 6-40 L/min for adults. Vapotherm, Optiflow, Aquinox, Precision Flow and Comfort-flow are some of brands manufacturing devices for high flow applications. Flexible delivery tubing system is able to provide a 70 L/min flow. A heating plate vapors water and delivers respiratory gas. This unit contains a passover humidifier, a high performance circuit and an Optiflow nasal cannula. This system delivers 44 mg H_2O/L gas heated to 37 °C and humidified, and is connectable to jack system directly. Nasal cannula may be in different sizes. Outer diameter of the cannula must be at least same with nostril diameter. This unit also has an adapter for use in connecting to tracheostomy of children weighing more than 15 kg.

AIRVO 2 is another mobile, ultrasonic, optiflow system. Pediatric nasal cannula contains a hydrocolloid sticky band which helps in fixing the unit. Aquinox TM high flow applicant system is able to deliver the gas in a flow rate of 35 L/min. Particles exiting from a Venturi heated and humidified shoes their effect in a closed chamber. Gas flow which contains humidified particles is delivered to the patient via a hollow tubing. Inner chamber forms particles as a humidifier and outer chamber delivers the gas to the paitent. PARI Hydrate system uses pre-heated water system as a principle and is able to create air-flow. The advantage of this system is the ability to control heating according to desired humidity levels. There is no guide available created for high flow oxygen therapy application in pediatric or adult patient population. It is recommended to begin with flow levels of 8-10 fold of minute ventilation in some studies. Recommended flow rate is 8-12 L/min in infantile patients and 20-30 L/min in juveniles, starting with low flow and

Table 1: The comparison of HFNCO and NIV systems.

HFNCO	NIV
Fixed flow and variable pressure levels	Variable flow for fixed pressure
Able to reduce dead space	Increases dead space
Does not effect tidal volume	May increase tidal volume
Reduces respiratory workload	More effective in reducing respiratory workload
Minimal gastric distention	Loss of pressure when mouth is opened
Pressure can be maintained	

Table 2: Potential indications of HFNCO.

Preoxygenation before intubation
Acute hypoxemic respiratory failure
Moderate obstructive sleep apnea
Oxygenation following extubation
Sedation
Decrease in CO_2 levels
Acute COPD flare-ups
Postoperative hypoxemia

increasing the flow to the rate that is tolerable by the patient:

-2-4 L/kg/min for 0-5 kg (up to 20 L/min)

-2 L/kg/min for 5.1-12.5 kg (up to 25 L/min)

-2 L/kg/min fow 12.6-35 kg

-Up to 70 L/min fow > 35 kg patients

i-THRIVE is successfully used in laser surgeries with FiO_2 levels up to 30%. High flow nasal cannula systems limit oxygen dilution and reduce respiratory dead space. This device also removes CO_2 in anatomic dead space and this is correlated with increases in flow rate [12]. Conventional oxygen devices provide dry and unheated air to patients, and this causes dehydration in oral and nasal mucosa, irritation of the eye with trauma risk. Heating and humidifying airway improve pulmonary compliance and elastance [13]. Additionally, reseptors in nasal mucosa reacts to the dry-cold air and causes a protective bronchoconstriction in normal and asthmatic patients. Heated and humidified air also improves ciliary activity with the removal of secretions and prevention of atelectasia. HFNCO creates a high flow rate and reduce inhalation resistance in airway passage. This is used in modification of respiratory workload.

Positive airway pressure formed by HFNCO interacts derogatorily with intrinsic PEEP partially and helps reducing workload. Thus, dynamic hiperinflation improves patient comfort. HFNCO therapy creates a flow-dependent positive airway pressure. Every 10 L/min increase in airflow increases airway pressure by 0.5-1 cm H_2O.

HFNCO is reported to increase end-expirium lung impedance [14]. This increase in lung volume is also used as alveolar recruitment. HFNCO was found significantly useful when applied to obese patients undergoing cardiac surgery. This increase in EELV is thought as alveolar recruitment and prevents alveolar collapse. This is possible thanks to the low positive pressure level system of HFNCO. In order to prevent dehydration of mucosa, absolute humidity should be above 20 mg H_2O/L. Mucosal clearance is completely halted after 1 hour when dry airflow is used.

Noninvasive Ventilation (NIV) vs. HFNCO

NIV connections increase anatomic dead space where as HFNCO reduces it. HFNCO does not actively cause increases in tidal volume, this only creates minor increases in end-expiratory airway pressure and reduces respiratory workload as effectively as NIV. But NIV is more effective in comorbid patients. A certain level of providing CPAP is possible with HFNCO therapy. This is flow-dependent and associated with mouth-opening. Features of HFNCO are summarized in Table 1 [15]. HFNCO system is potentially useful during awake fiberoptic intubation [16]. Conventional methods might be insufficient in preventing desaturation during awake intubation.

Miguel-Montanes, et al. [17] used non-rebreather mask and HFNCO during tracheal intubation in intensive care unit before and during the procedure. Lowest median SpO_2 during intubation for non-rebreathing masks was 94% while 100% for HFNCO. They demonstrated that HFNCO significantly reduces severe hypoxemia prevalence and increases patient safety. Potential areas of use for HFNCO are stated in Table 2. Causes of rapid desaturation of obese patients are increased oxygen consumption, increased CO_2 production and increased alveolar ventilation. Metabolic rate is directly proportionate to body weight and amount of fat tissue. This reduces chest wall compliance.

Obese patients with BMI over 40 have a relative baseline hypoxemia. HFNCO reduces this dead space and increases alveolar ventilation. This reduces the respiratory workload. Corley, et al. [18] evaluated end-expiratory lung volumes with lung impedance tomography and found it higher in patients receiving low flow oxygen therapy with HFNCO. Several previous studies demonstrated that HFNCO produces 5 cm H_2O pressure on pharyngeal tissue when 35-40 L/min oxygen flow is applied. However, Piastro, et al. [19] did not observe any pressure changes in middle ear. This may suggest that HFNCO therapy is a good option for patients undergoing otological procedures.

Incidence of respiratory failure following extubation is around 10-20% and may require re-intubation [20]. Re-intubation due to respiratory failure is associated with increased Ventilatory Associated Pneumonia

(VAP), mortality, prolonged stay in hospital and Intensive Care Unit (ICU). HFNCO is proven to be significantly increasing patient comfort and reducing the length of stay in hospital in patients undergoing lung resection.

Contraindications for this therapy include airway obstruction and facial trauma [21]. Airway obstruction restricts apneic oxygenation and this causes desaturation. Increase in CO_2 may also limit apneic oxygenation application. HFNCO therapy should be avoided if patient has risk of hypercapnia, increased intracranial pressure, hemodynamic instability or cardiac dysrhythmia. Complications are mucosal tissue damage, hypercarbia, acidosis and infection [10]. Hemodynamic changes occur due to sympathetic discharge following hypercarbia. Rising in venous return increases the left ventricular filling pressure, thus increasing cardiac output and possibility of life-threatening arrythmias [22]. Apart from this, inappropriate use of HFNCO may compromise patient safety despite all its advantages in patients with respiratory failure.

Conclusions

Apneic oxygenation is increasingly used in ICU and operating rooms for difficult airway management by HFNCO systems. It is possible to deliver humidified and heated oxygen flow rates of up to 70 L/min. Apneic oxygenation requires a patent airway regardless of the technique used. Contraindications for this therapy include airway obstruction and facial trauma.

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References

1. Smith RB, Sjöstrand UH (1985) Apneic diffusion oxygenation and continuous flow apneic ventilation. A review. Acta Anaesthesiol Scand 29: 101-105.
2. Holmdahl MH (1956) Pulmonary uptake of oxygen, acid-base metabolism, and circulation during apnoea. Acta Chir Scand 212: 1-128.
3. Frumin MJ, Epstein RM, Cohen G (1959) Apneic oxygenation in man. Anesthesiology 20: 789-798.
4. Frerk C, Mitchell VS, McNarry AF, Mendonca C, Bhagrath R, et al. (2015) Difficult Airway Society 2015 guidelines for management of unanticipated difficult intubation in adults. Br J Anaesth 115: 827-848.
5. Saracoglu A (2015) Structural differences in respiratory system and airway of parturients. Glob J Anesthesiol 2: 52.
6. Benumof JL, Dagg R, Benumof R (1997) Critical hemoglobin desaturation will occur before return to an unparalyzed state following 1mg/kg intravenous succinylcholine. Anesthesiology 87: 979-982.
7. Taş Z, Hoşten T, Kuş A, Cesur S, Türkyılmaz N, et al. (2017) Comparison of tidal volume and deep breath preoxygenation techniques undergoing coronary artery bypass graft surgery: Effects of hemodynamicresponse and arterial oxygenation. Turk J Med Sci 47: 1576-1582.
8. Pratt M, Miller AB (2016) Apneic oxygenation: A method to prolong the period of safe apnea. AANA 84: 322-328.
9. Rudlof B, Hohenhorst W (2013) Use of apneic oxygenation for the performance of pan-endoscopy. Otolaryngol Head Neck Surg 149: 235-239.
10. Patel A, Nouraei SA (2015) Transnasal humidified rapid-insufflation ventilatory exchange (THRIVE): A physiological method of increasing apnoea time in patients with difficult airways. Anaesthesia 70: 323-329.
11. Law JA, Broemling N, Cooper RM, Drolet P, Duggan LV, et al. (2013) The difficult airway with recommendations for management--part 2--the anticipated difficult airway. Can J Anaesth 60: 1119-1138.
12. Schwabbauer N, Berg B, Blumenstock G, Haap M, Hetzel J, et al. (2014) Nasal high-flow oxygen therapy in patients with hypoxic respiratory failure: effect on functional and subjective respiratory parameters compared to conventional oxygen therapy and non-invasive ventilation (NIV). BMC Anesthesiol 14: 66.
13. Sotello D, Orellana-Barrios M, Rivas AM, Nugent K (2015) High Flow Nasal Cannulas for Oxygenation: An Audit of Its Use in a Tertiary Care Hospital. Am J Med Sci 350: 308-312.
14. Parke RL, Bloch A, McGuinness SP (2015) Effect of very-high-flow nasal therapy on airway pressure and end-expiratory lung impedance in healthy volunteers. Respir Care 60: 1397-1403.
15. Spoletini G, Alotaibi M, Blasi F, Hill NS (2015) Heated humidified high-flow nasal oxygen in adults: Mechanisms of action and clinical implications. Chest 148: 253-261.
16. Badiger S, John M, Fearnley RA, Ahmad I (2015) Optimizing oxygenation and intubation conditions during awake fibre-optic intubation using a high-flow nasal oxygen-delivery system. Br J Anaesth 115: 629-632.
17. Miguel-Montanes R, Hajage D, Messika J, Bertrand F, Gaudry S, et al. (2015) Use of high-flow nasal cannula oxygen therapy to prevent desaturation during tracheal intubation of intensive care patients with mild-to-moderate hypoxemia. Crit Care Med 43: 574-583.
18. Corley A, Bull T, Spooner AJ, Barnett AG, Fraser JF (2015) Direct extubation onto high-flow nasal cannulae post-cardiac surgery versus standard treatment in patients with a BMI ≥ 30: A randomised controlled trial. Intensive Care Med 41: 887-894.
19. Piastro K, Chaskes M, Agarwal J, Parnes S (2016) The effect of high flow nasal cannula oxygen therapy on middle ear pressure. Am J Otolaryngol 37: 221-224.
20. Ansari BM, Hogan MP, Collier TJ, Baddeley RA, Scarci M, et al. (2016) A randomized controlled trial of high-flow nasal oxygen (optiflow) as part of an enhanced recovery program after lung resection surgery. Ann Thorac Surg 101: 459-464.
21. Nishimura M (2015) High-flow nasal cannula oxygen therapy in adults. J Intensive Care 3: 15.
22. Kolettas AA, Tsaousi GG, Grosomanidis V, Karakoulas KA, Thomareis O, et al. (2014) Influence of apneic oxygenation on cardiorespiratory system homeostasis. J Anesth 28: 172-179.