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Improvement of Gas Exchange by Apneic Oxygenation with Nasal Prong during Fiberoptic Intubation in Fully Relaxed Patients

To evaluate the effect of apneic oxygenation with a nasal prong during fiberoptic orotracheal intubation (FOI) in fully relaxed patients, 46 patients, who underwent tympanomastoidectomy under general anesthesia whose intubation lasted more than 3 but less than 4 minutes, were studied. Changes of arterial oxygen tension (PaO_2), arterial carbon dioxide tension ($PaCO_2$) and vital signs were measured every minute. Twenty-three patients who underwent FOI in apneic state without oxygen administration (Group I), showed similar increases in heart rate (HR) and mean arterial pressure (MAP) to the other 23 patients who received 5 L/min of apneic oxygenation (Group II) with nasal prong. $PaCO_2$ increased less and PaO_2 decreased less in Group II at 3 minutes. In summary, apneic oxygenation during fiberoptic orotracheal intubation in fully relaxed patients is useful because it could delay the onset of hypoxia and hypercarbia, thereby providing extra time for intubation. And attempts to intubate a fully relaxed patient could probably be kept at least under 3 minutes.

Key Words : *Apneic oxygenation, nasal prong; Pulmonary gas exchange; Intubation, intratracheal, fiberoptic*

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INTRODUCTION

Flexible fiberoptic laryngoscopy and subsequent intubation is a useful method for establishing a safe airway. It is now important and essential to the administration of high quality anesthesia and intensive care that every anesthesiologist should know how to perform this technique and when to use it rather than reserving it for patients in whom rigid techniques have proven to be unsuccessful. There are many reasons why fiberoptic equipment improves anesthetic care. First, fiberoptic endoscopy-aided single lumen endotracheal tube intubation in awake or generally anesthetized patient is recognized as an indispensible tool in the management of a difficult airway. Second, fiberoptic bronchoscopy is considered by most authorities to be the best way to confirm the proper position of double lumen tubes and bronchial blockers, and the endobronchial location of single lumen tubes. Third, fiberoptic bronchoscopy is an extremely important diagnostic tool, both in the operating room and intensive care unit for such conditions as obstructed airways and airway burns. Fourth, fiberoptic bronchoscope permits precise therapeutic lavage, suctioning and reinflation of any specific and/or all parts of the airways.

Fiberoptic laryngoscopy can be performed with relative ease on a patient under general anesthetic, as long as the following cautions are kept in mind. First, as the patient under general anesthetic has lost the ability to maintain his own airway, a second pair of hands is often necessary. Second, patients breathing spontaneously under a general inhalational anesthetic still have reactive vocal cords, and may have laryngospasm as the laryngoscope is advanced towards the glottic opening, thus obscuring the view. But, the patient who has received a full dose of a neuromuscular blocking drug will not be able to oppose with his vocal cords, eliminating laryngospasm as an impedance to intubation.

In general, it has been believed that attempts at intubating a fully relaxed patient should probably be kept to under 2 minutes (1). It is also known that the risk of hypoxia is reduced if oxygen is constantly flowing to the apneic patients (2-6). But there has been no studies evaluating the effect of oxygen administration by continuous flow through nasal prong during fiberoptic laryngoscopy under general anesthetic and muscle relaxation. There is a possibility that apneic oxygenation via nasal prong during fiberoptic laryngoscopy would not give any advantage over the method that does not administer oxygen, considering of the distance from the nose to the inlet of the trachea. And oxygen flow through a nasal prong might be blocked anywhere in the passage to the lung, in anesthetized patients because of accompanied anomalies in anatomy and relaxed soft tissues by deep anesthesia and muscle relaxation.

This study was undertaken to evaluate the effect of oxygen administration via nasal prong during fiberoptic intubation in anesthetized patients by comparing the differences of PaO_2, $PaCO_2$, MAP and HR, between the patients with and without oxygen administration. I also tried to confirm the safety of fiberoptic intubation when intubation time is extended over 2 minutes.

MATERIALS AND METHODS

Author performed fiberoptic orotracheal laryngoscopy routinely on every patient who belonged to ASA classification 1 and 2 (7), aged between 20-40, and underwent elective tympanomastoidectomy. Patients taking antihypertensive medication and those with reflux, morbid obesity and airway problems including significant histories of tobacco use were excluded. I randomly divided the patients into two group. The first group (Group I) underwent fiberoptic orotracheal intubation in the apneic state without oxygen administration after removal of manual oxygen mask ventilation, while the second group (Group II) underwent fiberoptic orotracheal intubation with apneic oxygenation of O_2 5 L/min administration via nasal prong just after the removal of oxygen mask ventilation. Among the patients, 46 patients whose fiberoptic intubation lasted more than 3 minutes but less than 4 minutes (Group I; 23 patients, Group II; 23 patients) were included in this study.

All patients were premedicated one and a half hours prior to operation with lorazepam 2 mg and glycopyrrolate 0.5 mg intramuscularly. Continuous EKG monitoring was established after arrival in the operating room. The radial artery was cannulated with a 20G teflon catheter. The arterial blood pressure was monitored continuously and sampling for arterial blood gas analysis was collected from arterial line per 1 minute interval. Pulse oximetry was applied to the thumb of the patient to prevent a dangerous drop in arterial oxygen saturation during apneic fiberoptic intubation. If the SaO_2 fell below 90%, the procedure was abandoned and the patient was ventilated manually with 100% oxygen.

Thiopental sodium 4-5 mg/kg was given to the patients intravenously after a test dose to induce anesthesia. As soon as manual ventilation with a face mask was considered satisfactory, vecuronium 0.1 mg/kg was given. The controlled ventilation with 100% O_2 and 2-3 vol% isoflurane mixture was given for at least 5 minutes to make the patient fully relaxed for intubation. Fiberoptic intubation was done with the patient in a supine position. After the endotracheal tube (internal diameter 7.0 for male and 6.5 for female) was mounted on it, the fiberoptic laryngoscope was advanced via mouth opening to the tracheal inlet with the jaw pulled forward by an assistant, to widen the retropharyngeal space. After entrance into the trachea, the tip of the fiberoptic laryngoscope was positioned above the carina and the endotracheal tube was slowly and carefully advanced into the trachea. As the endotracheal tube was properly positioned, the fiberoptic laryngoscope was removed gently.

Just before the removal of the oxygen mask (control value: Vc), and 1 minute (V_1), 2 minutes (V_2) and 3 minutes (V_3) after removal of oxygen mask, HR and MAP were measured by a PC monitor 3.660.27EN (Spacelab. Med. Inc., U.S.A.) and a sampling of arterial blood was done. Blood gas analysis was done by STAT Profile 5 (NOVA Biomedical, U.S.A.). The averages of the measured parameters were expressed as mean $\pm$ standard deviation. Differences between two groups were compared by paired t-test and $p<0.05$ was considered statistically significant.

RESULTS

There was an increasing tendency in MAP and HR after the removal of the oxygen mask in both groups, compared with those of just before the oxygen mask removal. The greatest increases in MAP and HR occurred at 3 minutes after removal of the oxygen mask ($p<0.05$). PaO_2 decreased from 479 ± 58 mmHg (Vc) to 256 ± 81 mmHg (V_3) in Group I, while it decreased from 489 ± 48 mmHg (Vc) to 345 ± 78 mmHg (V_3) in Group II (Table 1).

$PaCO_2$ increased from 35.0 ± 6.1 mmHg (Vc) to 53.6 ± 5.3 mmHg (V_3) in Group I and increased from 35.6 ± 3.4 mmHg (Vc) to 47.1 ± 4.7 mmHg(V_3) in Group II. Group II revealed significantly less increase in $PaCO_2$ compared to Group I ($p<0.05$).

There was no significant difference between the two groups in MAP and HR. The differences of $PaCO_2$ and PaO_2 at 1 and 2 minute between the two groups were not statistically significant but the differences at 3 minute after removal of the oxygen mask showed statistical significance ($p<0.05$).

DISCUSSION

Some anesthesiologists recommended fiberoptic intubation under general anesthesia to prevent the cardiovascular response by intubation in awake patients with the

Table 1. Changes in vital signs and gas exchange during fiberoptic intubation with or without apneic oxygenation under general anesthesia

Time	Oxygenation	MAP	HR	PaO_2	$PaCO_2$
0	−	81±14	93±11	479±58	35.0±6.1
	+	84±13	91±14	489±48	35.6±3.4
1 min	−	104±21	103±14	437±54	44.7±6.5
	+	96±14	99±17	446±59	41.9±4.8
2 min	−	109±18	104±13	351±85	49.3±7.4
	+	112±15	102±14	402±68	44.9±4.7
3 min	−	119±22	109±18	256±81	53.6±5.3
	+	123±15	109±22	345±78*	47.1±4.7*

MAP, mean arterial pressure; HR, heart rate; PaO_2, arterial oxygen tension; $PaCO_2$, arterial carbon dioxide tension.
Values are mean±S.D., *$p<0.05$ compared to the group without oxygenation.

increased intracranial pressure of severe hypertension. In this study, there was a similar increasing tendency in MAP and HR during fiberoptic intubation under general anesthesia. The percentages of increase were not less than those of previous studies which were done at our department during awake intubation or rigid technique (8, 9). Therefore, fiberoptic intubation under general anesthesia would also cause an activation of sympathetic nervous activity.

Several methods have been tried to improve oxygenation and carbon dioxide elimination for procedures in which we could not adequately ventilate the patients. Successful ventilation with a continuous flow of air without respiratory movement was described in dogs by Meltzer and Auer (10). Draper and Whitehead (11) described the successful use of diffusion respiration in dogs, but there was an alveolar accumulation of carbon dioxide. Comroe and Dripps (12) demonstrated accumulation of carbon dioxide in comatose human subjects using this technique with an oxygen flow as high as 11 L/min into the trachea. Enghoff et al. (13) were the first to introduce diffusion respiration in anesthetized patients, using oxygen at an F_IO_2 of 1.0 for ten minutes through a cuffed tracheal tube. An extensive review on the subject of diffusion respiration was presented by Holmdahl in 1956 (14), who introduced apneic diffusion oxygenation (ADO). ADO was used by Frumin et al. (15) and Payne (16), who observed severe respiratory acidosis in the presence of adequate oxygenation.

Introduction and development of high frequency ventilation (17, 18) has renewed interest in the mechanism of gas exchange, particularly using tidal volumes less than dead space. Lehnert et al. (2) studied constant flow endobronchial ventilation in four apneic dogs. They found normal blood gases could be obtained for as long as 2 hours. We could apply this new methods of gas exchange without respiratory movement for cardiac surgery, pneumonectomy, tracheal or bronchial surgery and treatment of acute respiratory distress syndrome. But because the placement of a catheter into the tracheal lumen is needed for this high frequency ventilation, this method could not be applicable during fiberoptic intubation to improve oxygenation.

In this study, I administered oxygen via a nasal prong which is the simplest way it could be done. And I gave 5 L/min, which cannot raise F_IO_2 over 0.4, to evaluate whether the simple and routinely performed procedure could offer any advantage during fiberoptic intubation under general anesthesia.

Due to alveolar gas tension in proportional to mixed venous blood gas tension in apneic state, PCO_2 increases and PO_2 decreases (14, 19). General anesthesia usually increases alveolar dead space and shunt, which might have made the situation worse in this experiment. The volume of gas which crosses the alveolar-capillary membrane is proportional to the tension of that gas. The increase of alveolar oxygen tension by constant oxygen flow into the alveoli during apneic state might increase the volume of the gas crossing the alveolar-capillary membrane and also improve the elimination of carbon dioxide from capillary blood. But carbon dioxide elimination appears to be related to gas velocity, elimination being increased with increasing velocities and volume. Therefore, a large volume of oxygen to the alveoli has to be given to improve CO_2 elimination (20).

From several studies including Frumin et al. (15), the mean rate of rise of $PaCO_2$ in apneic anesthetized man was found to be 3.8 mmHg/min. Group II showed a similar increase of carbon dioxide tension to other studies but Group I revealed that it increased more than expected values which might also show the advantage of oxygen administration. From this result, if I use more oxygen, I may assume that I could get a much lesser degree of increase in carbon dioxide tension under the same experimental condition.

There was an interesting report by Mackenzie et al.

(5) who observed no advantages in carbon dioxide removal in pigs compared to apneic oxygenation in dogs, which may be due to the species anatomic differences, i.e. pig lungs are lobulated with septa and are without collateral airways. Their result suggests that endobronchial insufflation with or without oxygen supplementation may be an effective means of oxygenation and carbon dioxide removal in humans with chronic obstructive pulmonary disease, but not in neonates. More studies are needed to clarify this complicated issue.

The morbidly obese patient showed a more rapid decrease of arterial oxygen saturation compared to normal weight people, which is due to low functional residual capacity in the obese patient. Therefore, patients with obesity and other conditions that could effect functional residual capacity and other respiratory parameters, were excluded in this study.

Gembee et al. (21) observed an increase in safety interval until hypoxia occurred during intubation when enough denitrogenation was done with 100% oxygen because oxygen tension and degree of denitrogenation at the beginning of apnea had a serious effect on the onset time of hypoxia. Therefore, anesthesiologists routinely used at least 5 minutes of preoxygenation before attempting intubation to improve oxygenation in practice.

Teller et al. (22) reported that oxygen insufflation via nasopharyngeal cannular (3 L/min) provided at least ten minutes of adequate oxygenation in unintubated, denitrogenated, apneic patients whose airways are unobstructed. They suggested that nasopharyngeal oxygen insufflation may be life-saving by providing extra time to obtain control of the airway in a critical situation by significantly delaying the onset of hypoxia. In this experiment, probably because I gave oxygen through nasal prong which is far from the tracheal introitus and I could not guarantee the patency of the airway from the nasal prong to the tracheal lumen, I gave up continuing fiberoptic intubation which lasted more than 4 minutes. Various kinds of arrythmia could be occurred due to hypercarbia. Imai and Kemmotsu (1) reported that attempts at intubating a fully relaxed patient should be kept under 2 minutes. But this investigation showed that intubation could be kept until 3 minutes.

The results of this study showed that PaO_2 decreased from 489±48 mmHg to 345±78 mmHg, while $PaCO_2$ increased from 35.6±3.4 to 47.1±47 when I administered oxygen by nasal prong. The values of PaO_2 and $PaCO_2$ between the two groups at 3 minutes, were statistically significant implying that oxygen administration with nasal prong could broaden safety range during fiberoptic intubation in the apneic state.

In conclusion, first, I would say that oxygen administration via nasal prong is helpful in preventing the rapid fall of oxygen tension, and at the same time, the rapid elevation of carbon dioxide tension during fiberoptic intubation in the apneic state under general anesthesia. Second, intubation time can be extended until 3 minutes safely for an attempt on a fully relaxed patient.

REFERENCES

1. Imai M, Kemmotsu W. *Anesthesia adapter for fiberoptic endotracheal intubation for anesthetized patients. Anesthesiology 1989; 70: 374-8.*
2. Lehnert BE, Oberdorster G, Stutsky AS. *Constant flow ventilation of apneic dogs. J Appl Phys 1982; 53: 483-9.*
3. Smith RB, Babinski MF, Bunegin L. *Continuous flow apneic ventilation. Acta Anaesthesiol Scand 1984; 28: 631-6.*
4. Babinski MF, Smith RB, Bunegin L. *Normocapnia after five hours of continuous flow apneic ventilation in dogs. Anesthesiology 1984; 61: A510.*
5. Mackenzie CF, Shin B, Takeda J, Haris M, Helrich M. *Comparison of gas exchange during endobronchial insufflation and apneic oxygenation. Anesthesiology 1985; 63: A527.*
6. Babinski MF, Sierra OG, Smith RB. *Clinical application of continuous flow apneic ventilation. Acta Anaesthesiol Scand 1985; 29: 750-6.*
7. Longnecker DE, Murphy FL. *Introduction to anesthesia. Philadelphia: W.B. Saunders, 1992: 19-30.*
8. Lee SC, Kim SD. *The effect of endotracheal intubation and intravenous lidocaine on blood pressure and pulse rate during induction of anesthesia. Human Science 1985; 9: 575-83.*
9. Oh YS, Kim JW, Do SH, Lee KH, Yum KW. *Clinical study on fiberoptic awake intubation and self pronation in cervical spine disease patients. J Korean Soc Anesthesiol 1990; 23: 714-8.*
10. Meltzer SJ, Auer J. *Continuous respiration without respiratory movements. J Exp Med 1909; 11: 622-5.*
11. Draper WB, Whitehead RW. *Diffusion respiration in the dog anesthetized by pentothal sodium. Anesthesiology 1944; 5: 262-73.*
12. Comroe JH Jr, Dripps RD. *Artificial respiration. JAMA 1946; 130: 381-3.*
13. Enghoff H, Holmdahl MH, Fisholm L. *Diffusion respiration in man. Nature 1951; 168: 830.*
14. Holmdahl MH. *Pulmonary uptake of oxygen, acid-base metabolism, and circulation during prolonged apnea. Acta Chir Scand 1956; 212(Suppl): 128.*
15. Frumin MJ, Epstein RM, Cohen G. *Apneic oxygenation in man. Anesthesiology 1959; 20: 789-98.*
16. Payne JP. *Apneic oxygenation in anaesthetized man. Acta Anaesthesiol Scand 1962; 6: 129-42.*
17. Lunkenheimer PP, Raffleneul W, Keller H, Frank I, Dickhut HH, Fuhrmann C. *Application of transtracheal pressure-oscillations as a modification of "diffusion respiration". Br J Anaesth 1972; 44: 627.*

18. Klaain M, Smith RB. *High frequency percutaneous transtracheal jet ventilation. Crit Care Med 1977; 5: 280-7.*
19. Fraioli RL, Sheffer LA, Steffenson JL. *Pulmonary and cardiovascular effects of oxygenation in man. Anesthesiology 1973; 39: 588-95.*
20. Tweed WA, Phua WT, Chung KY, Lim E, Lee TL. *Tidal volume, lung hyperinflation and arterial oxygenation during general anaesthesia. Anaesth Intensive Care 1993; 21: 806-10.*
21. Gambee AM, Robert RE, Fisher DM. *Preoxygenation techniques: comparison of three minutes and four breaths. Anesth Analg 1987; 66: 486-70.*
22. Teller LE, Alexander CM, Gross JB, Frumin MJ. *Nasopharyngeal insufflation of oxygen prevents hypoxia in apneic patients. Anesthesiology 1988; 69: A729.*