Apnoeic oxygenation with high-flow nasal oxygen for laryngeal surgery

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Summary

Background: This study aims to evaluate the effectiveness of high-flow nasal oxygen as the sole method of gas exchange in apneic conditions for airway management during laryngeal surgery. *Subject and method:* From April to August 2023, 45 patients aged 30 to 69 underwent laryngeal surgery. Patients received total anesthesia and neuromuscular blocking agents for the duration of their surgery and airway management using a high flow oxygen 70 liters/minutes under apnoeic conditions as the sole method of gas exchange. *Result:* The mean (SD) apnoea time was 18.36 (4.97) minutes, and the time for laryngeal surgery was 16.82 (4.69) minutes. The oxygen saturation was stable during all procedures at 99-100%. A blood gas analysis showed hypercapnia and acidosis acute respiratory. However, the parameters returned to normal at 30 minutes postoperative. The blood pressure and heart rate were stable at times. All 45 patients were safe at the end of the operation. There were no complications such as bleeding, hemothorax, pneumothorax, or barotrauma. *Conclusion:* Apnoeic oxygenation with high-flow nasal oxygen for airway management during laryngeal surgery is a safe and effective method for gas exchange. The surgical field is ultimately spacious, with optimal conditions for laryngeal surgery.

Keywords: Laryngeal surgery, high-flow oxygen, apnoeic.

I. BACKGROUND

Endoscopic microsurgery is a revolution in surgery for laryngeal diseases. Many anesthetic techniques are also performed to meet the requirements for laryngotracheal surgery. In laryngeal surgeries, the surgeons and anesthesiologists work on the airway, so the surgical field is often narrow and difficult to operate. Therefore, controlling the airway safely while ensuring a spacious surgical field is the main task of anesthesiologists in laryngeal surgery[1, 2]. Recently, high-flow oxygenation has been applied through the nose, pharynx, laryngoscope, and laryngeal mask to provide oxygen for some laryngotracheal surgeries without endotracheal tube placement as well as prolonging apnea time in difficult intubation around the world[3]. This method does not require intubation or ventilation; the patient stops breathing, and oxygen exchange is provided through a high-flow oxygen system of 30-70 liters/minute, making the surgical field more spacious and convenient for surgeons to perform operations[4].

The study aims to evaluate the gas exchange effectiveness of the high-flow oxygen method at 70 liters/minute during apnea in laryngeal surgery.

II. SUBJECT AND METHOD

2.1. Subject

45 patients had indications for laryngeal surgery at the Department of Anesthesiology and Resuscitation at 108 Military Central Hospital, ≥ 16 years old, classified ASA I, II (according to the classification of the American Society of Anesthesiology - American Society of Anesthesiologists), Mallampati I, BMI < 30kg/m^2, from January to August 2023.

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2.2. Method

Prospective intervention study.

2.3. Preoperative preparation and materials

Omedha anesthesia ventilator, multi-parameter monitor, TCI (target-controlled infusion) system.

Newzelan high flow oxygenation system (VBM Medizintechnik GmbH, Sulz, Germany).

Rapid Point blood gas testing machine, depth of anesthesia monitor (BIS), Sentec transcutaneous CO_2 monitoring.

Flexible endotracheal tube and Proseal laryngeal mask.

Anesthesia agents: Propofol, rocuronium, fentanyl, morphine.

Emergency instruments.

2.4. Procedure

Careful preoperative assessment, especially ASA classification and Malampati classification.

Place an 18G peripheral intravenous line.

Monitoring the patient (Do not use pre-anesthetic drugs).

Induction: Give 100% oxygen through a mask. Slowly inject in order: Fentanyl 3mcg/kg; propofol TCI 3.5-4mcg/ml; esmeron 0.6mg/kg.

Anesthesia is maintained intravenously by combining propofol using TCI 3.5-4µg/ml, fentanyl 2-3µg/kg/h, and rocuronium 0.3mg/kg/h.

Intraoperative phase: Supply the oxygen at 70 liters/min. During this period, the patient is still under general anesthesia, has neuromuscular blocking agents, and stops breathing. Closely monitor SpO_2 and arterial blood gases (ABG). If SpO_2 < 90%, supply ventilation with 100% oxygen.

The end of surgery: The patient received good pain relief and reverse muscle relaxation with sugamadex. When the patient is awake and cooperative, breathing well with Vt > 8ml/kg; SpO_2 > 95%, TOF > 90%, stop using high flow and send the patient to the recovery room.

2.5. Monitoring and evaluation criteria

Patient characteristics: Age, gender, height, weight, ASA classification.

Surgical characteristics: Anesthesia time, surgery time.

Apnoeic time: Calculated by stopping ventilation and using high-flow oxygen until the patient can breathe well.

Results of anesthesia release after surgery.

The vital parameters were monitored continuously: Heart rate, mean artery pressure (MAP), SpO_2, and $TcCO_2$.

Arterial blood gas analysis was performed at the 7 periods : T0, T1, T2, T3, T4, T5, T6:

T0: Before using high flow

T1: After using high flow for 05 minutes.

T2: After using high flow for 10 minutes.

T3: After using high flow for 15 minutes.

T4: End of surgery.

T5: After using high flow.

T6: After stop using high flow for 30 minutes.

Complications and side effects in surgery include hypoxia, respiratory acidosis, pneumothorax, hemothorax, and pulmonary barotrauma.

III. RESULT

Table 1. Patient characteristics

Age $\bar{X} \pm SD$ Min-Max (year)	Height $\bar{X} \pm SD$ Min-Max (cm)	Weight $\bar{X} \pm SD$ Min-Max (kg)	Gender		ASA	
			Female n (%)	Male n (%)	I n (%)	II n (%)
40.50 ± 12.03 24-69	162.33 ± 6.57 155-178	60.83 ± 8.08 48-72	30 (66.7)	15 (33.3)	36 (80)	09 (20)

Comments: Patients aged 24 to 69, more women than men. ASA I were major.

Table 2. Surgical characteristics

Time	Min- Max	$\bar{X} \pm SD$
Anesthesia time (minute)	27- 36	29.18 ± 2.61
Surgery time (minute)	14 -30	16.82 ± 4.69
Apnoeic time using high flow oxygen (minute)	15 - 32	18.36 ± 4.97

Comments: The average time of apnea and use was 18.36 ± 4.97.

Table 3. Arterial blood gas exchange data

Time	T0 $\bar{X} \pm SD$	T1 $\bar{X} \pm SD$	T2 $\bar{X} \pm SD$	T3 $\bar{X} \pm SD$	T4 $\bar{X} \pm SD$	T5 $\bar{X} \pm SD$	T6 $\bar{X} \pm SD$
pH	7.32 ± 0.05*	7.26 ± 0.0.04	7.21 ± 0.04*	7.19±0.04*	7.18±0.06	7.25±0.06	7.30±0.05
$PaCO_2$ (mmHg)	46.13 ± 8.49*	56.15 ± 7.32	62.59 ± 7.39*	66.55±8.25*	67.42±11.04	55.07±9.97	48.02±9.14
PaO_2 (mmHg)	404.12±53.84*	371.61±52.87	355.47±71.06	347.25±71.78	376.29±72.24	363.44±43.54	249.31±135.44
Lactat (mmol/l)	1.06±0.28	1.08±0.35	1.28±1.84	1.00±0.34	1.03±0.35	1.07±0.26	1.08±0.31
HCO_3^- (mEq/L)	21.85±1.87	21.73±1.76	20.99±1.87*	20.67±1.63*	20.35±2.11	20.98±1.75	21.18±1.73
DaO_2 (mmHg)	265.84±52.81	286.49±53.23	301.39±71.54	289.60±79.02	293.48±56.10	337.64±125.87	401.55±153.95
Qs/Qt %	20.5±3.03	21.71±2.91	22.77±5.36	22.79±5.76	21.56±2.39	24.71±8.51	28.80±9.95

**: p<0.05 compare with T0 and T1*

Comments: Before using high-flow oxygen (T0), CO_2 pressure in the blood was normal. During surgery using high flow (T1, T2, T3), blood oxygen pressure was significantly higher than at T6, and acute respiratory acidosis was evident, showing a significant decrease in blood PH and an increase in $PaCO_2$ and HCO_3^-. However, these indices returned to normal at T6.

Table 4. Changes in respiratory and hemodynamic

Time	T0 $\bar{X} \pm SD$	T1 $\bar{X} \pm SD$	T2 $\bar{X} \pm SD$	T3 $\bar{X} \pm SD$	T4 $\bar{X} \pm SD$	T5 $\bar{X} \pm SD$	T6 $\bar{X} \pm SD$
Heart rate *(beat/min)*	72.00±10.63 *	81.64±14.48	85.73±18.33	95.38±13.11	96.90±15.66	91.60±16.95	86.60±13.05
MAP *(mmHg)*	86.00 ± 13.90*	88.36±12.78	92.18±15.43	107.50±32.46	93.00±15.25	87.70±16.07	86.8±8.69
SpO_2 (%)	99.90± 0.316*	99.91±0.302	99.82±0.405	99.25±0.463	98.90±1.595	99.20±1.229	100± 0.00
$TcCO_2$ (mmHg)	43.44±5.86	56.82 6.10	64.02±5.20	70.94±6.15	69.06±7.55	55.98±8.68	41.82±4.71

**: p<0.05 compare with T0*

Comments: Hemodynamics, SpO_2, and $TcCO_2$ were within normal limits.

Table 5. Side effects

Side effect	Number of patients (n)	Percentage %
Acute hypoxia ($PaO_2 < 60$. $SpO_2 < 90$)	0	0
Acute respiratory acidosis	45	100
Acute airway obstruction	0	0
Arrhythmia	0	0
Pneumothorax, hemothorax, pulmonary barotrauma	0	0

Comments: The main side effect during surgery was acute respiratory acidosis in all 45 patients and acute hypoxia in 0 patients. There were no arrhythmia, pneumothorax, hemothorax, or pulmonary barotrauma complications**.**

IV. DISCUSSION

Results in Table 1 show that the study group was mainly adults with an average age of 40.50 ± 12.03 years old. This is the working age, and it is necessary to use the voice in communication and daily work, so laryngeal diseases in general and vocal cord fibrosis will significantly affect communication, work quality, and life quality. The youngest in our study was 24 years old, and the oldest was 69. There are similarities because we proactively selected patients aged 16 and older in the patient selection criteria. The proportion of women was 66.7%, higher than that of men, with 33.3%. Many studies have shown that women speak about 20,000 words daily, 13,000 words more than men. In addition, in our study, female patients worked in jobs such as sales teachers more than male patients. Besides, vocal cord diseases, including vocal cord nodules, vocal cord polyps, and vocal cord cysts, are mainly found in males due to their occupation and living habits, especially subjects who have to talk a lot, such as teachers and singers.

During vocal cord endoscopy, surgical operations are often affected, obstructed, or obscured due to the endotracheal tube inserted through the trachea to ventilate. The high-flow oxygen system provides oxygen by gas flow through the surgical field. Apnoeic oxygenation is the ability to oxygenate when the lungs stop working. During this stage, oxygen is still transferred from the alveoli into the blood to meet the body's metabolic needs. This shift creates a pressure gradient in the alveoli and is compensated by elastic reflexes that reduce alveoli volume and facilitate CO_2 diffusion from the blood into the alveoli. This compensatory mechanism also creates a pressure gradient between the alveoli and the bronchial air, which increases the oxygen content in the alveoli and creates negative pressure in the alveoli when oxygen moves into the blood [4].

In our study, the mean complete apnea time was 18.36 ± 4.97 minutes, corresponding to the duration of high-flow oxygen, the most prolonged apnea time was 32 minutes. The patient remains anesthetized during this period and uses complete muscle relaxants, maintaining BIS 40-60, TOF 0. From November 2016 to March 2017, C. Lyons, M. Callaghan, and colleagues used nasal oxygen at 35-70 liters/minute without intubation on 28 patients during laryngeal and tracheal surgery. Patients were anesthetized entirely, with an average apnea time of 19 minutes and a maximum of 34 minutes. Most patients maintained $SpO_2 > 95\%$, only 4 patients had transient hypoxemia with SpO_2 86-90%, and CO_2 pressure in blood fluctuated between 45-86mmHg[5]. The authors concluded that apneic high-flow nasal oxygen can provide adequate oxygenation for laryngeal surgery without ventilation[4]. The safe apnea time was calculated when the patient began to stop breathing until the SaO_2 dropped < 90%[5]. In healthy people, the safe apnea time can be extended to 8-9 minutes if they have enough preoxygenation but only about 1 minute if using only air.

Results in Table 3 show that before using high-flow oxygen (T0), CO_2 pressure in the blood was normal. During laryngeal surgery using high-flow (T1, T2, T3), blood oxygen pressure was significantly higher than at T6 with PaO_2 > 170mmHg. Acute respiratory acidosis was shown by a decreased blood pH, lowest at T3 with pH 7.19±0.04 and $PaCO_2$ 78.75±14.09, HCO_3^- increases significantly. However, these indices return to normal immediately after coming out of anesthesia for 30 minutes at T6.

When a patient stops breathing and is provided with high-flow oxygen, on average, 200-250 ml/min of oxygen from the alveoli will be absorbed into the circulatory system, but only 8-20 ml/min of CO_2 will be excreted from the blood into the alveoli. Thus, apnea only leads to respiratory acidosis and increased CO_2 pressure in the blood without hypoxia. However, many authors have demonstrated that acute respiratory acidosis within the pH range > 7.13 is the acceptable safety limit for cases without contraindications[6, 7].

Recently, Gustafsson et al. reported 31 patients who had successful laryngeal surgery (polypectomy or tumor biopsy) during apnea using high-flow oxygen at a flow of 50 liters/min for induction of anesthesia and 70 liters/minute to maintain during the apnoeic phase[7]. Research by Shan-Han Yang et al. showed similar results to Gustafsson's, suggesting that high-flow oxygen is safe in anesthesia for simple laryngeal surgery such as a small polyp or cyst[8]. In a study, using high-flow oxygen in laryngeal surgery was safe. The rate of hypercapnia increased along with apnea time by 0.844mmHg per minute or 0.11kPa per minute, similar to other studies. However, using capnography to measure CO_2 is only applicable at the beginning and end of the anesthesia process[8].

In contrast, transcutaneous CO_2 measurement is a continuous measure well correlated with arterial blood gas CO_2. Several studies reported that high-flow oxygen during laser knife surgery had no adverse events or airway burning. Huang et al. used the laser knife with high-flow oxygen in 11 cases without any adverse events by turning off the oxygen for 40 seconds before using the laser. However, in research, a patient was reported to get burns in nasopharyngeal surgery using high-flow oxygen when using a laser knife. Still, the author concluded that high-flow oxygen is a safe and effective technique that overcomes the disadvantages of other methods in laryngeal surgery.

Results of Tables 4 and 5 show that during surgery, hemodynamic indexes, oxygen pressure, and capillary blood oxygen saturation (SpO_2) were all in the normal range, and lactate at all times was normal (< 2mmol) shows that the patient has no signs of ischemic tissue. The oxygenation method applied in the study is safe and effective with the usual indicators of gas exchange. In particular, the surgical field is downright spacious, and the surgery is unaffected by the tubes, wires, or tube changes. There were no arrhythmias or complications of pneumothorax, hemothorax, or pulmonary barotrauma.

V. CONCLUSION

Providing high-flow oxygen during apnea without intubation and ventilation can ensure safe gas exchange of patients in laryngeal surgery. Acute respiratory acidosis is the only side effect, but it quickly returns to normal at 30 minutes postoperative. The surgical field is spacious and convenient for surgery without requiring intubation and ventilation.

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