Comparison of Safe Apneic Period and Tracheal Intubation Duration Between Air Mask Ventilation and Pure Oxygen Mask Ventilation During General Anesthesia Induction Postprint

Authors: Li Zijia, Lu Kun, Wang Kai, Zhao Yingyin, Huang Xia, Jin Sanqing

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Abstract

Objective: To explore and compare the safe apneic period and tracheal intubation duration between air mask ventilation and pure oxygen mask ventilation during general anesthesia induction. Methods: Eighty patients with ASA physical status I-II, predicted to have no difficult airway and scheduled for elective surgery under general anesthesia with tracheal intubation, were selected and randomly divided into 2 groups using a random number method: Group I patients received routine preoxygenation with pure oxygen before anesthesia induction (n=40); Group II patients received air mask ventilation before anesthesia induction (n=40). Mask ventilation and tracheal intubation during induction were performed by two experienced anesthesiologists in both groups, while an assistant adjusted the gas supply (pure oxygen or air) and observed and recorded pulse oxygen saturation (SpO2) and related parameters. Cases where SpO2 fell below 90% before completion of tracheal intubation were considered failures, and pure oxygen mask ventilation was provided immediately. After completion of tracheal intubation, ventilation was withheld until SpO2 decreased to 90%. The number of failure cases, safe apneic period (i.e., duration of SpO2 90% under apnea state), and tracheal intubation duration were recorded. Results: There were no failure cases in either group. The safe apneic periods in Groups I and II were 469.5±143.0 s and 63.6±20.0 s, respectively, and the tracheal intubation durations were 34.4±12.6 s and 32.8±9.6 s, respectively. The safe apneic period in both groups was significantly longer than the tracheal intubation duration ($P<0.01$). There were no statistically significant differences between the two groups in tracheal intubation duration or in the number of cases with SpO2 90% upon completion of tracheal intubation ($P>0.05$). The safe apneic period in Group II was significantly shorter than that in Group I ($P<0.01$) and was significantly correlated with body mass index ($P<0.05$). Conclusion: For experienced anesthesiologists, general anesthesia induction with air mask ventilation can provide a sufficiently long safe apneic period to complete tracheal intubation.

Full Text

Comparison of Safe Duration of Apnea and Intubation Time in Face Mask Ventilation with Air Versus 100% Oxygen During Induction of General Anesthesia

Li Zijia, Lu Kun, Wang Kai, Zhao Yingyin, Huang Xia, Jin Sanqing
Department of Anesthesiology, Sixth Affiliated Hospital of Sun Yat-sen University, Guangzhou 510655, China

Abstract

Objective: To compare the safe duration of apnea and intubation time between face mask ventilation with air and 100% oxygen during induction of general anesthesia.

Methods: Eighty adult patients with ASA physical status I-II, without predicted difficult airways, scheduled for elective surgery under general anesthesia were randomized into two groups. Group 1 (n=40) received conventional preoxygenation with 100% oxygen, while Group 2 (n=40) received mask ventilation with air (FiO =0.21) before induction. Two experienced anesthesiologists performed mask ventilation and tracheal intubation during induction, while assistants adjusted the gas concentration (oxygen or air) and recorded pulse oxygen saturation (SpO) and related parameters. Cases where SpO decreased below 90% before completion of intubation were considered failures and received immediate mask ventilation with 100% oxygen. After successful tracheal intubation, mechanical ventilation was withheld until SpO decreased to 90%. The number of failure cases, safe duration of apnea (time from cessation of mask ventilation to SpO reaching 90%), and intubation time were recorded.

Results: No failure cases occurred in either group. The safe duration of apnea was 469.5±143.0 s in Group 1 and 63.6±20.0 s in Group 2, while intubation times were 34.4±12.6 s and 32.8±9.6 s, respectively. The safe duration of apnea was significantly longer than intubation time in both groups (P<0.01). There were no statistically significant differences between groups in intubation time or in the number of patients with SpO 90% at completion of intubation (P>0.05). However, Group 2' s safe duration of apnea was significantly shorter than Group 1' s (P<0.01) and showed significant correlation with body mass index (BMI) (P<0.05).

Conclusion: For experienced anesthesiologists, induction of general anesthesia with air mask ventilation can provide a sufficient safe duration of apnea to complete tracheal intubation.

Keywords: preoxygenation; general anesthesia; apnea; intratracheal intubation

Introduction

Clinically, all patients routinely receive preoxygenation before induction of general anesthesia. This classic method, also known as "denitrogenation," involves providing high-concentration oxygen (typically 100%) before induction to displace nitrogen from the respiratory tract through breathing movements, thereby increasing oxygen reserves in blood and alveoli and ensuring adequate time for tracheal intubation. This has been considered an essential step in traditional anesthesia induction for over half a century. For patients with normal cardiopulmonary function, this method provides approximately 7 minutes of safe apnea duration, defined as the time SpO remains above 90% during apnea. Current evidence indicates that most tracheal intubations can be completed within 40 seconds, with modern techniques shortening this to approximately 10 seconds. Even in patients with difficult airways, intubation can often be accomplished within about 20 seconds.

However, inhalation of high-concentration oxygen has been associated with complications including oxidative stress, coronary artery spasm, and atelectasis. Studies in mice and humans have demonstrated that these complications are significantly less severe when breathing air. Therefore, we hypothesized that induction of general anesthesia under air mask ventilation might offer benefits in reducing or preventing these complications. Meanwhile, as intubation techniques continue to improve and intubation times shorten, the necessity of routine preoxygenation for all patients warrants reconsideration.

The key to evaluating the feasibility and safety of anesthesia induction under air mask ventilation lies in whether it provides sufficient safe apnea duration for anesthesiologists to complete tracheal intubation. No relevant studies have been reported to date. This study compared the differences in safe apnea duration and intubation time between conventional preoxygenation and air mask ventilation to determine the feasibility and safety of anesthesia induction with air ventilation.

Methods

Study Design and Patient Selection

This randomized, double-blind study enrolled 80 patients aged 18-60 years, with ASA physical status I-II, BMI 18-30 kg/m², scheduled for elective surgery under general anesthesia. Exclusion criteria included predicted difficult intubation, hemoglobin <90 g/L, SpO <95% on room air, severe cardiopulmonary disease, high risk of reflux/aspiration, poor cooperation, or breath-holding time <30 s. Predicted difficult intubation was assessed using standard criteria including medical history, obesity, short neck, thyromental distance <6.5 cm, mouth opening

<2.5 cm, and Mallampati classification. All patients provided informed consent. The study was approved by the Ethics Committee of the Sixth Affiliated Hospital of Sun Yat-sen University and registered at https://clinicaltrials.gov (NCT03239678).

Patients were numbered sequentially (1-80) upon enrollment. SPSS 22.0 software generated random numbers corresponding to patient numbers, which were sorted in ascending order. Patients corresponding to the first 40 random numbers were assigned to Group 1 (preoxygenation), and the remaining 40 to Group 2 (air mask ventilation). Both patients and the anesthesiologists performing intubation were blinded to group assignment. Assistants managed gas concentration adjustments and recorded SpO and related parameters.

Anesthesia Protocol

Patients fasted for 6 hours and abstained from fluids for 2 hours before surgery. Thirty minutes before anesthesia, intramuscular phenobarbital sodium 0.1 g and atropine 0.5 mg were administered. After standard monitoring and establishment of intravenous access, 200 mL lactated Ringer' s solution was infused to prevent hypotension after induction. A left radial artery catheter was placed under local anesthesia with 2% lidocaine for continuous blood pressure monitoring. The SpO probe was placed on a finger without a blood pressure cuff, and its audio was muted to prevent the intubating anesthesiologist from estimating saturation values.

After recording baseline SpO in the supine position for 5 minutes, patients breathed the assigned gas through a well-sealed mask (FiO =1.0 for Group 1, FiO =0.21 for Group 2) at 6 L/min flow. Patients performed 8 deep breaths over 1 minute, followed by induction: midazolam 2 mg, propofol 1 mg/(kg · min) infusion, and fentanyl 4 g/kg infused over 90 seconds. Modified Observer' s Assessment of Alertness/Sedation (MOAA/S) score was assessed every 10 seconds until patients showed no response to shaking (MOAA/S=1). Propofol was then changed to maintenance infusion at 1 mg/(kg · min) and adjusted according to blood pressure. Cisatracurium 0.3 mg/kg was administered, followed by jaw thrust and firm mask application to ensure no leak, then assisted mechanical ventilation (tidal volume 10 mL/kg, rate 16 breaths/min). After 4 minutes of cisatracurium administration, ventilation was stopped for tracheal intubation, and Cormack-Lehane grade was recorded. All intubations were performed by two trained anesthesiologists with >5 years of experience using a Macintosh laryngoscope (blade size Mac3; tube size 7.5# for males, 7.0# for females). After intubation, the cuff was inflated but mechanical ventilation was withheld until SpO decreased to 90%. Fiberoptic bronchoscopy confirmed tracheal tube placement.

If SpO decreased below 90% during mask ventilation, immediate 100% oxygen mask ventilation was provided. If SpO decreased below 90% during intubation, intubation was completed as quickly as possible followed by 100% oxygen mechanical ventilation. If intubation could not be completed promptly, mask ventilation was resumed; if ventilation was inadequate, laryngeal mask or cricothyroid membrane puncture ventilation was considered. All three scenarios were considered failure cases.

After intubation confirmation and waiting for SpO to decrease to 90%, the tracheal tube was connected to the anesthesia machine for mechanical ventilation (tidal volume 10 mL/kg, rate 16 breaths/min, FiO =0.40). Once SpO returned to 96%, tidal volume was reduced to 6-8 mL/kg and rate to 12 breaths/min to prevent hyperventilation.

Observation Indicators

Patient demographics (gender, age, height, weight), safe duration of apnea (time from cessation of mask ventilation to SpO reaching 90%), intubation time (time from cessation of mask ventilation to cuff inflation completion), number of patients with SpO 90% at intubation completion, baseline SpO , SpO at intubation completion, time for SpO to return to 96% after connecting to the anesthesia machine, lowest SpO value during this period, and end-tidal CO (PetCO) at the end of mask ventilation and when connecting to the anesthesia machine.

Statistical Analysis

All data were analyzed using SPSS 22.0 software. Continuous variables were expressed as mean±standard deviation and compared using t-tests. Categorical data were analyzed using chi-square tests. $P<0.05$ was considered statistically significant.

Results

Among the 80 enrolled patients, 2 in Group 1 were excluded: one received 100% oxygen due to tongue base prolapse before muscle relaxant administration, and another had incomplete data recording.

Patient Demographics

No statistically significant differences were found between groups in age, gender, hemoglobin, BMI, ASA classification, or Mallampati classification ($P>0.05$,).

Comparison of Outcomes

All 38 remaining patients in Group 1 and all 40 patients in Group 2 had SpO 90% at intubation completion, with no statistically significant difference between groups ($P>0.05$,). There was no significant difference in intubation time between groups ($P>0.05$,).

Safe duration of apnea was significantly shorter in Group 2 (63.6±20.0 s) compared to Group 1 (469.5±143.0 s) ($P<0.01$,). In Group 2, safe duration of apnea showed significant correlation with BMI ($P<0.05$,) but not with age, gender, hemoglobin, breath-holding duration, or smoking status ($P>0.05$,).

Safe Apnea Duration vs. Intubation Time

In both groups, safe duration of apnea was significantly longer than intubation time ($P<0.01$, , [Figure 1: see original paper]).

Other Parameters

The lowest SpO value during the period before SpO returned to 96% after connecting to the anesthesia machine and the PetCO at connection were significantly lower in Group 2 ($P<0.01$,). No significant differences were found between groups in baseline SpO , time for SpO to return to 96%, or PetCO at the end of mask ventilation.

Discussion

Preoxygenation before anesthesia induction, also known as "denitrogenation," has been used clinically for over half a century. Increasing evidence suggests that inhaling high-concentration oxygen causes various adverse effects. Compared to FiO =0.4, FiO =0.8 significantly decreases oxygenation index, inhibits antioxidant stress response, and increases lactate and oxidative stress levels. Exposure of mammalian cells to high oxygen concentrations increases intracellular reactive oxygen species and impairs antioxidant and repair systems. High-concentration oxygen can also cause coronary artery spasm. In a study comparing coronary ultrasound in 7 healthy adults before and after 5 minutes of 100% oxygen inhalation, coronary vascular resistance increased by (20±4)% and blood flow velocity decreased by (15±3)% after oxygen administration. Additionally, patients receiving 0.6 FiO , 0.8 FiO , or 100% oxygen for 5.5 minutes before intubation, followed by mechanical ventilation with 0.4 FiO for 9 minutes, developed varying degrees of atelectasis; higher preoxygenation FiO correlated with more severe atelectasis. However, after 14 minutes of oxygen administration, the advantage of 0.8 FiO over 100% oxygen in reducing atelectasis diminishes.

In summary, conventional preoxygenation can cause adverse effects in anesthetized patients through oxidative stress, coronary spasm, and atelectasis. This study is the first to confirm that under air mask ventilation conditions, the safe duration of apnea during anesthesia induction reaches 63.6±20.0 s, providing experienced anesthesiologists with adequate time to complete tracheal intubation.

We found that safe duration of apnea under air ventilation (FiO =0.21) was significantly shorter than with preoxygenation ($P<0.01$), consistent with Edmark et al.' s findings. In Group 2, safe duration of apnea was not associated with age, gender, hemoglobin, breath-holding duration, or smoking, but correlated significantly with BMI. Patients with BMI 25 had significantly shorter safe apnea duration than those with normal weight, consistent with Jense et al.' s finding that overweight or obese patients develop hypoxemia more readily during apnea, likely due to reduced lung capacity, maximal inspiratory volume, expiratory reserve volume, functional residual capacity, and respiratory system compliance.

No significant difference in intubation time was observed between groups. Excluding the 2 excluded cases, the remaining 78 patients had an intubation time of 32.8±9.6 s, similar to other studies. Alternative intubation devices (e.g., light wand, video laryngoscope) show advantages in shortening intubation time, particularly for difficult airways or non-anesthesiologists. In a study of 265 patients using a light wand, 206 with difficult intubation history or prediction had intubation times of 25.7±20.1 s, while 59 after failed conventional intubation had times of 19.7±13.5 s. Another study using a light wand in 152 patients achieved first-attempt success in 148 cases (97.4%) with intubation time of 11.5±6.7 s. As intubation technology advances, the safety and feasibility of anesthesia induction under air ventilation may be further confirmed.

In our 80 patients, all 38 evaluable patients in Group 1 and all 40 patients in Group 2 had SpO 90% at intubation completion, with no statistically significant difference. In conclusion, compared to intubation time, anesthesia induction with air mask ventilation provides experienced anesthesiologists with adequate safe apnea duration to complete tracheal intubation.

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Note: Figure translations are in progress. See original paper for figures.