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Original Article

Improvement of airway ventilation effect in recovery of anesthesia with oxygen supply tracheal tube

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Abstract: *Background:* During recovery from general anesthesia, patients need to experience disadvantages such as carbon dioxide accumulation and increased airway pressure. *Objectives:* To observe whether the oxygen supply tracheal tube could reduce the airway resistance of patients during recovery from anesthesia. *Methods:* Ninety patients under general anesthesia for limbs operation were averaged into three groups applied with tracheal tube No. 7.0. Patients were sent to PACU after surgery with tracheal tube. After patients got autonomous respiration, three groups were supplied oxygen with three methods at the oxygen flow rate of 3 $L \cdot min^{-1}$: Group C were supplied by T-tube; Group T were administered via nasal prongs; Group O were supplied by oxygen supply tracheal tube connecting to an oxygen humidification bottle. *Results:* When train of four stimulation (TOF) T4/T1≥0.9, heart rate (HR), mean arterial blood pressure (MAP), peak airway pressure (P_{peak}), airway plateau pressure (P_{pla}), mean airway pressure (P_{mean}) and Raw of patients in Group C and Group T increased obviously compared to Group O. There was no obvious difference between Group C and Group T. There was no obvious difference in respiration rate (RR) and tidal volume (V_T) among three groups. *Conclusions:* Oxygen supply tracheal tube was able to supply oxygen but not increase airway pressure or resistance. It helped patients get rid of auxiliary breathing devices. It is of great significance to protect airway of patients and to reduce the work of breathing.

Keywords: Oxygen supply tracheal tube, airway pressure, airway resistance, work of breathing

Introduction

Patients with general anesthesia after operation have to breathe carrying tracheal tubes before extubation. During this course, common tracheal tubes have to resort to auxiliary breathing devices and may lead to increase airway resistance and work of breathing for patients. This study analyzed the application of an innovative oxygen supply tracheal tube. The purpose of this study was to verify the function of oxygen supply tracheal tube supplying sufficient oxygen without increasing airway pressure and airway resistance, ensuring the safety of patients during the recovery from general anesthesia.

Materials and methods

Study design

The study was registered in Chinese Clinical Trial Registry (Grant No. ChiCTR-INR-16009047). After local ethical committee approval (Fudan University and Shanghai Pudong Hospital Human Research Ethics Committee) and written informed consent were obtained, 90 patients with total intravenous anesthesia (TIVA) for limbs operation were enrolled between August 2016 and December 2016. They were allocated randomly by sealed envelopes, according to a computer-generated sequence of random numbers, to undergo with tracheal tube No. 7.0: Group C with common tracheal tube; Group T with tracheal gas insufflation; Group O with oxygen supply tracheal tube (**Figure 1**).

Inclusion criteria: (1) ASA: Grade I-II; (2) Age: 25-60; (3) Body fat percentage: Male at 10%-18%; Female at 17%-25%; (4) BMI at 18.5-24.9, Weight at 50 kg-70 kg.

Exclusion criteria: (1) Pulmonary disease history such as asthma, chronic bronchitis; (2) Thoracic or pulmonary history; (3) Smokers abstaining for less than four weeks before sur-

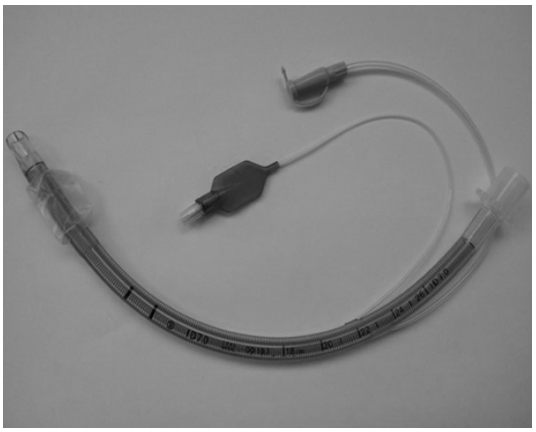

Figure 1. Additional oxygen could be supplied to patients through the pipeline embedded in the oxygen supply tracheal tube's wall.

gery; (4) Patients with irregular treatment of hypertension or poor controlled hypertension.

Methods

General anesthesia was induced with midazolam 0.05 mg·kg^{-1}, propofol 2 mg·kg^{-1}, sufentanil at 0.5 μg·kg^{-1} and cisatracurium 0.25 mg·kg^{-1}. Tracheal tube No. 7.0 was used for oral intubation. After confirmation of the tube location, controlled ventilation by anesthesia machine breathing was applied.

Maintenance of anesthesia was conducted with BIS monitoring. Propofol was adjusted to maintain BIS between 45 and 55. With TOF monitoring, cisatracurium at 0.1 mg·kg^{-1} was timely supplemented. Sufentanil at 0.3 μg·kg^{-1} was supplemented in necessary. HR at 12 bpm and V_T at 8-10 ml·kg^{-1} were adjusted according to weight and maintaining $PetCO_2$ at 32.5±2.5 mmHg. Once the operation was finished, neostigmine or naloxone was not applied and the intubated patients were transferred to PACU with continuous infusion of propofol maintaining BIS at 70-80.

Upon entering PACU, basic vital signs were recorded, including heart rate (HR), mean arterial blood pressure (MAP) and SPO_2. Patients were continuously pumped propofol before extubation in PACU to maintain bispectral index (BIS) between 70 to 80 and train of four stimulation (TOF) being consecutively monitored. Patients without autonomous respiration were applied with mechanical control breath by anesthesia machines at the oxygen flow rate of 3 L·min^{-1}. After patients recovered to autonomous respiration, anesthesia machine was set under manual respirator model with APL completely opened. Three groups were supplied oxygen with three methods respectively at the oxygen flow rate of 3 L·min^{-1}. Group C were by T-tube with the other end connecting to anesthesia machine and oxygen flow closed. Group T were with anesthesia machine's oxygen flow closed, and oxygen was supplied by a slim hollow tube set in the tracheal tube via an extension tube, connecting to oxygen humidification bottle. Group O were with anesthesia machine's oxygen flow closed, and oxygen was supplied by oxygen supply tracheal tube connecting to oxygen humidification bottle. When TOF was equal to or more than 0.9, RR, HR, MAP, SPO_2, respiration rate (RR), tidal volume (V_T), peak airway pressure (P_{peak}), airway plateau pressure (P_{pla}), mean airway pressure (P_{mean}) and airway resistance (Raw) were recorded.

The study should be stopped and artificial respiration should be performed at any time if the patient's SpO_2 was below 95%. No patients dropped from this study during the study period.

Statistical analysis

Fisher's exact test was adopted for the comparison of basic profile of patients in three groups. The respiratory parameters in all three groups were in accord with the normal distribution. The continuous data are presented as mean ± standard deviation. One-way ANOVA statistical analysis was adopted to HR and MAP among groups in PACU. The RR, V_T, P_{peak}, P_{pla}, P_{mean} and Raw among groups using ANOVA with Bonferroni corrections. Statistical software version SPSS 20.0 was used. $P<0.05$ was considered as statistical difference.

Results

Comparison of basic profile of patients in different groups was set: no obvious difference ($P>0.05$) for gender percentage, age, weight, operative site, surgery duration (**Table 1**).

There was no statistical significance in baseline HR ($p=0.1924$) and MAP ($p=0.1312$) among the three groups at the entrance into PACU. When TOF T4/T1≥0.9, HR ($p<0.0001$) and MAP ($p<0.0001$) of the patients in Groups C and T

Table 1. Comparison of basic profile of patients in different groups

	Group C	Group T	Group O	*P*-value
Gender (male/female)	16/14	15/15	13/17	0.7325
Age (yr)	45 (11; 27-56)	46 (10; 25-53)	44 (13; 28-60)	0.7944
Weight (kg)	64 (4; 50-68)	66 (5; 53-70)	65 (3; 52-67)	0.1714
Surgical site (arms/legs)	14/16	17/13	16/14	0.7322
Duration of surgery (min)	102 (15)	108 (13)	105 (12)	0.2276

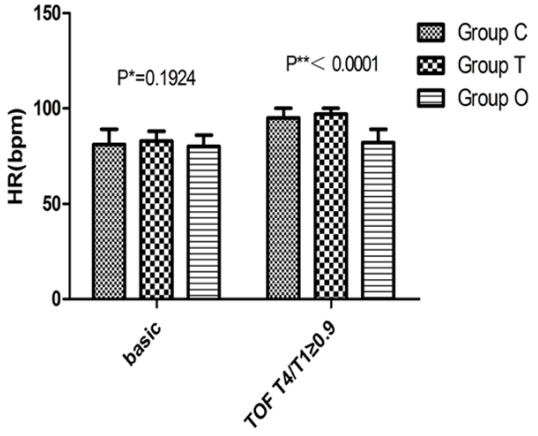

Figure 2. HR comparison among groups was set when the patients entered into PACU (left) and TOF T4/T1≥0.9 (right).

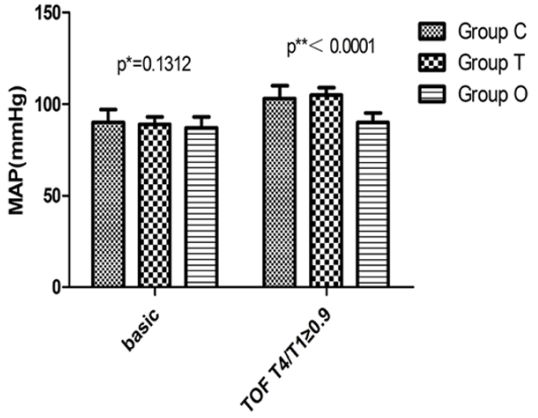

Figure 3. MAP comparison among groups was set when the patients entered into PACU (left) and TOF T4/T1≥0.9 (right).

increased obviously as compared to those of Group O. There was no obvious difference between Group C and Group T (P>0.05). It was noted that the work of breathing for patients in Group C and Group T increased obviously (**Figures 2** and **3**).

When TOF T4/T1≥0.9, there was no statistical significance in RR (p=0.3597) and V_T (p=0.2721) among the three groups. It was noted that patients in all groups could maintain the same sufficient RR and V_T (**Table 2**).

When TOF T4/T1≥0.9, there was no statistical meaning (P>0.05) for P_{peak}, P_{pla}, P_{mean} and Raw between Group C and Group T, but all obviously higher than Group O with statistical meaning (P<0.05). It revealed that patients in Groups C and T had to overcome more Raw to maintain normal V_T, therefore increasing work of breathing, potentially threatening the safety of the airway (**Figures 4** and **5**).

Discussion

For patients with general anesthesia, the airway management after surgery in PACU is very critical. Any misconduct could lead to complication such as laryngismus, high airway pressure and hypoxemia. The proper and effective management of airway could enable patients a safe and stable anesthesia recovery period [1].

For patients having laparoscopic operation, airway pressure arose obviously after carbon dioxide pneumoperitoneum. And high airway pressure would jeopardize airway function [2]. For patients having thoracoabdominal surgery, the postoperative soreness could significantly impact the amplitude of spontaneous breathing [3, 4]. Therefore, this study selected limbs surgery as the analysis target. Meanwhile, inhalation anesthetic would lead to cough, airway secretions increase, bronchial smooth muscle relaxation and so on, which would impact the respiratory parameters of the patients [5]. Therefore, this study adopted TIVA as anesthesia method.

Patients with general anesthesia after surgery usually had residual effect of muscle relaxation during the recovery of anesthesia in PACU. Tsai [6] and Baillard's [7] suggested extubation would cause respiratory depression to many patients during the recovery period of general anesthesia, and further threatening life security [8, 9]. With propofol pumping to maintain BIS between 70 and 80 in PACU, extubation when TOF detecting T4/T1≥0.9 could effectively prevent patients not only from bucking and fluctua-

Table 2. Comparison of RR and V_T of patients in different groups

	Group C	Group T	Group O	*P*-value
RR (bpm)	17±3	18±2	17±4	0.3597
V_T (ml)	578±15	564±22	559±26	0.2721

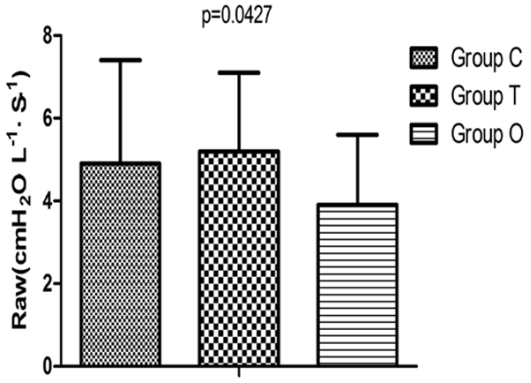

Figure 4. Assistive breathing tools increased airway resistance in Groups C and T.

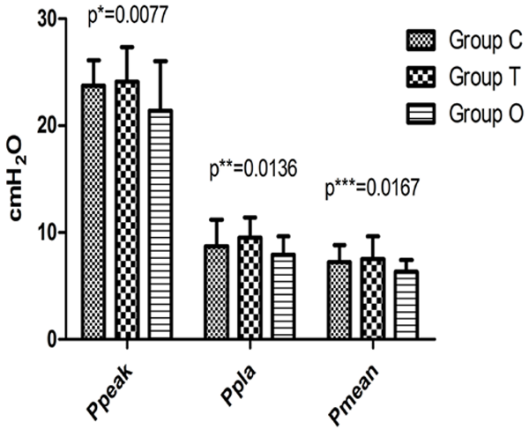

Figure 5. The P_{peak}, P_{pla} and P_{mean} in Group O were significantly lower than those in Groups C and T. Patients in Group O didn't need to overcome increased airway pressure to maintain normal breathing.

tion of hemodynamics [10], but also from respiratory depression due to extubation [11]. This study monitored BIS and TOF concurrently to main the depth of anesthesia and degree of muscle relaxation synchronously at the same level. This approach had patients keeping unconscious in superficial anesthesia status while enabling enough muscle strength to keep the spontaneous breathing.

In order to reduce the stress response of patients in PACU, researchers made a lot of efforts [12]. But their research were all focused on extubation under sedation via medication or in deep anesthesia, not reaching to the improvement of tracheal tube. The oxygen supply tracheal tube used in this study is an innovative tracheal tube with steel wire. The supporting function of steel wire could effectively avoid the airway obstruction caused by the bend-over of tracheal tube, ensuring smooth breathing. In addition to the lumen as normal tracheal tube having, the tube wall has another hollow pipeline which is a slim tube allowing certain oxygen flow passing with the front end opened in inner wall of the edge of the tracheal tube. This structure can significantly increase oxygen supply and accelerating CO_2 expelling without impact to diameter of tracheal tube and effective cross section, not increasing the resistance of inspiratory and expiratory during the spontaneous breathing. Meanwhile, it can eliminate dead space and reducing the resistance of breathing, generating the obvious advantage in the protection to the cardiac and pulmonary function of the patients during the recovery from anesthesia [13]. Its special structure can also effectively eliminate the possibility of hypoxemia incurred during tracheal suction.

This study revealed that the oxygen supply tracheal tube can effectively smooth patients' airway, securing the safe oxygen supply to patients, ensuring a safe and smooth recovery process from general anesthesia. It can reduce not only patients' airway pressure and resistance, but also the work of breathing at the maximum protection to the cardiac and pulmonary function and respiratory function of patients during the recovery from anesthesia. All these merits help the entire recovery after the surgery.

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Disclosure of conflict of interest

None.

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