Jing Xu, MD^{1*}
Zheng Yao, BD^{1*}
Shaoqing Li, MD¹
Lianhua Chen, MD²

¹Department of Anesthesiology, Eye Ear Nose and Throat Hospital, Fudan University, Shanghai 200031, China

²Department of Anesthesiology, First People's Hospital, Shanghai Jiao Tong University, Shanghai 200080, China

* These authors contributed equally to this work

A non-tracheal intubation (tubeless) anesthetic technique with spontaneous respiration for upper airway surgery

Abstract

Background: The most important consideration for administration of anesthesia in upper airway surgery is maintenance of a patient's airway for optimal surgical exposure, adequate ventilation and sufficient depth of anesthesia. The tubeless anesthetic techniques, including total intravenous anesthesia with a combination of propofol and remifentanyl or inhalation anesthesia with the insufflation of anesthetic gas, are considered experimental in many countries.

Methods: Fifteen pediatric (8 to 60 months) and 16 adult (23 to 55 years) patients were included in the study. Anesthesia (gas insufflation) was induced into the pediatric patients by inhalation of 8% sevoflurane in 8 L/min oxygen flow. An endotracheal tube, inserted through the nasal or oral cavity with its tip in the laryngopharynx, was used to maintain anesthesia with 3%-6% sevoflurane in 4 L/min oxygen flow. Total intravenous anesthesia was induced in adult patients by inhalation, 8% sevoflurane in 8 L/min oxygen flow, combined with intravenous injections of propofol (1.5-2 mg/kg) and fentanyl (1.5-2 µg/kg). Assisted ventilation was maintained by use of a face or laryngeal mask. Propofol infusion at 200-300 µg/kg/min, combined with remifentanyl infusion at 0.06-0.2 µg/kg/min, was used for maintaining anesthesia.

Results: All patients had surgery under tubeless anesthesia with steady spontaneous respiration. The mean time from induction of anesthesia to unconsciousness was 16 ± 3 s and 36 ± 14 s in pediatric and adult groups, respectively. The average times from induction of anesthesia to the attainment of necessary anesthetic level for surgery while keeping steady spontaneous respiration was 4.17 ± 0.96 min and 8.69 ± 3.17 min in pediatric and adult groups, respectively. The frequency and extent of respiration and heart rate were maintained within the normal range; SpO₂ was >98%. None of the patients developed complications.

Conclusion: Tubeless anesthesia with spontaneous ventilation induced in patients can provide both an interference-free operative field and continuous observation of airway activity, which may provide an effective approach in excellent surgical conditions for the actual airway operation.

Correspondence to:

Lianhua Chen

Department of Anesthesiology, First People's Hospital, Shanghai Jiao Tong University, 100# Haining Road, Shanghai 200080, China.

Email: chen_lianhua@163.com

Manuscript submitted 12th March, 2013
Manuscript accepted 5th May, 2013

Clin Invest Med 2013; 36 (3): E151-E157.

Table 1. Criteria for grading laryngeal obstruction preoperatively

Grade	Clinical symptoms
Grade I	Dyspnea appears only in exercise
Grade II	Dyspnea appears at rest and is aggravated with exercise; sleeping and eating is not influenced; no dysphoria
Grade III	Obvious inspiratory dyspnea and laryngeal stridor; the sign of a concave in supersternal notch and supraclavicular fossa; sleeping and eating is influenced; dysphoria
Grade IV	Severe dyspnea; cyanosis; disorientation; coma

The main challenge for upper airway surgery is the requirement for the simultaneous use of the same airway by both anesthesiologists and surgeons. These operations include implantation and removal of an airway dilator, resection of laryngeal papillomas or airway tumours, airway laser surgery, removal of a foreign body from the airway and various airway endoscopies. A compromised airway, caused by the airway lesion itself, is often a pre-existing risk factor for induction of anesthesia. To counteract the strong airway stimulation induced by suspension laryngoscopy, a sufficient depth of anesthesia must be maintained. If pathological changes are located in certain sites, such as the subglottis, tracheal intubation may disturb the operative field and interfere with the operative approach.

An endotracheal tube can be inserted to decrease the disturbance of the operative field, but subglottic lesions may still be obscured by the catheter. Tubeless techniques, in which tracheal intubation is not used, are under investigation by a number of groups worldwide. These techniques, including jet ventilation [1-3] and the apneic method with intermittent ventilation[4], can provide a satisfactory surgical approach, but certain problems are still present. Patients undergoing jet ventilation receive a neuromuscular block that often makes diagnostic observations of the larynx or trachea impossible after endoscopic insertion. In addition, blood and tissue fragments might be propelled into the lower airway by supraglottic jet ventilation. Severe complications, including pneumothorax, may be induced by improper application of jet ventilation. In contrast, the apneic method can only provide transient operation time and frequent alternating between the surgeon(s) and anesthesiologist(s) in the airway may not only make manipulation troublesome, but repeated intubations can also result in airway injury. Since the 1970s, spontaneous respiration anesthesia without tracheal intubation has been explored and recommended for this kind of surgery, but it has not been generally accepted because of technical difficulties. Since the introduction of new anesthetics, such as propofol, sevoflurane and remifentanyl, the use of spontaneous respiration anesthesia has been accepted [5-

7]. Currently, in international first-class hospitals, tubeless anesthetic techniques, including total intravenous anesthesia with a combination of propofol and remifentanyl [8,9] or inhalation anesthesia with the insufflation of anesthetic gas, have been widely used for upper airway surgeries [10,11]. These techniques, however, are still considered experimental in developing countries. This study investigates a tubeless anesthetic technique, combined with spontaneous respiration, in either total intravenous anesthesia (adults) or insufflation of anesthetic gas (pediatrics) in upper airway surgery.

Materials and Methods

A total of 31 patients (15 children and 16 adults), scheduled for upper airway surgery, were included in this study. Approval was obtained from the hospital's Human Research Committee prior to the study. Informed consent was obtained from adult patients or the parents or legal guardians of the pediatric patients prior to the surgical procedures. The degree of laryngeal obstruction was evaluated preoperatively using clinical indicators of general appearance, voice quality and ventilation pattern (Table 1). In the pediatric group, there were eight males and seven females, ages 8 to 60 months and weighing 6 to 20 kg. The surgical methods and pathology were composed of suspension laryngoscopy for removal of intratracheal papilloma (four cases) and granulomatosis (three cases), diagnostic tracheoscopy for subglottic/tracheal stenosis (three cases) and laryngeal tracheomalacia (five cases). The degree of laryngeal obstruction was defined as grade I in three cases, grade II in 11 cases and grade III in 1 case. In the adult group, there were six males and 10 females, ranging in age from 23 to 55 years old and weighing from 50 to 76 kg. The disease categories and treatments consisted of suspension laryngoscopy for resection of posterior vocal cord or intratracheal tumours in 10 cases and injection of abdominal fat into the vocal cord for unilateral vocal cord paralysis in six cases. The degree of laryngeal obstruction was defined as grade I-II in all patients (Table 2). No tracheotomies were performed before surgery. No preoperative sedatives and/or narcotic analgesics were administered. Atropine (0.01 mg/kg) and methylprednisolone (2 mg/kg) were injected intravenously before induction of anesthesia. Inhalation anesthesia with insufflation of anesthetic gas was used in the pediatric patients and total intravenous anesthesia was given to the adult patients.

Anesthetic gas insufflation technique (pediatric group)

Anesthesia was induced by inhalation of sevoflurane at an initial concentration of 8% in 8 L/min oxygen flow through a face

Table 2: Characteristics of patients

	Pediatrics	Adults
Number of patients	15	16
Age (Months for children, years for adults)		
Mean $\pm$ SD	26.09 $\pm$ 19.79	40.73 $\pm$ 10.13
Range	8 - 60	23 - 55
Gender (M/F)	8/7	6/10
Weight of patients (kg)		
Mean $\pm$ SD	12.64 $\pm$ 4.61	61.18 $\pm$ 7.63
Range	6 - 20	50 - 76
Pathology of diseases		
Intratracheal papilloma	4	0
Subglottic granuloma / tumour	3	10
Subglottic/tracheal stenosis	3	0
Laryngeal malacia	5	0
Vocal cord paralysis	0	6
Degree of laryngeal obstruction		
I	3	6
II	11	10
III	1	0
IV	0	0

mask. Insertion of an intravenous catheter was followed by infusion of Ringer's solution after the patients became unconscious as indicated by midline pupils. Facemask inhalation was continued, with the concentration of sevoflurane and oxygen flow adjusted to 3-6% in 8 L O₂/min, until the temporomandibular joint relaxed while still maintaining steady spontaneous breathing. Lidocaine aerosol was then sprayed over the epiglottis using laryngoscope guidance (4.5 mg/press, 2-3 press, add up to 9-13.5 mg). An endotracheal tube (size 3.0-4.5) was inserted through the nasal or oral cavity until its tip slid into the laryngopharynx but did not enter the trachea. Subsequently, the anesthetic gas and oxygen were insufflated into airway through the endotracheal tube for maintaining anesthesia (Fig. 1). The concentration of sevoflurane was maintained at 3%-6%, and oxygen flow was 4 L/min. During the entire surgical procedure, the amplitude and frequency of spontaneous respiration were closely monitored by observing chest excursions and auscultation of the lungs. Heart rate and pulse oxygen saturation (SpO₂) were continuously monitored; intravenous injection of fentanyl at 0.5 μ g/kg and propofol at 1 mg/kg were applied when the depth of anesthesia was not enough, as

indicated by an increase in heart or spontaneous respiratory rates.

Total intravenous anesthesia technique (adult group)

The induction of anesthesia was performed by inhalation of 8% sevoflurane in 8 L/min oxygen flow through a face mask, and by the simultaneous intravenous injection of propofol (1.5-2 mg/kg) and fentanyl (1.5-2 μ g/kg). Most patients lost spontaneous respiration at approximately 2 min after the injection. Assisted ventilation was maintained by the facemask. Propofol infusion at 200-300 μ g/kg/min combined with remifentanyl infusion at 0.06-0.2 μ g/kg/min was subsequently used for maintaining anesthesia. Among the 16 patients, six who were scheduled for vocal cord fat injection were given laryngeal mask airway insertion during the period when the abdominal fat was obtained, which usually took about 20 min. The dosages of propofol and remifentanyl were regulated under laryngeal mask ventilation, which was manually assisted until the patients recovered steady spontaneous respiration and P_{ET}CO₂ was maintained at 35-45 mmHg. The laryngeal mask was removed after suturing of abdominal wounds and epiglottic lido-

FIGURE 1. An endotracheal tube was inserted until its tip slid into the laryngopharynx but did not enter into the trachea. Anesthetic gas was insufflated through this tube. The arrow indicates the tracheal tube.

FIGURE 2. Tubeless anesthesia provides an unimpeded surgical approach for resection of the posterior vocal cord tumour.

FIGURE 3. Tubeless anesthesia with spontaneous respiration could provide the advantage of being able to observe the degree of closure of the anterior vocal cord after adequate fat injection.

caine aerosol spray had been administered (4.5 mg/press, 3-4 press, add up to 13.5 -18 mg). Vocal cord fat injections were then performed under tubeless spontaneous respiration anesthesia. In the other 10 patients, who underwent resection of airway tumours, manually-assisted ventilation was applied by a facemask, and the dosages of propofol and remifentanyl were regulated until the patients recovered steady spontaneous respiration and maintained $P_{ET}CO_2$ at 35-45 mmHg. The facemask was then removed, epiglottic lidocaine aerosol spraying administered and the operation was performed under tubeless spontaneous respiratory anesthesia; the required oxygen was then insufflated into the airway through the lateral aperture of the suspension laryngoscope at a flow rate of 4 L/min. The patients' chest and abdominal wall excursions were closely monitored during the surgery so as to judge the extent and frequency of spontaneous respiration. Heart rate and pulse oxygen saturation (SpO_2) were continuously monitored, and the rate of propofol and remifentanyl infusion was regulated according to the heart rate or frequency of spontaneous respiration.

The demographics of the patients, including age, gender, weight, pathology of disease and degree of preoperative laryngeal obstruction, were recorded. Information including the dose and agents of induction and maintenance of anesthesia, the concentration of inhalation anesthetics, oxygen flow, intravenous anesthetics and analgesics infusion rate, the duration of operation and emergence from anesthesia and intraoperative or postoperative complications were also recorded. The activity of the glottis vera was continuously observed through a rigid tra-

cheoscope connected to a video system. Occurrence of laryngeal or bronchial spasm can be detected by the observation or pulmonary auscultation: if spontaneous respiration decreases to the extent that SpO_2 progressively declines, or laryngeal/bronchial spasm occurs, tracheal intubation must be performed and the tubeless anesthesia procedure should be considered a failure. Complications, including body movements resulting in interruption of the surgery, arrhythmia, SpO_2 less than 90% and the delay of emergence from anesthesia, were considered adverse events.

Results

Pediatric group (anesthetic gas insufflation technique)

The average time from induction of anesthesia to unconsciousness was 16 ± 3 s. The average concentration of sevoflurane for induction was $6.36 \pm 1.21\%$ and oxygen flow was 8 L/min. The average time from induction of anesthesia to the attainment of necessary anesthetic level for surgery, while keeping steady spontaneous respiration, was 4.17 ± 0.96 min. The average concentration of sevoflurane for maintaining anesthesia was $5.7 \pm 1.32\%$ and oxygen flow was 4 L/min and the frequency of spontaneous respiration was maintained between 25-35 breaths/min. Five patients underwent intravenous injection of fentanyl at 0.5 μ g/kg/time and propofol at 1 mg/kg/time when the frequency of spontaneous respiration or heart rate had increased; the ages of those five patients were >32 months (mean age=43.6 months). The duration of surgery was 15-60 min and the average time was 27.6 ± 3.67 min. The duration of emer-

gence from anesthesia ranged from 2-10 min, with an average time of 6.2 ± 2.23 min.

Adult group (total intravenous anesthesia technique)

The mean time from induction of anesthesia to unconsciousness was 36 ± 14 s. The average dose of propofol for induction was 103 ± 20.03 mg and fentanyl 118.18 ± 33.71 μ g. The average times from the beginning of induction of anesthesia to the attainment of necessary anesthetic level for surgery while keeping steady spontaneous respiration were 8.69 ± 3.17 min. The dose of propofol for maintaining anesthesia was 221.82 ± 29.94 μ g/kg/min and remifentanyl 0.10 ± 0.03 μ g/kg/min. The frequency of spontaneous respiration was maintained between 10-15 breaths/min. The duration of operation that occurred in the airway under tubeless anesthesia ranged from 6-40 min and the average was 16.73 ± 10.59 min. The average time for emergence from anesthesia ranged from 6-10 min; the average time was 7.82 ± 1.40 min.

All patients had their surgeries performed and completed under tubeless anesthesia with steady spontaneous respiration. The frequency and extent of respiration and heart rate were all maintained within the normal range, and SpO₂ was kept higher than 98%. None of the patients had adverse events such as arrhythmias, laryngeal or bronchial spasms, body movements resulting in interruption of the surgery, or delay of emergence from anesthesia. None of the patients required postoperative tracheal intubation.

Discussion

Successful airway management can provide excellent surgical conditions for the actual airway operation. Tubeless anesthesia has been widely welcomed as a way to improve airway management [10,11]. Currently, there are three main types of tubeless anesthesia techniques. 1) The intermittent apnea technique can be used in any anesthetic procedure. After a short period of hyperventilation with 100% oxygen through a facemask or endotracheal tube, the ventilation is temporarily stopped by removal of the facemask or endotracheal tube allowing a short surgical procedure to occur within a time frame of 2-5 min. When the SpO₂ decreases to 90-92%, ventilation is then reinitiated by reintubation or reapplication of the facemask. The alternating of ventilation and operation is performed until the end of surgery. This method is only feasible in short, simple and uncomplicated surgeries such as removal of intratracheal residual focus. In the current study, the average operation time in the pediatric group was 27.6 ± 3.67 min, and in the adult group, it was 16.73 ± 10.59 min; none of the surgi-

cal procedures used in our study could be completed in 2-3 cycles of alternating ventilation-surgery so this method was not attempted. 2) Jet ventilation requires the use of a muscle relaxant to facilitate ventilation; it is therefore not feasible for use in the dynamic observation of airway activity. In our study, the laryngotracheal endoscopy in the pediatric group and injection of vocal cord fat in the adult group required this type of dynamic observation. In addition, there is also a significant risk of propelling blood and tissue debris into the airway if supraglottic jet ventilation is applied. In general, the risk of more severe complications, such as pneumothorax, are increased if subglottic jet ventilation is applied when there is airway obstruction; this eventually leads to total occlusion of airway outflow with a significant increase in intrathoracic pressure [12]. In our study, this type of risk is present in patients with laryngeal papilloma in the pediatric group and with subglottic tumour in the adult group. Therefore, the jet ventilation method was not considered for our study. 3) Maintaining spontaneous respiration under anesthesia can provide both an interference-free operation field and continuous observation of airway activity. This is especially suited to conditions where removal of subglottic or intratracheal lesions is required (as described in our results, four cases had subglottic laryngeal papillomas and three cases had airway granulomas in the pediatrics, as well as 10 patients had posterior vocal cord or intratracheal tumours in the adults, Fig. 2) and to situations in which the activity of larynx and trachea should be examined (as described in our results, five cases of tracheomalacia and three cases of subglottic stenosis in the pediatrics and six cases of paralyzed vocal cords treatments in the adults, Fig. 3).

Upper airway surgery is generally carried out under the suspension laryngoscope, which can stimulate airway movement. The most important consideration for spontaneous respiration anesthesia is to keep an adequate depth of anesthesia because insufficient depth of anesthesia can easily induce laryngeal or bronchial spasms. At the other extreme, excessive depth of anesthesia may cause inhibition of respiration. To prevent either of these complications, continuous monitoring of the balance between adequate depth of anesthesia and stable spontaneous respiration is required. In infants, this type of immediate regulation is quite difficult to maintain using intravenous anesthesia. Unlike older children and adults, these patients do well with gas insufflation. Neonates, infants, and young children have relatively higher alveolar ventilation and lower functional residual capacity (FRC) when compared with older children and adults. This higher ventilation-to-FRC ratio with relatively higher blood flow to vessel-rich organs contributes to a rapid rise in alveolar anesthetic concentration and speeds in-

halation induction [13]. Sevoflurane does not cause stimulation to airway, it can be used to maintain stable spontaneous breathing even under deep anesthesia and can be rapidly cleared after drug discontinuation. Therefore, the high-flow sevoflurane inhalational anesthesia may have advantages in younger infants and young children [14,15]. In the present study, infants <30 months all acquired satisfactory anesthesia effect with this method. The average time to loss of consciousness was only 16 ± 3 s; no patients had respiratory depression or laryngeal bronchospasm. As the patient's age increases, sufficient depth of anesthesia can not be maintained by sevoflurane inhalation alone; but intermittent injections of low doses of propofol and remifentanyl can rapidly compensate for the inadequate level of sevoflurane-induced anesthesia without inhibiting respiration [16]. Insufflation of anesthetic gas in adults, who have larger lung capacity than infants and small children, does not allow for the required alveolar concentration to be attained. Other ancillary drugs were used, including topical lidocaine to reduce airway irritation, methylprednisolone injections to minimize airway edema and atropine injections to decrease airway secretions.

Our previous study indicated that a high body mass index (BMI) value >25.2 is a primary risk factor for CO₂ retention in tubeless anesthesia with high jet ventilation [17]. Therefore, obese patients (BMI ≥ 25) were not included in our study due to an increased risk of hypoventilation without intubation. Whether obesity should be considered a contraindication for receiving tubeless anesthesia may require further clinical observation.

The biggest disadvantage of tubeless anesthesia is that it is impossible to monitor the respiratory function and end-tidal anesthetic gas concentration through an open airway; anesthesiologists must pay close attention to a patient's respiratory frequency, chest excursion and lip colour during an entire surgical procedure. This type of anesthetic technique is technically challenging for anesthesiologists who must maintain the balance between an adequate depth of anesthesia and sufficient spontaneous respiration. A second disadvantage is the possible aspiration of blood and tissue debris that can occur without the protection of a cuffed endotracheal tube; if aspiration occurs, cooperation between the anesthesiologists and surgeons is needed to clear the airway immediately.

Conclusion

Tubeless anesthesia with spontaneous ventilation using anesthetic gas insufflation (pediatrics) or total intravenous anesthesia (adults) for upper airway surgery can provide both an interference-free operative field and continuous observation of

airway activity. Using this method requires skillful anesthetic technology; thus, it should be used cautiously with close cooperation between experienced anesthesiologists and surgeons.

Acknowledgments

The authors acknowledge Dr. Jun-Zheng Wu, an anesthesiologist in Cincinnati Children's Hospital Medical Center, USA, for his technical guidance and assistance with English language editing and Dr. Tian-yu Zhang, an otorhinolaryngologist for surgical cooperation.

References

1. Rezaie-Majd A, Bigenzahn W, Denk DM, *et al.* Superimposed high-frequency jet ventilation (SHFJV) for endoscopic laryngotracheal surgery in more than 1500 patients. *Br J Anaesth* 2006; 96 (5): 650-9.
2. Bourgain JL, Desruennes E, Fischler M, *et al.* Transtracheal high frequency jet ventilation for endoscopic airway surgery: a multicenter study. *Br J Anaesth* 2001; 87:870-875.
3. Ihra G, Hieber C, Adel S, *et al.* Tubeless combined high-frequency jet ventilation for laryngotracheal laser surgery in paediatric anaesthesia. *Acta Anaesthesiol Scand* 2000; 44:475-479.
4. Weisberger EC, Emhardt JD. Apneic anesthesia with intermittent ventilation for microsurgery of the upper airway. *Laryngoscope* 1996; 106(9 Pt 1): 1099-1102.
5. Peacock JE, Cuntley JB, O'connor B. *et al.* Remifentanyl in combination with propofol for spontaneous ventilation anaesthesia. *Br J Anaesth* 1998; 80: 509-511.
6. Murdoch JA, Hyde RA, Kenny GN. Target-controlled remifentanyl in combination with propofol for spontaneously breathing day-case patients. *Anaesthesia* 1999; 54: 1028-1031.
7. Meretoja OA, Taivainen T, Raiha L, *et al.* Sevoflurane-nitrous oxide or halothane-nitrous oxide for pediatric bronchoscopy and gastroscopy. *Br J Anaesth* 1996; 76: 767-771.
8. Migel B, Joanne L, Erica A, *et al.* Relationship between age and spontaneous ventilation during intravenous anesthesia in children. *Pediatric Anesthesia* 2007; 17: 948-955.
9. Nouraei SAR, Giussani DA, Howard DJ *et al.* Physiological comparison of spontaneous and positive-pressure ventilation in laryngotracheal stenosis. *Br J Anaesth* 2008; 101: 419-23.
10. Richards SD, Kaushik V, Rothera MP, *et al.* A tubeless anaesthetic technique for paediatric laryngeal laser surgery. *International Journal of Pediatric Otorhinolaryngology*. 2005; 69: 513-516.
11. Stern Y, McCall JE, Mueller KL *et al.* Spontaneous respiration anesthesia for respiratory papillomatosis. *Ann Otol Rhinol Laryngol* 2000; 109: 172-76.

12. Jaquet Y, Monnier P, Van Melle G *et al.* Complications of different ventilation strategies in endoscopic laryngeal surgery: a 10-year review. *Anesthesiology* 2006;104:
13. Morgan GE, Mikhail M, Murray MJ. *Clinical Anesthesiology*[M]. 4th ed. New York: McGraw-Hill Companies, 2006, 929.
14. Lerman J, Davis PJ, Welborn LG, *et al.* Induction, recovery, and safety characteristics of sevoflurane in children undergoing ambulatory surgery. A comparison with halothane. *Anesthesiology* 1996; 84(6): 1332-40.
15. Lopezgil M, Brimacombe J. Sevoflurane versus propofol for induction and maintenance of anaesthesia with the laryngeal mask airway in children. *Pediatr Anesth* 1999; 9(6): 485-490.
16. Ansermino JM, Whyte SD, Amari E, *et al.* Airway Surgery with TIVA and spontaneous ventilation in children. Proceedings of the 2009 Annual meeting of the American Society of Anesthesiologists, A155.
17. Tang F, Li SQ, Chen LH, *et al.* The comparison of various ventilation modes and the association of risk factors with CO₂ retention during suspension laryngoscopy. *Laryngoscope*,2011,121(3):503-508.