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Total intravenous anesthesia and spontaneous respiration for airway endoscopy in children – a prospective evaluation

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Summary

Introduction: Inhalational anesthesia with spontaneous respiration is traditionally used to facilitate airway endoscopy in children. The potential difficulties in maintaining adequate depth of anesthesia using inhalational anesthesia and the anesthetic pollution of the surgical environment are significant disadvantages of this technique. We report our institutional experience using total intravenous anesthesia (TIVA) and spontaneous respiration.

Methods: We prospectively studied 41 pediatric patients undergoing 52 airway endoscopies and airway surgeries. Following induction of anesthesia, a propofol infusion was titrated to a clinically adequate level of anesthesia, guided by the Bispectral Index (BIS), and a remifentanil infusion was titrated to respiratory rate. ECG, BP, pulse oximetry, BIS level, transcutaneous CO_2 ($TcCO_2$), respiratory rate, and drug infusion rates were recorded. Adverse events and the response to these events were also recorded.

Results: Forty-one children underwent 52 airway procedures; 17 rigid bronchoscopies and 35 microlaryngobronchoscopies, including 18 LASER treatments, were performed. The mean (SD) age was 6.9 (5.8) years and weight 26.9 (21.2) kg. The mean induction time was 13 (6) min, and anesthesia duration was 49 (30) min. The mean highest $TcCO_2$ recorded during the procedures was 62.8 ± 15.3 mmHg. Coughing occurred in 14 (27%) patients, requiring additional topical anesthesia (3), a bolus of propofol (4) or remifentanil (1), or removal of the bronchoscope (1). Desaturation below 90% occurred in 10 (19%) cases; only three required intervention in the form of temporary assisted ventilation (2) or inhaled bronchodilators (1). No laryngospasm, stridor, or arrhythmias were observed.

Conclusion: TIVA and spontaneous respiration is an effective technique to manage anesthesia for airway endoscopy and surgery in children.

Keywords: airway endoscopy; total intravenous anesthesia; spontaneous respiration; propofol; remifentanil; transcutaneous carbon dioxide

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Introduction

Airway endoscopy and surgery in children is challenging for both the anesthesiologist and the otolaryngologist. The small diameter of the airways and the propensity for rapid desaturation requires close communication between the parties involved. The ideal anesthetic technique would allow for adequate oxygenation and ventilation, guarantee continuous ventilation when the eyepiece of the bronchoscope is removed, produce an adequate depth of anesthesia to minimize bucking, coughing, or straining during instrumentation, result in rapid emergence from anesthesia, and produce minimal environmental pollution. A number of anesthetic techniques have been described for airway endoscopy, each with associated advantages and disadvantages. Most texts emphasize the desirability of maintaining spontaneous ventilation (1–3), but some authors specifically recommend the use of muscle relaxants and light inhalational anesthesia (4). The key question arising in this context is whether spontaneous ventilation, which maintains acceptable oxygenation and facilitates completion of the procedure without significant complications, is possible during airway endoscopy in children. There is no evidence for the superiority of any particular anesthetic technique during rigid bronchoscopy for foreign body removal in children.

Traditionally, deep inhalational anesthesia has been used to facilitate airway endoscopy and surgery. We undertook this prospective observational trial to investigate the feasibility of using spontaneous ventilation and total intravenous anesthesia (TIVA), with a combination of propofol and remifentanil for airway endoscopy and surgery. We present our clinical experience in neonates, infants, and children.

Methods

Following institutional ethics approval and parental consent, we prospectively studied 52 airway endoscopy and airway surgical procedures on 41 pediatric patients, utilizing TIVA with propofol and remifentanil. Recruitment took place over an 18-month period during elective operating hours and depended on the availability of a part-time research assistant.

The anesthetic technique was standardized as follows: following the establishment of intravenous access, an anticholinergic agent was administered at the discretion of the attending anesthesiologist, followed by a loading dose of propofol 1–5 $mg{\cdot}kg^{-1}$, aiming to maintain spontaneous respiration while breathing 100% oxygen via the anesthetic circuit. If an intravenous cannula could not be placed, a volatile induction with sevoflurane was performed and the anesthetic maintenance was changed to TIVA as soon as intravenous access was obtained. The loading dose of propofol was administered over 3–5 min to avoid apnea. Following induction, infusions of propofol 200–500 $\mu g{\cdot}kg^{-1}{\cdot}min^{-1}$ and remifentanil 0.1–0.2 $\mu g{\cdot}kg^{-1}{\cdot}min^{-1}$ were commenced. If apnea occurred during induction, ventilation was gently assisted until spontaneous ventilation resumed. The rate of remifentanil administration was adjusted in 0.05 $\mu g{\cdot}kg^{-1}{\cdot}min^{-1}$ increments every 3–5 min, titrating the effect to respiratory rate. Once a respiratory rate of 10–15 breaths per min in older children or a 50% reduction in respiratory rate in neonates and infants was reached, the anesthesiologist performed a careful laryngoscopy and applied 2–4 $mg{\cdot}kg^{-1}$ lidocaine spray to the vocal cords and into the trachea. Lack of response from the patient during and following laryngoscopy served as an indication that an adequate depth of anesthesia had been reached and that surgery could commence. The rate of remifentanil administration was adjusted throughout the procedure to maintain the above-mentioned target respiratory rate. The propofol infusion was titrated to a clinically adequate depth of anesthesia and targeting a Bispectral Index (BIS) level of 40–60. After instrumentation of the airway, 100% oxygen was administered via a side arm of the bronchoscope or suspension laryngoscope.

The heart rate, BP, pulse oximetry, BIS level, transcutaneous CO_2 ($TcCO_2$), and respiratory rate were recorded at 3-min intervals intraoperatively, by a research assistant not involved with administering the anesthetic. The starting and highest infusion rates of propofol and remifentanil, as well as all other medication administered, were documented. The incidence and severity of intra- and post-operative adverse events were documented. All incidences of coughing and bucking, patient movement during surgery, other adverse events such as laryngospasm, arrhythmias, and stridor, and the anesthesiologist's

intervention in response to these adverse events were documented. All episodes of desaturation below 90%, and lasting more than 15 s, during surgery were documented, as well as the intervention required. Apnea during surgery was classified according to the duration as follows: mild (lasting <15 s), moderate (lasting 15–30 s), and severe (lasting more than 30 s). All episodes of apnea and the required intervention were documented. The induction time, defined as the time from the start of anesthesia to the start of surgery, and the recovery time, defined as the time from the end of anesthesia to time of consciousness, were recorded.

Results

Consent to participate was sought from 63 patients, of whom 22 declined (mean age 3.7 years). Thus, a total of 41 patients (21 male and 20 female) who underwent 52 airway endoscopy procedures between March 2007 and September 2008 were recruited. After-hours recruitment was not possible because of the unavailability of research staff. The age ranged from 13 days to 17 years 3 months, and the body weight ranged from 3.8 to 75.6 kg. This included 7 infants and 12 patients between the ages of 1 and 3 years. The endoscopic procedures included 17 rigid bronchoscopies and 35 microlaryngobronchoscopies, including 18 with LASER ablation treatment. These procedures were performed by 20 different anesthesiologists and equally distributed among four different otolaryngologists.

An intravenous induction of anesthesia was performed on 31 patients (60%), while the remaining 21 (40%) underwent inhalation induction of anesthesia. Of the 31 patients who underwent intravenous inductions, the mean propofol induction dose was 2.7 ± 1.3 mg·kg^{-1}. An anticholinergic agent was administered in 40 patients (glycopyrrolate in 34; atropine in six). The mean starting and highest propofol and remifentanil infusion rates, as well as the mean lidocaine spray dose, are summarized in Table 1.

The following adverse events were recorded: A total of 11 episodes of apnea during the procedure occurred in 11 different patients (21%). Of these 11 episodes, five were classified as *mild* (<15 s); of these, two required intervention, consisting of a decrease in the remifentanil infusion rate. A single patient experienced *moderate* apnea (15–30 s) but did not require intervention. Five patients experienced a *severe* episode of apnea (>30 s); three of these required temporary assisted ventilation and two required a decrease in the remifentanil infusion rate.

Table 1
Type and dose of drugs used

Drug	*Doses used*[a]
Lidocaine (spray) mg·kg^{-1}	2 (1.2)
Propofol starting infusion rate μg·kg^{-1}·min^{-1}	338.5 (83.2)
Propofol highest infusion rate μg·kg^{-1}·min^{-1}	368.5 (103.4)
Remifentanil starting infusion rate μg·kg^{-1}·min^{-1}	0.155 (0.26)
Remifentanil highest infusion rate μg·kg^{-1}·min^{-1}	0.212 (0.31)

[a]Mean (SD).

Unwanted movement occurred on 10 occasions in nine different patients (17%). No intervention was required in three cases. The remaining seven responded to a bolus dose of propofol.

A total of 14 episodes of coughing occurred in 14 patients (27%). Three episodes were treated with additional lidocaine spray to the vocal cords or into the trachea, four with a bolus dose of propofol, and one with a bolus dose of remifentanil. One patient required suctioning of the airway, and the bronchoscope was removed in one case. Four episodes did not require any intervention.

Desaturation below 90% occurred 10 times in 10 different patients (19%). No intervention was required in six of these episodes, two patients required temporary assisted ventilation, and one required inhaled bronchodilators. In the remaining patient, a lower saturation was deliberately induced, in keeping with underlying prematurity and bronchopulmonary dysplasia. No other adverse events occurred. Specifically, no episodes of laryngospasm or stridor occurred nor were any arrhythmias observed.

The induction times did not differ between intravenous and inhalational induction of anesthesia; however, the recovery time was long, in keeping with the deep plane of anesthesia required for these procedures (Table 2).

The mean highest $TcCO_2$ during the procedures was 62.8 ± 15.3 mmHg, while the mean lowest BIS during the procedures was 33.7 ± 12.2. The respiratory rates were low with the mean lowest respiratory rate during the procedures at 9.1 ± 5.3·min^{-1} (Table 3).

Table 2
Duration of procedures

Induction of anesthesia[a] (min)	
Intravenous induction	13 (6)
Inhalational induction	14 (6)
Duration of surgery (min)	30.8 (34.4)
Time to consciousness[b] (min)	27 (19)

All values are Mean (SD).
[a]Induction of anesthesia defined as start of anesthesia to start of surgical procedure.
[b]Time to consciousness defined as the time between the end of anesthesia and the time in the postanesthesia recovery unit at which the patient was fully awake.

Table 3
Vital signs

	Highest	*Lowest*
Respiratory rate min^{-1}	23.5 (9.9)	9.1 (5.2)
Blood pressure (systolic) mmHg	113.5 (17.5)	88 (13)
SpO_2		93.4% (6.4)
Bispectral Index		33.7 (12.2)
TcCO2	62.8 (15.3)	

All values are Mean (SD).

Discussion

This purpose of this study was to describe the use of TIVA, using propofol and remifentanil, together with spontaneous respiration during airway endoscopy and surgery in children. The combination of TIVA with spontaneous ventilation, without an endotracheal tube, is a viable and effective technique to anesthetize children for airway endoscopy and surgery. In all 52 cases in our series, surgery or endoscopy was completed successfully using this technique with no serious adverse events. Apnea occurred in 11 patients; however, most of these episodes were not clinically significant and did not require intervention, while the remaining episodes responded to temporary assisted ventilation and a reduction in the remifentanil infusion rate. Respiratory depression, which is inevitable with the depth of anesthesia required, combined with spontaneous breathing, was well tolerated. A total of 14 episodes of coughing and/or bucking occurred but most of these did not require intervention or were treated with a propofol bolus. Ten patients experienced transient desaturations. Unwanted movement did occur but responded to a bolus dose of propofol. No episodes of laryngospasm, stridor, or arrhythmias occurred.

Management of anesthesia for airway endoscopy or surgery hinges on two inter-related choices: the mode of ventilation and the delivery route of anesthesia. The pros and cons of spontaneous vs controlled ventilation and of inhalational vs intravenous anesthesia have been rigorously debated (5–9). We have increasingly been employing TIVA, using infusions of propofol and remifentanil, with spontaneous respiration for airway endoscopy and surgery. The benefits we perceive are unobstructed surgical access; excellent ability to evaluate dynamic airway function and obstruction; ability to achieve deep anesthesia that is not ventilation-dependent; absence of environmental pollution; and minimal risk of airway fire. In addition, propofol and remifentanil have pharmacological properties that may confer particular value in airway surgery. Remifentanil, like all opioids, has antitussive properties, which makes it an ideal agent for airway endoscopy by reducing the incidence of coughing and gagging under anesthesia. Remifentanil obtunds airway reflexes and is a recognized method to facilitate endotracheal intubation in infants and children (10). In addition, its rapid metabolism makes it highly titratable. Propofol may offer distinct advantages over sevoflurane in airway endoscopy. Oberer *et al.* (11), in an elegant randomized controlled trial, reported on laryngeal and respiratory reflex responses in anesthetized children using either propofol or sevoflurane. Patients anesthetized with propofol experienced less apnea and laryngospasm than those anesthetized with sevoflurane, following a noxious stimulus to the larynx, although the incidence of coughing was higher. Combining a potent antitussive, such as remifentanil, with the unique airway properties of propofol, may contribute to a reduced incidence of coughing, gagging, and laryngospasm under anesthesia. Adequate local anesthesia is an important component of any technique, as this decreases the risk of coughing, gagging, and desaturation. We routinely apply lidocaine spray to the vocal cords, trachea, and on the carina during airway endoscopy.

TIVA using propofol and remifentanil is well established in pediatric anesthesia. The combination of propofol and remifentanil has successfully been

used for sedation in flexible fibreoptic bronchoscopy in spontaneously breathing children (12). Propofol, in combination with alfentanil, fentanyl, or remifentanil, has also been used for direct laryngoscopy and rigid bronchoscopy in spontaneously breathing adults (13,14). Mausser *et al.* (9) described the successful use of propofol and remifentanil in combination with high-frequency jet ventilation during endolaryngotracheal surgery in children, although patients were paralyzed with rocuronium.

Our observations contradict that of a recent controlled trial in which spontaneously breathing patients receiving TIVA with propofol and remifentanil during rigid bronchoscopy, experienced a high incidence of movement, breathholding, and laryngospasm. A possible explanation for this perceived difference is that the doses of propofol and remifentanil used in our study were significantly higher than those used by Chen *et al.* (15).

Our study has several limitations. The numbers in each age group are small, and the results are observational. The results of this study may have been biased by the failure to enroll all cases during the study period. Specifically, procedures on younger children and for emergency indications were less likely to consent to participation. A larger randomized controlled trial to compare a TIVA technique to traditional inhalational maintenance of anesthesia is warranted. Such a larger study should specifically look for differences between children at different ages.

In summary, the use of propofol and remifentanil TIVA and spontaneous ventilation is a feasible technique to manage anesthesia for airway endoscopy and surgery in children.

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