Case Report

Superimposed high-frequency jet ventilation used for endolaryngotracheal surgery in a child with congenital subglottic stenosis: a case report

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Background: Airway management and anesthesia during endolaryngotracheal surgery in patients with obstructive airway diseases pose a major challenge for anesthesiologists, especially in pediatric patients. Children with obstructive airway disease often have a potentially difficult airway. Adequate airway assessment and preparation before anesthesia is essential. In the formulation of the entire anesthesia strategy, the choice of ventilation mode is the most critical. Superimposed high-frequency jet ventilation (SHFJV) is an enormous step forward in the progress of difficult surgery of the larynx and trachea in neonates, infants and children. However, due to objective factors, it has not been extensively applied worldwide.

Case Description: In this article, our airway management strategy and clinical anesthesia experience is presented in a precisely designed, non-invasive and "tubeless" supraglottic SHFJV technique. This technique was used during a successful endolaryngotracheal surgery in a 3-year-old child with congenital subglottic stenosis under total intravenous anesthesia (TIVA) with propofol and remifentanil. Ultimately, the entire procedure and anesthesia were successful, and the child received effective treatment.

Conclusions: By summarizing and sharing our airway management strategy and clinical anesthesia experience in this case, anesthesiologists may have a clearer understanding of the challenges in this type of surgery. This case may add a valuable reference for the extensive application of SHFJV in endolaryngotracheal surgery.

Keywords: Superimposed high-frequency jet ventilation (SHFJV); subglottic stenosis; pediatric anesthesia; difficult airway; case report

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Introduction

Anesthesia and airway management during endolaryngotracheal surgery in children with obstructive airway diseases pose a major challenge for anesthesiologists, as they must share an already narrowed airway during such procedures with surgeons. The goals of anesthesia management in such procedures are to provide optimal operating conditions while ensuring adequate ventilation and oxygenation, and to minimize perioperative complications. As an innovative technique, superimposed high-frequency jet ventilation (SHFJV) has been reported to be a safe and highly effective ventilation technique even in high-grade laryngotracheal stenoses and pediatric patients (1). Here, an airway management strategy and clinical anesthesia experience of a successful SHFJV case is presented, in order to provide a reference for the extensive clinical application of SHFJV in pediatric endolaryngotracheal surgeries. We present the following article in accordance with the CARE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-22-218/rc).

Case presentation

A 3-year-old boy (99 cm, 16 kg) was scheduled to undergo an endoscopic procedure for congenital subglottic stenosis which caused exertional stridor. This child experienced unexpected difficulty with endotracheal intubation during an inguinal hernia repair surgery 1 year ago. A mass of subglottic soft tissue obstructing the trachea was then visualized with flexible fiberoptic laryngoscopy (FFL) in the outpatient clinic (*Figure 1*).

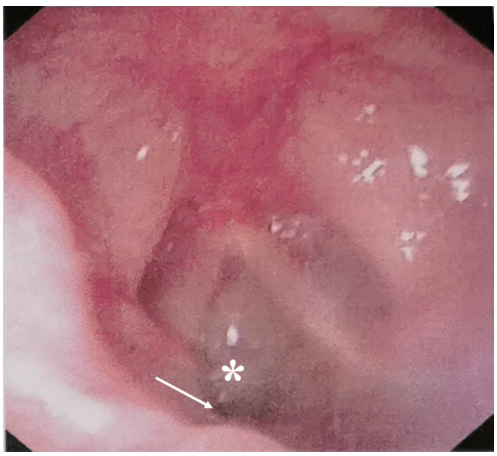

Figure 1 Subglottic stenosis. A mass of subglottic soft tissue obstructing the throat cavity was visualized by FFL in the outpatient clinic (labeled with a white asterisk), the subglottic lumen was so narrow that it was not even visible (labeled with a white arrow). FFL, flexible fiberoptic laryngoscopy.

Anesthesia management of this patient was led by a senior chief anesthesiologist with extensive experience in difficult airway management and was assisted by two senior resident anesthesiologists. On the day of surgery, the patient was fasted for 8 hours. Electrocardiogram, pulse oximetry, and noninvasive blood pressure were monitored upon his arrival at the operating room. The patient was stable with a heart rate of 108 beats/min, blood pressure of 100/65 mmHg, respiratory rate of 20 breaths/min, and oxygen saturation of 99% when breathing room air. Preoxygenation with 100% oxygen was started immediately. Otolaryngologic surgeons were ready in the operating room for surgical intervention in the event of a can't intubate can't oxygenate (CICO) emergency. Rescue medications, emergency tracheal intubation equipment, emergency cricothyroidotomy and tracheostomy equipment were well prepared and ready for immediate usage. General anesthesia was then induced with atropine sulfate (6 μg/kg i.v.), dexamethasone sodium phosphate (0.3 mg/kg i.v.), lidocaine hydrochloride (1 mg/kg i.v.), midazolam (0.05 mg/kg i.v.), hydromorphone (30 μg/kg i.v.), remifentanil (1 μg/kg i.v.) and propofol (3 mg/kg i.v.). After the patient's loss of consciousness, positive pressure ventilation via a face mask with 100% oxygen was started. When the mean airway pressure (M Paw) was maintained at 15 cmH_2O, the tidal volume reached 10 mL/kg. The bilateral thoracic undulations were observed to be symmetrical, and the breath sounds of both lungs were symmetrical on auscultation, and no significant upper airway obstruction was found. The end-tidal carbon dioxide ($PetCO_2$) monitoring curve fluctuated between 25 and 35 mmHg and oxygen saturation was maintained at 100%. Cisatracurium (0.1 mg/kg i.v.) was then administered. After about 3 min, the jet laryngoscope (C. Reiner Corp., Vienna, Austria) was inserted and mounted in an appropriate position with the gas nozzle right above the larynx (*Figure 2A*). The laryngoscope was then connected to the SHFJV ventilator (TwinStream^{TM}; C. Reiner Corp.) (*Figure 2B*). For this patient, the ventilator settings were as follows (*Figure 2C*): firstly, the driving pressure was 0.5 bar in the low-frequency part of jet ventilation and 0.6 bar in the high-frequency

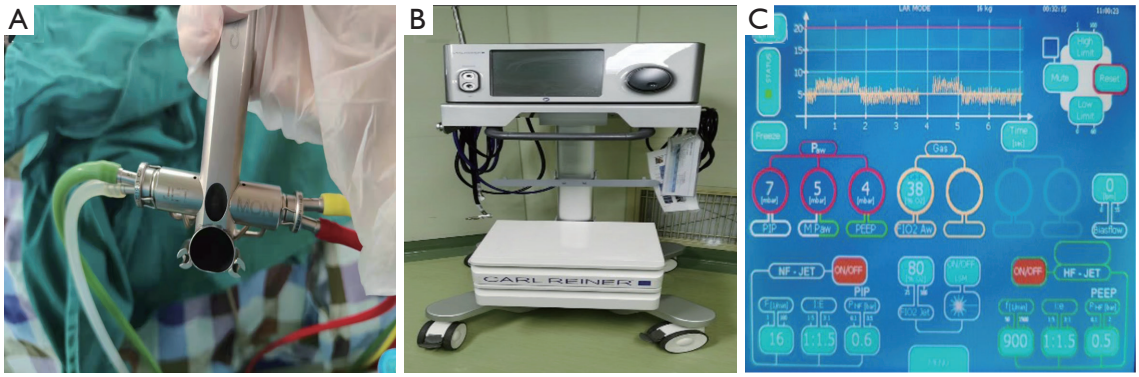

Figure 2 Superimposed high-frequency jet ventilation. (A) Jet laryngoscope (C. Reiner Corp., Vienna, Austria). (B) SHFJV ventilator (TwinStream™; C. Reiner Corp.). (C) Ventilation parameters of superimposed high frequency jet ventilation ventilator. SHFJV, superimposed high-frequency jet ventilation.

part. Secondly, the inspiration-to-expiration (I:E) ratio was set at 1:1.5. Thirdly, the high-frequency jet ventilation was set at 900 pulsations/min and the low-frequency jet ventilation at 16 breaths/min. During the entire SHFJV period, the airway pressure, and the fraction of inspiration O_2 (FiO_2) were continuously measured through a cannula integrated in the wall of the jet laryngoscope. Important parameters were positive end-expiratory pressure (PEEP) of 4 mbar, peak airway pressure 7 mbar, M Paw 6 mbar, and FiO_2 38%. For the maintenance of anesthesia, a total intravenous anesthesia (TIVA) with propofol supplemented with remifentanil was used. After satisfactory ventilation was determined by observing the thorax excursions and auscultation, endolaryngotracheal surgery was started. A semicircular membranous Myer-Cotton grade 2 anterior subglottic stenosis was observed 1 to 1.5 cm below the glottis during suspension microlaryngoscopy (*Figure 3A*). After standard laser precautions were applied, a CO_2 laser with a micromanipulator was utilized to transect anterior subglottic membranous tissue (*Figure 3B*). The remaining stenosis was treated with endoscopic balloon dilation (*Figure 3C*). After repeated laser resections and balloon dilations, the membranous tissue was significantly contracted, and the tracheal lumen was significantly enlarged (*Figure 3D*).

The operation duration was 37 min. After adequate wound hemostasis and thorough tracheal suction of secretions, a laryngeal mask was inserted to implement transitional mechanical ventilation before the resumption of spontaneous breathing. Spontaneous breathing began to recover 5 min after the TIVA was discontinued. Neuromuscular blockade was reversed by the administration of neostigmine and atropine. Approximately 10 min later, the child was fully awake with stable vital signs and was sent to the post-anesthesia care unit. On the first postoperative day, the patient received nebulization therapy with steroids. No complications related to SHFJV were observed throughout the perioperative period. The patient achieved a partial recovery and was discharged from the hospital two days later. Compared with the preoperative FFL image, the follow-up at 7 months postoperative showed that although the residual anterior subglottic stenosis could still be seen, the subglottic lumen was enlarged (*Figure 3E*). To date, the patient's exertional stridor has basically disappeared and there is no apparent evidence of upper airway obstruction. All procedures performed in this study were in accordance with the ethical standards of the institutional and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient's parents for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

Discussion

Various ventilation techniques for endolaryngotracheal surgery have been described in the literature (2). Each of these techniques has its characteristic advantages and disadvantages. Maintaining spontaneous ventilation may ensure sufficient ventilation and oxygenation. However, it is only suitable for laryngotracheal and endotracheal surgeries with short operation duration and mild operation stimulation. Apneic anesthesia with intermittent ventilation does not impede surgery, and the laser can be safely applied.

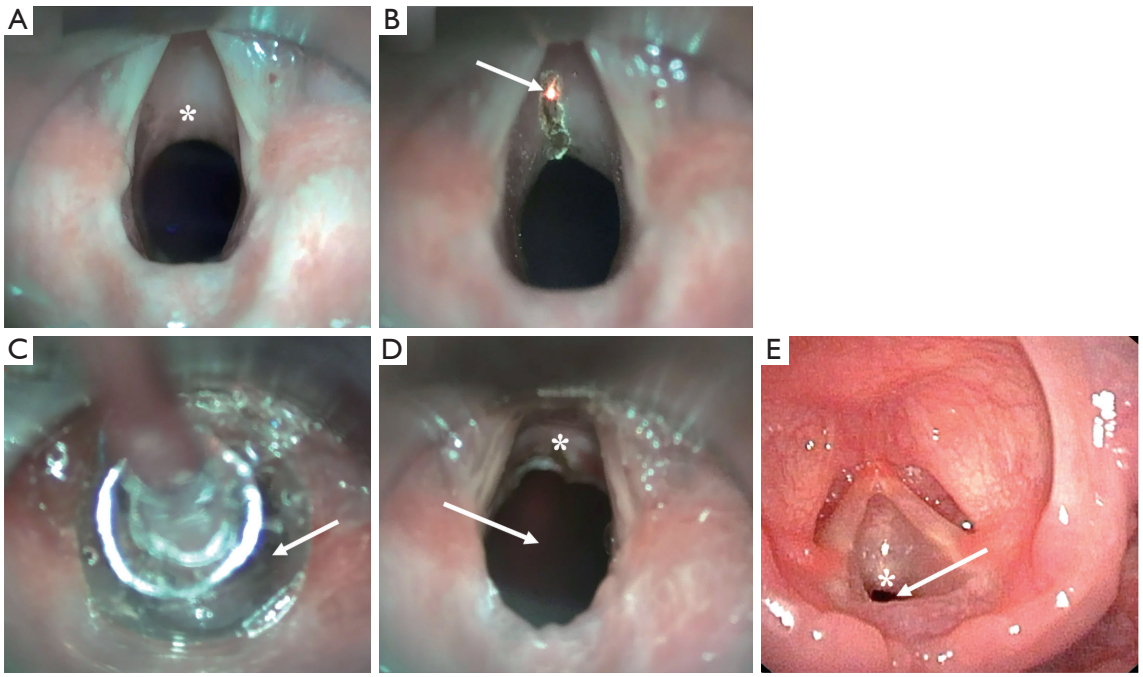

Figure 3 Endolaryngotracheal surgery. (A) A semicircular membranous Myer-Cotton grade 2 anterior subglottic stenosis was observed 1–1.5 cm below the glottis during suspension microlaryngoscopy (labeled with a white asterisk). (B) A CO_2 laser was utilized to transect anterior subglottic membranous tissue (labeled with a white arrow). (C) Endoscopic balloon dilation of the subglottic stenosis (labeled with a white arrow). (D) After repeated laser resection and balloon dilation, the membranous tissue was significantly contracted (labeled with a white asterisk) and the lumen was significantly enlarged (labeled with a white arrow). (E) Compared with the preoperative FFL image, the follow-up 7 months after surgery showed that although the residual anterior subglottic stenosis could still be seen (labeled with a white asterisk), the subglottic lumen was enlarged (labeled with a white arrow). FFL, flexible fiberoptic laryngoscopy.

Nevertheless, it is prone to hypoxemia and hypercapnia when used in patients with prolonged operation duration or poor oxygen reserves. Conventional ventilation via an endotracheal tube is the safest choice, but it may interfere with the visualization and the dissection of the lesion. Moreover, severe endolaryngotracheal lesions may lead to difficult or even failure of intubation. For young children and patients with severe airway stenosis, there are no laser-safe endotracheal tubes available. Furthermore, endotracheal intubation may exacerbate airway trauma and even lead to metastasis in patients with neoplasms. Traditionally, transcatheter subglottic jet ventilation techniques are applied through endotracheal tubes, percutaneous tracheal needles, or jet nozzles in the endoscopy tube to ventilate the patient during endolaryngotracheal surgery with a single frequency jet stream. Although transcatheter subglottic jet ventilation techniques are frequently used in adults, they are rarely used in children. In infants, neonates and patients with severe airway stenosis, even a cannula with 2 to 3 mm in diameter can significantly impair the luminal space, where there is no residual lumen available for the expiratory gas flow and could result in barotrauma and pneumothorax. Hypoxemia and hypercapnia caused by cannula displacement or prolonged operation duration are also serious complications that limit its clinical application. Supraglottic SHFJV as a noninvasive ventilation method was introduced in the late 1990s. The greatest advantage of SHFJV is that a "tubeless" supraglottic jet ventilation can be achieved due to the integration of the two jet nozzles in the wall of a specially designed jet laryngoscope (3). As SHFJV applies gas volumes with a combined low and high frequency, it can achieve an adequate tidal volume and a sufficient pressure plateau in an open system with low driving pressure. The low-frequency jet stream mimics a normal respiration rate. By extending the exhalation time, CO_2 can be removed. The high-frequency jet ventilation

produces a PEEP which reduces the risk of blood, smoke and debris inhalation. In addition, the ventilation is delivered above the stenosis; thus, the risk of barotrauma is lowered. However, SHFJV also has some limitations. The respiratory gas cannot be humidified and $PetCO_2$ concentration is difficult to be detected. Although the application of this technology is an enormous step forward in the progress of the naturally difficult surgery of the larynx and trachea in neonates, infants and children, it is limited if they suffer from pulmonary pathology or have a high body-mass index (BMI) (4). Up until now, due to objective factors such as high cost and few patients, SHFJV has not been extensively applied worldwide. Absolutely motionless general anesthesia, unimpaired surgical field, and safe application of the laser were the special requirements for surgery in this patient. After thorough consideration, SHFJV was finally selected as the ventilation method.

Combined with the patient's symptoms, preoperative laryngoscopy, and a history of failed endotracheal intubation, a difficult airway was identified. Subglottic lesions had caused difficult intubation and might also cause difficult ventilation, especially in children who have narrower anatomical structures, irritable tracheobronchial mucous membrane and higher oxygen consumption. Therefore, during the anesthesia induction process, a CICO emergency could not be excluded. The personnel, equipment and medications to manage difficult airways must be prepared in advance. During induction, after the patient was completely unconscious, adequate positive-pressure bag-mask ventilation was paramount before administration of muscle relaxants. If positive pressure ventilation should fail, the patient might have severe airway stenosis and may not be able to tolerate SHFJV. Further evaluation and preparation were required. For the maintenance of anesthesia, compared with volatile anesthetics, TIVA can guarantee a stable level of anesthesia in this open system and avoid contamination and potential flammability of volatile anesthetics. Continuous transcutaneous monitoring technique of the partial pressure of carbon dioxide in the arterial blood ($PaCO_2$) is generally accepted for use in infants and children for adjusting jet ventilation settings. However, we did not routinely monitor $PaCO_2$ due to insufficient recognition of the importance of this monitoring, and this should receive enough attention when applying SHFJV in the future. At the end of surgery, the depth of anesthesia was maintained until secretions were aspirated, the jet laryngoscope was removed, and the laryngeal mask was inserted. In this way, airway hyperresponsiveness can be fully suppressed and the occurrence of choking or laryngospasm can be avoided. Both the laryngeal mask and the face mask can be used as a transitional supraglottic ventilation device until the patient wakes up. Equipment for establishing an emergency airway should be readily available in case of severe upper airway obstruction due to postoperative airway edema. Perioperative monitoring of muscle relaxants in this type of surgery is conducive to the rational use of muscle relaxants and plays a very important role in patient safety. However, most of the currently available muscle relaxation monitors in China are cumbersome to operate and have harsh monitoring conditions, resulting in poor clinical feasibility. Therefore, muscle relaxation monitoring was not used in this case. Perioperative patient monitoring and skillful postoperative management are needed to minimize the risk of complications.

Conclusions

In summary, anesthesia management in pediatric endolaryngotracheal surgery is challenging and should be provided by adequately trained anesthesiologists. Our case showed that SHFJV can be administered relatively safely and effectively in pediatric patients undergoing endolaryngotracheal surgery without severe adverse events.

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Footnote

Reporting Checklist: The authors have completed the CARE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-22-218/rc

Peer Review File: Available at https://tp.amegroups.com/article/view/10.21037/tp-22-218/prf

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-22-218/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all

aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All procedures performed in this study were in accordance with the ethical standards of the institutional and with the Helsinki Declaration (as revised in 2013). Written informed consent was obtained from the patient's parents for publication of this case report and accompanying images. A copy of the written consent is available for review by the editorial office of this journal.

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