Airway management in pediatric patients undergoing suspension laryngoscopic surgery for severe laryngeal obstruction caused by papillomatosis

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Summary

Objectives: To review perioperative airway management and ventilation strategy during the surgical removal of papilloma under suspension laryngoscopy in pediatric patients with severe airway obstruction.

Methods: Seventy pediatric patients with degree III and IV laryngeal obstruction who underwent suspension laryngoscopy to remove laryngeal papillomatosis, between July 2005 and March 2009, were included in the study. All patients were intubated initially to secure the airway. Controlled ventilation through an endotracheal (ET) tube was used during the papilloma debulking near the glottis vera. Spontaneous ventilation or apneic technique was adopted based on the stage of the surgical procedure and the location of the remaining tumor. Hemodynamic parameters, pulse oxygen saturation (SpO₂), and CO₂ were closely monitored, and adverse events were recorded.

Results: The duration of the surgical operation and the duration of the extubation period were 5–35 min and 5–20 min, respectively. Thirty cases with degree III and twenty cases with degree IV laryngeal obstruction received inhalation induction. Sixteen cases with degree III laryngeal obstruction were given an intravenous induction. Four patients admitted with a comatose status were emergently intubated without any anesthetics. The ET tube size was determined by assessing the opening through the tumor mass or glottic aperture under direct laryngoscopy. SpO₂ was maintained above 97% after the airway was secured and sufficient ventilation established. Controlled ventilation was used in all children during the bulk removal of tumor. Spontaneous respiration and apneic technique were adopted for the removal of the remaining tumor in the hypolarynx or trachea in 16 and 28 cases, respectively. Three patients had to be re-intubated postoperatively because of persistent desaturation or laryngospasm.

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Conclusion: Key points of perioperative airway management in pediatric patients with papillomatosis-induced severe laryngeal obstruction include careful preoperative airway evaluation; the proper choice of induction methods, and ET tube size; maintenance of an adequate depth of anesthesia; and flexible ventilation strategy, continuous and close monitoring during the extubation and postextubation period; and prompt management of adverse events.

Keywords: papillomatosis; airway obstruction; airway management; suspension laryngoscopy

Introduction

Laryngeal papillomatosis is caused by the human papilloma virus. It occurs frequently in children under 10 years of age, but in many cases disappears after the patient has reached adolescence. The tumor often appears on the vocal cords and at the laryngeal ventricle. It can spread to the laryngeal or hypolaryngeal vestibules, the epiglottis and occasionally is found more distally in the trachea and bronchi. Because of the exophytic growth of the papilloma in a narrow pediatric airway, severe laryngeal obstruction may occur.

To date, there are no specific and effective treatments for pediatric recurrent laryngeal papillomatosis. Surgical removal of the tumor at frequent intervals to relieve symptoms of airway obstruction remains the choice of management. The most important consideration for anesthesia is to maintain a patent airway during surgery as well as assuring adequate ventilation and surgical exposure. In many institutes, spontaneous ventilation has become the technique of choice primarily because it facilitates surgical airway access. The risk of fire during laser surgery is also minimized (1,2). High frequency jet ventilation (HFJV) is another technique (3). However, both spontaneous ventilation and HFJV have disadvantages when used in patients with severe laryngeal obstruction. A compromised airway is a preexisting risk factor for the induction of anesthesia. Spontaneous ventilation may increase collapsibility of the upper airways (4). Supraglottic HFJV is ineffective in delivering anesthesia gases and oxygen through a narrow glottic aperture to the lungs and will increase the risk of pushing blood and tumor debris to the distal airway. Subglottic HFJV may cause barotrauma if the airway outlet is totally occluded (5). In patients with severely obstructed airways, papilloma removal with a microdebrider under the suspension microlaryngoscopy is one of the most commonly performed surgical procedures. The special measures needed for securing airway include thorough preoperative airway evaluation, appropriate choice of anesthesia induction, and careful intraoperative and postoperative airway management.

In this report, we review the techniques and strategies used for perioperative airway management in pediatric patients who had papilloma-induced severe airway obstruction and underwent microlaryngoscopic surgery at our institute between July 2005 and March 2009.

Patients and methods

Patient information

A total of seventy patients’ anesthesia and surgical records were reviewed. Approval was obtained from the hospital’s Human Research Committee. Informed consent was obtained from parents or legal guardians before the anesthetic and surgical procedure. Patients consisted of 43 men and 27 women, with age ranging from 10 months to 10 years and weight ranging from 8 to 27 kg. All patients presented with hoarseness or aphonia, significant laryngeal stridor, and dyspnea. No tracheotomies were performed before surgery.

The degree of laryngeal obstruction was evaluated preoperatively using clinical indicators of general...
appearance, voice quality, and ventilation pattern (Table 1). No patient was given sedatives or narcotic analgesics preoperatively except for oxygen.

**Induction of anesthesia**

The method for induction was chosen by the anesthesiologists based on the degree of laryngeal obstruction and the patient’s cooperation. A laryngologist was always present with required surgical instruments at this time. Before induction, all necessary tools for airway management were fully prepared and ready for use. They included various sizes of endotracheal (ET) tubes (2.5–5.0 mm), styles, tracheostomy kits, and resuscitation drugs and equipment. Preoxygenation via a face mask for 2–5 min was performed in all patients prior to anesthesia induction. For face mask induction, inhalation of 8% sevoflurane in an oxygen flow at ≥4 l/min was used for patients with grade III airway obstruction while 8% sevoflurane in an oxygen flow at 8 l/min was used for patients with grade IV laryngeal obstruction. One percent lidocaine aerosol was sprayed over the laryngeal area under direct laryngoscopy once the child became unconscious as indicated by midline pupils. Spontaneous ventilation was maintained, and the concentration of sevoflurane was adjusted to 4%. Intubation was performed with downsized ET tube after a relaxed temporomandibular joint was confirmed. For intravenous induction, fentanyl (1–2 µg·kg⁻¹) and propofol (3–5 mg·kg⁻¹) were administered intravenously after preoxygenation. Succinylcholine (1.5–2 mg·kg⁻¹) was given when manual ventilation via face mask was ensured. Then, tracheal intubation was performed. The size of tube was selected according to the size of the glottis vera directly observed under laryngoscope or sometimes according to the results from preoperative airway evaluation combined with patients’ ages when the glottis vera could not been observed. The tracheal tube was inserted through an opening of the tumor mass around the glottis. If this opening could not been viewed clearly, it was judged according to an air bubble produced when the patient breathed spontaneously or when the chest was compressed by a second anesthesia person. If the glottis was still not visible by using these methods, part of tumor was clamped and removed quickly by the laryngologists to facilitate intubation.

Noninvasive blood pressure (NIBP), pulse oxygen saturation (SpO₂), electrocardiogram, and endtidal carbon dioxide (PₑTCO₂) were monitored throughout the procedures. Methylprednisolone 1–2 mg·kg⁻¹ was given intravenously shortly after intubation.

**Maintenance of anesthesia and ventilation**

Three ventilation modes were employed during anesthesia and surgery. These included the following: (i) Controlled ventilation with a tidal volume of 8–10 ml·kg⁻¹, frequency of 16–24 per minutes, maintenance of airway pressure lower than 20 cm H₂O, and the PₑTCO₂ between 35–50 mmHg. This mode was used for the removal of the papilloma growing over the glottis vera (Figure 1). Anesthesia was maintained with 2–4% sevoflurane, 1–3 l·min⁻¹ oxygen flow, and a remifentanil infusion at 0.05–0.2 µg·kg⁻¹·min⁻¹. A small bolus of fentanyl (0.5 µg·kg⁻¹)

Table 1
Criteria for grading laryngeal obstruction preoperatively

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical symptom</th>
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<tbody>
<tr>
<td>Grade I</td>
<td>Dyspnea appears only in exercise</td>
</tr>
<tr>
<td>Grade II</td>
<td>Dyspnea appears at rest and aggravates in exercise, sleeping, and eating is not influenced, no dysphoria</td>
</tr>
<tr>
<td>Grade III</td>
<td>Obvious inspiratory dyspnea and laryngeal stridor, the sign of a concave in superternal notch and supraclavicular fossa, sleeping and eating is influenced, dysphoria</td>
</tr>
<tr>
<td>Grade IV</td>
<td>Severe dyspnea, cyanosis, unorientation, coma</td>
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Figure 1
Controlled ventilation through tracheal intubation. The patient presented severe laryngeal obstruction in degree IV. The endotracheal tube was inserted through the interspace of the papilloma.
was given intermittently as needed for analgesia and to increase the depth of anesthesia. (ii) Spontaneous ventilation (Figure 2) was used for the dissection of the residual papilloma under glottis vera or on the posterior part of glottis vera after initial tumor debulking had relieve laryngeal obstruction. The ET tube was pulled back until its tip slid into the laryngopharynx. Anesthetic gases were delivered through the ET tube to the patients’ airway. The concentration of sevoflurane was frequently adjusted to maintain an adequate anesthesia depth as well as to maintain spontaneous ventilation. Generally, sevoflurane (4–8%) with a high oxygen flow rate (4–6 l/min) was required for this insufflation technique. (iii) intermittent apnea ventilation (Figure 3) was used during removal of the remaining papilloma fragments in the hypolarynx and trachea. After a short period of hyperventilation, the ET tube was removed to improve surgical exposure. When the SpO₂ decreased to 90–92%, the patient was re-intubated and hyperventilation was re-initiated to maximize the oxygen reserve and oxygen saturation. This technique of alternation between hyperventilation and apnea allowed the surgery to proceed in a wider and more distal airway. Propofol (1–2 mg·kg⁻¹) and fentanyl (0.5–1 µg·kg⁻¹) were injected to maintain anesthesia during the apnea stage. Occasionally, a 1–2 mg·kg⁻¹ IV bolus of succinylcholine was administered to relax the glottis and to facilitate the surgical operation.

Airway management during extubation and postextubation period

Patients were extubated only after the return of spontaneous breathing, active deglutition or bucking reflex, and full consciousness. Before extubation, it was first determined that there was no fresh bleeding from the surgical field, and that the oral and laryngopharyngeal area were free of secretions, blood clots and tumor debris. Re-intubation was performed if patients had persistent desaturation.

Monitoring

Heart rate (HR), SpO₂, and NIBP were monitored preoperatively and in the recovery room after extubation. HR, SpO₂, and PETO₂ were continuously recorded, and NIBP was monitored at 5-min intervals during the surgical procedure.

Statistical analysis

All data were expressed as mean ± standard deviation (mean ± SD) and analyzed by SPSS13.0 software (SPSS Inc, Chicago, IL, USA). The repeated one-way ANOVA was used for comparisons among the means, and LSD analysis was used for within group comparisons. P < 0.05 was considered as statistically significant.

Results

The grade and severity of laryngeal obstruction

Among the 70 cases, 40 patients were graded as degree III airway obstruction while 24 patients as
degree IV airway obstruction. Four cases from degree IV group were in a comatose status at admission. Thirty-six (51.4%) cases (twelve in degree III and twenty-four in degree IV laryngeal obstruction) were admitted through the emergency department.

**Anesthetic induction and intubation**

In patients with degree III laryngeal obstruction, 30 patients received inhalation induction while 16 patients received IV induction. The latter group was older than 7 years of age and less cooperative. In the degree IV airway obstruction group, four comatose patients were emergently intubated without anesthetics. A mask induction was initiated in the remaining patients with degree IV airway obstruction. Twelve of these developed sudden complete airway obstruction during inhalation induction, and emergent intubation was performed. Eight patients were successfully intubated with one attempt, and three patients required two attempts. Severe bradycardia developed in the three patients because of hypoxemia and resolved after sufficient ventilation was established and SpO₂ was normalized. Negative pressure pulmonary edema (NPPE) occurred in one patient after prolonged complete airway obstruction, evidenced by noticeable pink and frothy secretion, wet crackles heard over the chest, and tachycardia. This patient was treated with high FiO₂, positive end expiratory pressure ventilation, and a dose of intravenous furosemide. Surgery proceeded after the resolution of the NPPE and the return of a normal heart rate. In the group of degree III laryngeal obstruction, ventilation was initially adequately provided via face mask followed by intubation with one attempt in all patients. Cuffed ET tubes, sizes 3.0–5.0, were used in all cases. None of the cases in this study required emergent resection of the tumors during induction periods.

**Intraoperative ventilation**

All 70 patients received tracheal intubation and controlled ventilation during surgical dissection of the supraglottic papilloma. Only 44 patients required the removal of papilloma tissue in the area of hypolarynx or in the tracheal lumen. Among them, 16 patients were allowed to breathe spontaneously and 28 had required an apneic technique.

**Postoperative extubation**

SpO₂ was maintained above 98% with oxygen by face mask at a flow rate 2 l min⁻¹ after extubation in 63 cases. There were a total of seven patients whose SpO₂ decreased to 90% after extubation. This desaturation resolved in four patients with a jaw-thrust maneuver and with airway suctioning of secretions. Three patients with desaturation were re-intubated. Among them, two had failed improved oxygen saturation via face mask, and one developed severe laryngospasm.

**Perioperative monitoring for physiological parameters**

When patients arrived in the operating room, a SpO₂, equal or higher than 97% was observed in all of 46 patients with degree III laryngeal obstruction. An initial SpO₂ of 90% was recorded in 20 patients with degree IV laryngeal obstruction, although severe cyanosis appeared in four comatose patients. After successful intubation and effective ventilation, SpO₂ was maintained successfully above 97% in all patients. Severe hypotension was observed in two comatose patients after emergent intubation. Blood pressures recovered after treatment with ephedrine, dopamine, and volume expansion. The durations of the operations were 5–35 min, and the durations of emergence from anesthesia were 5–20 min. No significant difference was found in mean blood pressure (MAP) and HR (P > 0.05), while SpO₂ and PETCO₂ values were improved significantly postoperatively compared to the preoperative values (P < 0.05, Table 2).

**Discussion**

In the current study, we reviewed the techniques and strategies of perioperative airway management in pediatric patients who underwent surgery for the treatment of recurrent laryngeal papillomatosis causing severe airway obstruction.

**Preoperative airway evaluation and premeds**

All patients in our study presented with significant preoperative dyspnea and anoxia because of the severe airway obstruction. Urgent surgery...
was indicated to avoid prolonged hypoxia and life-threatening events (6). The key point during preoperative airway evaluation is to make an early and prompt assessment of the severity of airway obstruction. It is critical in planning perioperative airway management. The main features used for clinical diagnosis are extent of laryngeal stridor, retractions of the suprasternal notch, supraclavicular fossa and intercostal space, SpO2, and cyanosis (Table 1). Preoperative sedatives and narcotic analgesics should not be used because their respiratory depressive effects can worsen the preexisting airway compromise. Anticholinergic agents can be used to decrease airway secretions and to prevent the potential risk of intraoperative bradycardia.

Anesthesia induction, intubation and the choice of ET tube

The safest way to prevent a partially obstructed airway from converting to a complete collapse is to keep the patient breathing spontaneously as long as possible after inhalation induction. It is especially true in neonates and infants because of the relatively difficult airway access if apnea were to occur. In an older or uncooperative child, intravenous induction may be more appropriate because of the strong resistance to facemask induction by those patients. Succinylcholine used for facilitating intubation should be given only when the controlled facemask ventilation is ensured. In this review report, 12 cases with degree IV laryngeal obstruction developed sudden and complete airway occlusion during the anesthesia induction and immediate intubation had to be performed to establish airway patency. This indicates that spontaneous breathing after inhalation induction is difficult to maintain in patients with preexisting severe laryngeal obstruction. It also highlights the fact that preparation for an emergent intubation to address a completely obstructed airway should be carefully planned prior to any anesthesia induction. Intubation with a proper ET tube after induction will assure adequate ventilation and oxygenation during the debulking of the tumor. A downsized cuffed ET tube inserted through the narrowed glottic vera which is surrounded by papilloma will facilitate surgical access. Initially, it can be difficult to estimate the exact size of glottis vera and therefore tubes of various sizes must be made ready before induction. In some cases, a proper sized tube can be determined by direct visualization of the glottis vera diameter, while in those cases if the opening cannot be seen at all, the sizes of the tubes should be decided by the estimation from clinical symptom together with ages. A careful and smooth intubation maneuver should be carried out to avoid avulsion of tumor tissue, which may occlude the ET tube and cause complete airway obstruction (6) or it may also spread the tumor tissue further into the airway. The cuff of the ET tube should be inflated immediately after intubation to protect the airway against blood or tissue fragment influx. In addition to larger cuffed ET tubes, an uncuffed 2.5 sized ET tube should also be made ready in case of the extremely narrow glottis vera.

Maintaining adequate depth of anesthesia

Adequate depth of anesthesia reduces the risk of complications such as breath holding, laryngospasm, and helps to prevent the cardiovascular reflex because of the airway stimulus (7). It also helps to assure a good surgical outcome. Inhaled Sevoflurane 1–2 MAC combined with intravenous continuous infusion of remifentanil and fentanyl can provide a
sufficient level of anesthesia and also allow a rapid emergence from anesthesia. Occasionally, a short-acting depolarizing muscular relaxant is required during anesthesia maintenance.

**Transition of ventilation mode with surgical stage**

Controlled ventilation with tracheal intubation was usually used during the debulking of the supraglottic papilloma tissue (Figure 1). The inflated cuff of the ET tube protects the airway against aspiration of tumor debris or blood. Ventilation mode was then changed to spontaneous breathing or apneic technique to improve surgical access during removal of the remaining papilloma tissue in the hypolarynx or intratracheal lumen (Figures 2 and 3). Spontaneous respiration under anesthesia can prolong operating time and minimize repeated intubation. The apnea mode can solely be initiated when required. Close cooperation between anesthesiologist and laryngologist was very important during this period of spontaneous ventilation/apnea and also during the transition between spontaneous ventilation and apneic technique. The laryngologists had to be familiar with the intubation maneuver through the suspension laryngoscopy. By using microdebrider, the tissue debris and blood could be sucked out continuously during the operation and aspiration could be prevented effectively. The disadvantage of apneic technique is that children can only tolerate it about 3 min (8). Also, its application may cause airway injury because of repeated intubation.

**Avoiding the need for a tracheotomy**

An emergent tracheotomy is rarely needed as a lifesaving measure. Prompt preoperative airway evaluation, careful intraoperative airway management, and prompt postoperative handling of airway problems will reduce the risk of tracheotomy. Tracheostomy can result in tracheal stenosis in children and affect tracheal development and should be avoided if possible. Laryngeal papillomas usually originate from the junctional zones between ciliated columnar epithelia and squamous epithelia. The incision site for a tracheostomy may cause the formation of a junctional zone and promote growth of the papilloma around the stoma and into the trachea (9).

Breathing through the incised trachea may mask symptoms of airway obstruction caused by the growth of the tumor. When dyspnea appears, the papilloma may have spread to a degree that is difficult to control.

**The management of side effects and monitoring in postextubation period**

In the patients with severe laryngeal obstruction, hypotension may occur after emergent intubation, presumably because of dehydration, prolonged hypoxemia, and elimination of accumulated carbon dioxide. These patients should be intensively monitored and treated with vasoactive agent and volume expansion. Extubation should be performed after the patient has woken from anesthesia and regained airway protective reflexes. This avoids aspiration of blood clots or tumor debris into the distal airway, laryngospasm, and pharyngolaryngeal obstruction which may lead to desaturation. In addition, patients should be closely monitored after extubation. Airway secretions should be removed prior to extubation and postextubation. A jaw-thrust maneuver would help to open up the airway. In the current report, seven patients had desaturation to SpO₂ of 90% caused by airway secretions, airway obstruction, or laryngospasm. This desaturation was resolved with airway toilet, jaw-thrust maneuver, or re-intubation.

In conclusion, pediatric laryngeal papillomatosis with severe laryngeal obstruction can be a life-threatening event. During surgery for this disorder, the key factors of perioperative airway management are the prompt preoperative airway evaluation, proper selection of ET tubes and the methods of intubation, adequate depth of anesthesia, careful management of the ventilation mode transition at different stages of surgery, close monitoring in the process of extubation and postextubation, and airway protection against aspiration, and prompt management of complications.

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