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REVIEW ARTICLE

# Congenital laryngeal anomalies☆,☆☆

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**KEYWORDS**
Congenital laryngeal anomalies;
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Vocal fold paralysis

**Abstract**
*Introduction:* It is essential for clinicians to understand issues relevant to the airway management of infants and to be cognizant of the fact that infants with congenital laryngeal anomalies are at particular risk for an unstable airway.
*Objectives:* To familiarize clinicians with issues relevant to the airway management of infants and to present a succinct description of the diagnosis and management of an array of congenital laryngeal anomalies.
*Methods:* Revision article, in which the main aspects concerning airway management of infants will be analyzed.
*Conclusions:* It is critical for clinicians to understand issues relevant to the airway management of infants.


**PALAVRAS-CHAVE**
Anomalias congênitas da laringe;
Intubação difícil;
Laringomalacia;
Estenose subglótica;
Paralisia das cordas vocais

**Anomalias congênitas da laringe**

**Resumo**
*Introdução:* As anomalias congênitas da laringe estão em risco de uma via aérea instável, sendo essencial que o clínico tenha uma boa compreensão dos problemas relevantes para o manuseio das vias aéreas de bebês.
*Objetivos:* Familiarizar os clínicos com os problemas relevantes para o manuseio das vias aéreas de bebês e apresentar uma descrição sucinta do diagnóstico e tratamento de uma série de anomalias congênitas da laringe.
*Método:* Artigo de revisão, no qual serão tratados os principais aspectos relacionados ao manuseio das vias aéreas de bebês.

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*Conclusões:* É essencial que o clínico tenha um bom conhecimento dos problemas relevantes ao manuseio das vias aéreas de bebês.


## Overview

Given that infants with congenital laryngeal anomalies are at risk for an unstable airway, it is critical for clinicians to understand issues relevant to the airway management of infants. With that in mind, this review provides an overview of these issues and subsequently presents a brief discussion of the diagnosis and management of a spectrum of congenital laryngeal anomalies.

## General considerations

### Prevention of complications

Although prolonged intubation may be tolerated for weeks or even months in neonates, this tolerance decreases with age. The longer the infant is intubated, the higher the relative risk of developing subglottic stenosis (SGS) or posterior glottic stenosis (PGS). A combination of factors may increase the risk of laryngeal injury secondary to intubation. These factors include (1) the composition and size of the endotracheal tube, (2) the duration of intubation, (3) patient agitation while intubated, and (4) problems that predispose patients to mucosal damage (e.g., extra-esophageal reflux and airway burns). Of these factors, the most critical is the size of the endotracheal tube. To minimize the likelihood of post-intubation injury, endotracheal tube size should be based on the ventilatory needs of each individual child rather than the age of the child. More specifically, the tube should be large enough to allow adequate ventilation but small enough to permit a leak of air through the subglottis at a subglottic pressure of <20 cm $H_2O$. Although the average term newborn should accommodate a 3.5-mm endotracheal tube, a newborn with mild, asymptomatic congenital SGS may require a 2.5-mm endotracheal tube. In some infants, the size of the endotracheal tube ideal for the larynx may not allow adequate pulmonary ventilation and toilet. In these children, a larger endotracheal tube without a leak may be tolerated for a period of time, as the actual risk of developing SGS is still low.

A similar problem may occur with poor pulmonary compliance, whereby a leak pressure of <20 cm $H_2O$ may not allow adequate ventilation. One possible solution is the use of a low-pressure cuffed endotracheal tube that permits higher-pressure ventilation while still minimizing laryngeal trauma. For some infants, the risks associated with tracheal intubation may be circumvented by the use of alternatives such as continuous positive airway pressure (CPAP), bilevel positive airway pressure (BiPAP), high flow nasal cannula, or tracheotomy.

### Difficult intubation

Infants and children with anatomic anomalies of the mandible are particularly difficult to intubate. In addition, children with microsomia, temporomandibular fixation, macroglossia, and maxillofacial trauma present a challenge to the clinician. Children with retrognathia, especially those with Pierre–Robin sequence, may be extremely difficult to intubate irrespective of the degree of retrognathia or airway obstruction.

Standard intubation techniques also may be challenging in children in whom neck extension should be avoided, such as the child with an unstable cervical spine. The risk may be known, as in a child with Down syndrome, or unknown, as in an unconscious child with a head injury and possible cervical injury. If intubation is elective, flexion–extension plain films of the cervical spine of children at risk for cervical instability are useful. Although children with Down syndrome, mucopolysaccharide storage disorders, and major chromosomal anomalies are at higher risk of complications, in most, intubation without neck extension can still be safely performed.

It is usually possible to intubate in a standard fashion, with the largest possible anesthetic laryngoscope blade, a styletted endotracheal tube (with the tip of the stylet angled anteriorly 30–45° in a retrognathic child), and with laryngeal pressure applied. If this is unsuccessful, intubation may be performed with flexible fiberoptic transnasal endoscopy, rigid ventilating bronchoscopy, an endotracheal tube threaded over a Hopkins rod telescope, or a laryngeal mask airway. Even in children who are difficult to intubate, a bag and mask with an oral airway may be sufficient until a more definitive solution can be attained. For children in whom intubation is particularly difficult, either elective or emergent tracheotomy is generally required. When possible, it is desirable to place a tracheotomy with the airway already secured with an endotracheal tube.

### The child with a tracheotomy

Tracheotomy tube complications may be divided into those related to a fresh tracheotomy tract and those related to tube obstruction. A fresh tracheotomy carries the risk of tube displacement and subsequent difficulty with tube replacement. Precautions to prevent displacement include

maturing the stoma (the skin is sewn directly to the tracheal cartilage) and placing stay sutures. These precautions are taken so that if the tracheotomy is displaced, traction on the stay sutures will open the tracheotomy and aid in replacement of the tube. Flexible bronchoscopy at the time of tracheotomy placement permits assessment of the tube position, assuring that it is not too close to the carina or down a bronchus.

Respiratory symptoms may occur from obstruction within the tube or distal to the tube. Regular suctioning to the tip of the tube, but not beyond, usually prevents tube obstruction. Suctioning is the initial intervention for suspected obstruction. If difficulties persist, the tube should be replaced. If symptoms continue, obstruction distal to the tube should be suspected. Ideally, flexible bronchoscopy down the tracheotomy tube will confirm the site of obstruction, and a longer tube may be all that is required to bypass the obstruction. Positive pressure alleviates obstruction stemming from tracheomalacia or bronchomalacia. In an emergency situation, a longer tracheotomy tube or an endotracheal tube placed through the stoma will generally bypass the obstruction.

## Congenital anomalies of the larynx

### Laryngomalacia

Laryngomalacia is the most frequent cause of stridor in the neonate,[1] and most children with this anomaly are symptomatic at birth or within the first few days of life. Stridor is generally mild, but is exacerbated by feeding, crying, and lying in a supine position. In 50% of the cases, symptoms worsen during the first 6 months of life, and, in virtually all children with laryngomalacia, symptoms resolve by 1 year of age.[1] In children with severe laryngomalacia (approximately 10%), surgical intervention is required[1–3]; symptoms in these children may include apnea, cyanosis, severe retractions, and failure to thrive. In extremely severe cases, cor pulmonale is observed.

Diagnosis is confirmed by flexible transnasal fiberoptic laryngoscopy. Characteristic findings include short aryepiglottic folds, with prolapse of the cuneiform cartilages. In some cases, a tightly curled (Ω-shaped) epiglottis is also observed. Because of the Bernoulli effect, characteristic collapse of the supraglottic structures is seen on inspiration. Inflammation suggestive of reflux laryngitis is also frequently present. The need for intervention is not determined by the endoscopic appearance of the larynx, but rather by the symptoms of the infant.

Children with laryngomalacia rarely present with acute airway compromise. In the 10% of children who require operative management, this may be arranged in a semi-elective fashion within one to two weeks of presentation. Preoperative management of gastroesophageal reflux (GER) is prudent. Supraglottoplasty (also termed epiglottoplasty) has replaced tracheotomy as the preferred intervention. This is a rapid and effective endoscopic procedure, directed at the infant's specific laryngeal pathology. Both aryepiglottic folds usually are divided. In addition, one or both cuneiform cartilages may be removed. If the aryepiglottic folds alone are divided, postoperative intubation is generally not required; however, overnight intubation should be considered if more extensive surgery has been performed.

Following supraglottoplasty, overnight observation in the intensive care unit is desirable, as laryngeal edema may compromise the airway, necessitating reintubation. Extubation is usually possible within 24 h of the surgery. In some children, obstruction persists postoperatively.[4] Bedside fiberoptic laryngoscopy can differentiate between laryngeal edema and persistent laryngomalacia. Reflux management helps mitigate laryngeal edema. Occasionally, the postoperative appearance of the larynx is adequate, but the infant is still struggling. In such cases, there is sometimes an underlying neurologic component to the laryngomalacia. Although the neurologic problems may be extremely subtle initially, they may become much more evident with time.[1,5] This subset of children is far more likely to require tracheotomy placement.

### Bilateral vocal fold paralysis

In contrast to unilateral vocal fold paralysis, bilateral paralysis is usually congenital. Although this condition is generally idiopathic, it may be seen with central nervous system pathology, including hydrocephalus and Chiari malformation of the brainstem.[6] For an infant with stridor and retractions due to bilateral paralysis, tracheotomy is indicated. As with laryngomalacia, the diagnosis is established with awake flexible transnasal fiberoptic laryngoscopy. Stabilization may be achieved with intubation, CPAP, or high-flow nasal cannula as an alternative temporizing measure. In up to 50% of children, the paralysis spontaneously resolves by 1 year of age. Surgical intervention to achieve decannulation is therefore usually postponed until after this period.

The aim of surgery is to achieve an adequate decannulated airway while maintaining voice and not exacerbating aspiration. Surgical options include laser cordotomy, partial or complete arytenoidectomy (endoscopic or open), vocal process lateralization (endoscopically guided or open), and posterior cricoid cartilage grafting.[1,7] No single option offers a perfect result. In a child with a tracheotomy, it is often desirable to maintain the tracheotomy to ensure an adequate airway before decannulation.

Acquired bilateral vocal cord paralysis is usually more recalcitrant to treatment than idiopathic cord paralysis, and more than one procedure may be required to achieve decannulation. For patients who have undergone any such procedures, post-extubation stridor may respond to CPAP or high-flow nasal cannula. A child's postoperative risk of aspiration should be assessed by a video swallow study prior to resuming a normal diet. During the initial weeks following surgery, there is sometimes an increased risk of aspiration with certain textures, particularly thin fluids.

### Subglottic stenosis

Congenital SGS, defined as a lumen 4.0 mm in diameter or less at the level of the cricoid in a term newborn, is thought to stem from a failure of the laryngeal lumen to recanalize. It is one of a continuum of embryologic failures that include laryngeal atresia, stenosis, and webs. In its mildest form, congenital SGS appears as a normal cricoid

with a smaller than average diameter, usually elliptical in shape. Mild SGS may manifest in recurrent upper respiratory infections in which minimal subglottic swelling precipitates airway obstruction. In a young child, the greatest obstruction is usually 2–3 mm below the true vocal folds. More severe cases may present with acute airway compromise at delivery. If endotracheal intubation is successful, the patient may require intervention before extubation. When intubation cannot be achieved, tracheotomy placement at the time of delivery may be lifesaving. It is important to note that infants typically have surprisingly few symptoms. Even those with grade 3 SGS (71–99% obstruction)[8] may not be symptomatic for weeks or months.

Congenital SGS is often associated with other congenital head and neck lesions and syndromes (e.g., a small larynx in a patient with Down syndrome). After initial management of SGS, the larynx will grow with the patient and may not require further surgical intervention. However, if initial management requires tracheal intubation, there is a considerable risk of developing an acquired SGS in addition to the underlying congenital SGS.

Radiologic evaluation of an airway that is not intubated may give the clinician clues about the site and length of the stenosis. Useful imaging modalities include (1) inspiratory and expiratory lateral soft-tissue neck films, (2) fluoroscopy to demonstrate the dynamics of the trachea and larynx, and (3) chest X-ray. The single most important investigation, however, is high-kilovoltage airway film. These films can identify the classic steepling observed in patients with SGS as well as possible tracheal stenosis. The latter condition is generally caused by complete tracheal rings, which may predispose the patient to a life-threatening situation during rigid endoscopy.

Evaluation of SGS requires endoscopic assessment. Flexible fiberoptic endoscopy provides information on dynamic vocal fold function. Rigid endoscopy with Hopkins telescopes provides the best possible examination. Precise evaluation of the endolarynx should be carried out, including grading of the SGS.[8]

For children with mild symptoms and a minor degree of SGS, endoscopic intervention may be effective. Endoscopic options include radial incisions through the stenosis with steroid injections and laryngeal dilatation.[9] More severe forms of SGS are better managed with open airway reconstruction. Laryngotracheal reconstruction using costal cartilage grafts placed through the split lamina of the cricoid cartilage is reliable and has withstood the test of time.[10,11] Costal cartilage grafts may be placed through the anterior lamina of the cricoid cartilage, the posterior lamina of the cricoid cartilage, or both. These procedures may be performed as two stages, maintaining the tracheal tube and temporarily placing a suprastomal laryngeal stent above the tracheal tube. Alternatively, in select cases, a single-stage procedure may be performed, with removal of the tracheal tube on the day of surgery and with the child requiring intubation for 1–14 days.[12] For the management of severe SGS, better results are achieved with cricotracheal resection than with laryngotracheal reconstruction.[13–15] However, this is a technically demanding procedure that carries a significant risk of complications. Reconstruction of the subglottic airway is a challenging procedure and the patient should be optimized before undergoing surgery. Preoperative evaluation includes assessment and management of GER, EE, and low-grade tracheal infection, particularly oxacillin-resistant *Staphylococcus aureus* (ORSA) and *pseudomonas*.[16]

## Saccular cysts

The laryngeal saccule is a small diverticulum containing numerous mucous glands at the anterior end of the laryngeal ventricle, extending superiorly between the vestibular fold and the inner surface of the thyroid cartilage.[17] Congenital saccular cysts are mucus filled, and usually extend posterosuperiorly into the false vocal fold and aryepiglottic fold (the lateral saccular cyst).[18] These cysts typically present with respiratory obstruction in the first few days of life, a muffled cry, and dysphagia. Because low muscle tone predisposes to obstruction, one of the greatest risks for children with saccular cysts is the induction of general anesthesia, with subsequent loss of the airway and complete obstruction. It is therefore mandatory to perform preoperative awake transnasal flexible laryngoscopy to evaluate the airway, as this will forewarn of potential problems with subsequent anesthesia. During anesthesia, the airway may be secured with an appropriate ventilating bronchoscope, a styletted endotracheal tube, or an endotracheal tube placed over a small Hopkins rod telescope. Given the risks associated with anesthesia, this should be attempted only in the presence of equipment and personnel capable of securing the airway. Sending an infant for a radiologic evaluation that may require sedation or an anesthetic could be disastrous. It is thus advisable to evaluate and secure the airway in the operating room, and consider radiologic evaluation after the airway is secured.

Although saccular cysts have historically been managed endoscopically using needle aspiration, marsupialization, or endoscopic excision, the results have been poor, often requiring multiple procedures and tracheotomy placement. The author's preference is to use an anterior cervical approach whereby the superior border of the thyroid alar cartilage is identified and the thyrohyoid membrane is incised along its superior border. This approach provides access to the cyst, which may gently be dissected free and removed intact. Part of the thyroid cartilage may be removed to improve access and replaced after the cyst is removed.

## Posterior laryngeal clefts

Posterior laryngeal clefts result from a failure of the laryngotracheal groove to fuse during embryogenesis. Patients commonly have associated anomalies that affect the airway or other organ systems. Associated airway anomalies include tracheomalacia (>80%) and tracheoesophageal fistula (TEF) formation (20%). Non-airway associations include anogenital anomalies and GER. The most common syndrome associated with posterior laryngeal clefting is Opitz–Frias syndrome, characterized by hypertelorism, anogenital anomalies, and posterior laryngeal clefting.

A useful anatomic classification proposed by Benjamin and Inglis[19] divides posterior laryngeal clefts into the following four subtypes:

**Type 1**: supraglottic interarytenoid cleft present to, but not below, the level of the true vocal folds. This cleft could also be considered a deep interarytenoid notch.
**Type 2**: partial cricoid cleft that extends into, but not through, the posterior cricoid cartilage.
**Type 3**: total cricoid cleft with or without extension of the cleft into the cervical trachea.
**Type 4**: cleft extending to the thoracic trachea.

A rare variant of the type 4 cleft (referred to as type 4 long) is a cleft that extends into the carina or beyond.

It is important for clinicians to note that there is a great deal of symptom overlap among the various cleft types and that symptoms are not indicative of cleft severity. Aspiration is the hallmark clinical feature of this anomaly. Although gross aspiration may occur with associated apnea, cyanosis, and even pneumonia, the symptoms often include microaspiration, with choking episodes, transient cyanosis, and recurrent chest infections. Severe tracheomalacia may significantly compromise the airway, especially in children with an associated tracheoesophageal fistula.

Although diagnostic tools include flexible nasopharyngoscopy, fiberoptic endoscopic evaluation of swallowing, video fluoroscopy-barium swallow, and flexible bronchoscopy, the gold standard for diagnosis is rigid bronchoscopy and esophagoscopy. Given that the cleft is often hidden by redundant mucosa in the posterior glottis, it is not uncommon for it to be undiagnosed or misdiagnosed on initial evaluation with flexible or rigid bronchoscopy.

Management involves maintaining an appropriate airway while minimizing the risk of aspiration. Initial management decisions should consider whether the infant requires tracheotomy placement, gastrostomy tube placement, or Nissen fundoplication. Although none of these is essential, each increases the likelihood of successful cleft repair. Protection against aspiration is also crucial, and nasojejunal feeding may be a useful way of stabilizing an infant. Surgical repair may be performed endoscopically for most type 1 and some type 2 clefts; however, longer clefts that extend into the cervical or thoracic trachea require open repair. The transtracheal approach provides unparalleled exposure of the cleft while protecting the recurrent laryngeal nerves. A two-layer closure is recommended, with the option of performing an interposition graft if warranted; a useful interposition graft is a free transfer of the sternal periosteum.

The most challenging cleft to repair is the rare type 4 long cleft. These clefts are prone to anastomotic breakdown and the infant often has multiple anomalies, both airway and non-airway.[20] The latter may include microgastria, polysplenia, and annular pancreas. Microgastria may result in uncontrollable gastroesophageal reflux and is not amenable to fundoplications. Before attempting surgical repair of the cleft, the surgeon must decide if the child is salvageable.

Success rates for posterior laryngeal cleft range from 50% to 90%, depending on a number of factors. The most influential factor compromising successful cleft repair is the presence of a coexistent congenital tracheoesophageal fistula. Other factors include the severity of the cleft, the type of operation chosen by the surgeon, and whether a double-layer or single-layer closure is performed. Revision surgery is less successful than primary surgery.[20]

## Laryngeal webs

Laryngeal webs represent a failure of recanalization of the glottic airway in the early weeks of embryogenesis. Virtually all (95%) glottic webs are anterior; however, these webs are rare, comprising only 5% of congenital laryngeal anomalies. Although there is currently no known gene that causes congenital glottic webbing, a significant association between this anomaly and chromosome 22q11.2 deletion syndrome (velocardiofacial syndrome) has been reported.[21,22] Given that more than 50% of the patients with an anterior glottic web have chromosome 22q11.2 deletion syndrome, it is prudent to refer all patients with congenital anterior glottic webs for genetic evaluation.

Some webs are gossamer thin; however, most are thick and usually associated with a subglottic ''sail'' compromising the subglottic lumen.[1] They may therefore be considered as a form of partial laryngeal atresia. Neonates usually present with an abnormal cry or respiratory distress at birth. If a neonate with an anterior glottic web presents with significant airway compromise in the first few hours or days of life, the web is severe and emergent airway intervention is required. Nonetheless, the clinician should be cognizant of the fact that infants are remarkably tolerant of airway compromise and even those with a moderate to severe glottic web may initially show only subtle airway symptoms. These symptoms typically exacerbate over the first few months of life. In infants with moderate to severe webs, biphasic stridor and retractions become increasingly evident, particularly when these infants are upset or feeding.

A definitive evaluation requires rigid or flexible bronchoscopy. Both the severity of the web and its subglottic extension are evaluated. Flexible bronchoscopy provides an excellent view of the anterior commissure, whereas rigid bronchoscopy is more advantageous in evaluating the degree of associated SGS. In children with a severe web, care must be taken not to further compromise an already compromised airway, and spontaneous ventilation with the infant maintaining his or her own airway is preferable to intubation or emergent tracheotomy.

Management of the infant with a gossamer-thin anterior glottic web is different from management of the far more frequent thick web with subglottic extension. The infant with a thin glottic web may never be diagnosed, as it is thought that in a child with neonatal airway compromise due to such a web, intubation for airway stabilization may actually lyse the web and completely resolve the problem. In an infant presenting with a thin anterior web on bronchoscopy, division of the web with a sickle knife while the infant is suspended on a small Lindholm laryngoscope is curative.

In infants presenting with a thick glottic web, an initial decision must be made as to whether repair should be performed early in the neonatal period or later in childhood. In children with a mild or moderate web and in whom no clinical airway compromise is present, late repair is preferable, as this is technically easier to perform in a larger larynx. Late repair is usually performed by age 4, so as to improve the quality of a child's voice prior to school age. In children

with a more severe degree of glottic compromise, repair may be performed early. Alternatively, a tracheotomy may be placed and late repair may be planned. This approach is required in approximately 40% of patients with thick webs.

Options for repair of a congenital anterior glottic web include open keel placement and open reconstruction of the anterior commissure. Endoscopic procedures such as laser division of the web or endoscopic keel placement are not advocated. Laser division is likely to result in web reformation and does not adequately address the inherent SGS that is generally present. Similarly, endoscopic keel placement does not address SGS. Furthermore, although it may be an appropriate option in an older child, it is technically demanding in an infant.

### Subglottic hemangioma

Although hemangiomas generally present cutaneously, they can occur in any anatomic site. The larynx, particularly the subglottis, is the most common site of presentation within the airway. More than 50% of the patients with a subglottic hemangioma also have cutaneous hemangiomas, which provide an indication for the possible presence of a synchronous subglottic lesion. Patients with a hemangioma occurring in a beard distribution (i.e., the chin, jawline, and preauricular areas) are at the highest risk for a subglottic hemangioma.[23] The natural history of these hemangiomas mirrors that of cutaneous lesions, with an initial phase of proliferation followed by a phase of involution; however, subglottic hemangiomas expand and involute more rapidly. As the hemangioma increases in size, progressive deterioration of the airway usually occurs. Symptoms include biphasic stridor with retractions, especially when the child is upset or feeding. A barking cough similar to that seen with the croup may also be present. When airway obstruction is severe, apnea, cyanosis, and ''dying spells'' may occur.

Optimally, initial evaluation is performed with awake transnasal flexible laryngoscopy. This may allow for visualization of the compromised subglottis, and more importantly, should also rule out other causes of neonatal stridor such as laryngomalacia and vocal fold paralysis. A child with progressive stridor and a normal glottic and supraglottic examination requires a laryngoscopy and bronchoscopy performed in the operating room under general anesthesia. As mentioned earlier in this article, because infants are so remarkably tolerant of progressive subglottic airway compromise, there may be an 80–90% compromise of the subglottic lumen by the time the child presents for rigid bronchoscopy. In infants in whom extralaryngeal involvement is suspected (e.g., those with cutaneous hemangiomas occurring in a beard distribution), magnetic resonance imaging (MRI) with T2-weighted gadolinium contrast is performed. Because of the risk of hemorrhage, biopsy is not advised.

Most patients require treatment, and treatment modalities are often combined. At Cincinnati Children's Hospital Medical Center, symptomatic patients with significant stridor are managed with systemic steroids combined with propranolol, a nonselective beta-blocker used to treat infants with cardiovascular conditions. Over the past several years, a plethora of reports have documented dramatic results achieved with the use of this agent,[24–29] thereby changing the traditional paradigm of pharmacotherapy and surgical management. For the most part, propranolol therapy has replaced both open and endoscopic resection and has obviated the need for tracheotomy placement. Moreover, a recent (2013) review of 41 propranolol studies revealed a low rate of serious adverse advents.[30] Treatment is typically maintained for a minimum of six months; patients are then weaned off the propranolol. Because premature cessation of this therapy may result in hemangioma regrowth,[29] careful monitoring during the weaning process is essential.

## Conflicts of interest

The author declares no conflicts of interest.

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