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Mini-symposium: Upper Airway Abnormalities

Laryngomalacia: Review and Summary of Current Clinical Practice in 2015

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EDUCATIONAL AIMS

The reader will be able:

- To discuss the etiology, prevalence and clinical presentation of laryngomalacia.
- To discuss the use of conservative treatment for children with mild-moderate laryngomalacia.
- To review surgical indications for supraglottoplasty and discuss surgical goals, outcomes and peri-operative care.
- To discuss treatment alternative treatment options for children who fail supraglottoplasty or are not appropriate surgical candidates.

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SUMMARY

Laryngomalacia is the most common cause of stridor in neonates and infants. Associated feeding difficulties are present in approximately half of the children. A definitive diagnosis can generally be made with flexible fiberoptic laryngoscopy. The disorder is most often self-limited with resolution of symptoms within the first 24 months of life, and the majority of children can thus be managed conservatively. The approximately 5%-20% of children with severe or refractory disease may require more aggressive intervention, most commonly in the form of trans-oral supraglottoplasty [1,2]. High success rates and a low rate of complications have been reported for this procedure in otherwise healthy children. Children with syndromes or medical comorbidities are more likely to have complications or persistent symptoms after supraglottoplasty and may require additional interventions.

DEFINITION AND PRESENTATION

Laryngomalacia is defined as collapse of supraglottic structures during inspiration, resulting in intermittent airflow impedance and associated stridor. It is the most common cause of stridor in neonates and children, accounting for 60-70% of cases [3].

The characteristic high pitched inspiratory stridor associated with laryngomalacia is not always present at birth but generally becomes apparent by several weeks of age. Symptoms may worsen over the first 4-8 months of life. The stridor is often exacerbated by agitation, crying, feeding, upper respiratory tract infections or supine positioning. The stridor commonly diminishes or resolves during sleep in mild to moderate cases. In approximately 5%-20% of children, respiratory concerns such as obstructive sleep apnea, tachypnea, dyspnea, respiratory distress or hypoxemia can occur. In the most severe cases, progression to pulmonary hypertension and cor-pulmonale can occur without appropriate treatment [4]. Feeding difficulties are present in approximately half of children with mild to moderate laryngomalacia and virtually all children with more severe disease, and can include coughing and

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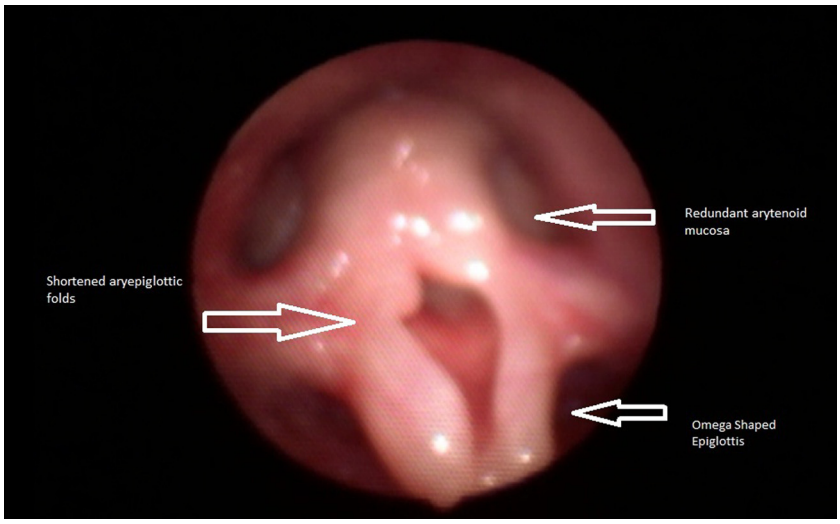

Figure 1. Fiberoptic view of child with laryngomalacia during expiration. Note the typical findings including omega-shaped epiglottis, shortened AE folds and redundant arytenoid mucosa obstructing view of vocal folds.

choking, cyanotic episodes, regurgitation, emesis or slow feeding. In more severe disease, recurrent aspiration pneumonia or failure to thrive from decreased caloric consumption and heightened metabolic demand from increased work of breathing occurs [5].

ETIOLOGY

Historically, it was thought that laryngomalacia represented an anatomic abnormality of the laryngeal cartilage. This theory was supported by a prospective study showing a lower aryepiglottic (AE) fold to glottic length ratio in patients with severe laryngomalacia compared with unaffected children [6], but failed to explain why some children with similar laryngeal examinations were asymptomatic. The theory of immature and abnormally collapsible cartilage was further discredited by histologic examinations demonstrating normal fibro-elastic cartilage tissue in children with symptomatic disease [7]. Recently, attention has focused on a neuromuscular etiology, consisting of immaturity or abnormal integration of the peripheral nerves, brainstem nuclei and pathways responsible for swallowing and maintenance of airway patency. This is supported by physiologic studies in infants with laryngomalacia demonstrating increased stimulus threshold requirements for elicitation of normal motor responses correlating with disease severity [4]. Additional corroboration is provided by histologic studies showing significant size differences in the superior laryngeal nerve branches of patients with severe laryngomalacia compared to age matched controls [8]. Subsequent neurological and central nervous system maturation would provide a reasonable explanation for the spontaneous resolution generally seen in the disease.

DIAGNOSIS

History and Examination

A presumptive clinical diagnosis of laryngomalacia can be made based on the classic symptoms of inspiratory stridor worsened by feeding, agitation, supine positioning or crying. Pertinent history should include birth circumstances (including gestational age and endotracheal intubation), congenital or genetic abnormalities, respiratory symptoms with aggravating or temporizing factors, and feeding concerns including retarded growth, choking or gagging, reflux symptoms, or recurrent pneumonia. Physical examination should include height and weight, respiratory sounds including timing in the respiratory cycle, chest movement to determine the presence of retractions or pectus excavatum, and auscultation of the lung fields.

A definitive diagnosis of laryngomalacia can be made accurately by flexible fiberoptic laryngoscopy alone in the vast majority of cases (88%), regardless of the experience level of the examiner [9]. The procedure can generally be performed on awake children in the arms of their caregiver without the need for sedation. The flexible fiberoptic laryngoscope is passed along the nasal floor and positioned above the larynx during several cycles of spontaneous respiration. Topical anesthetics should be avoided when possible as they may exacerbate airway collapse and alter the examination [10]. Characteristic findings include inspiratory supraglottic collapse with poor visualization of vocal cords due to shortened AE folds, collapse of arytenoids into airway, edema of the posterior glottis or a curled (omega-shaped) or retroflexed epiglottis. (Figures 1 and 2) Of note, the severity of stridor or symptoms does not reliably correlate closely with the extent of collapse on flexible fiberoptic examination.

Several anatomical staging systems for laryngomalacia have been proposed which focus on defining the site of collapse including:

1. posterior collapse (from redundant arytenoid mucosa or cuneiform cartilage)
2. lateral collapse (from shortened AE folds)
3. anterior collapse (from a retroflexed epiglottis)
4. combined collapse (involving multiple areas of anatomic collapse)

Although none of these systems has achieved universal acceptance to date, consistent and detailed documentation of the type and severity of collapse seen on flexible laryngoscopy provides crucial information when contemplating surgical manipulation.

Alternately, iterations of symptom based grading systems are frequently used in clinical practice to stratify disease severity and help inform the timing or need for more aggressive intervention (Table 1) [11].

Additional Diagnostic Evaluations

Associated conditions, most notably reflux disease or synchronous airway lesions (SALs), have been commonly reported in

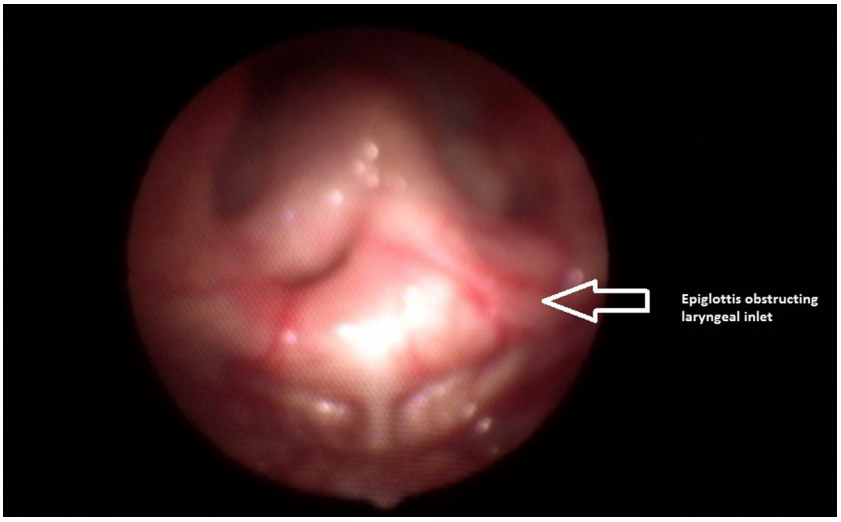

Figure 2. Fiberoptic view of same child in Figure 1 during inspiration. The epiglottis has inverted into the laryngeal inlet with resulting airway obstruction.

children with laryngomalacia. Other frequently reported co-morbidities include neurologic disease, congenital syndromes and anomalies, and heart disease. These conditions have the potential to worsen the severity of laryngomalacia symptoms or adversely affect surgical outcomes, necessitating their recognition and timely treatment when possible.

The most commonly reported co-morbidity associated with laryngomalacia is gastroesophageal or laryngopharyngeal reflux disease (GERD). Reflux disease has been reported in 65%-100% of infants with laryngomalacia [12,13]. Theoretically, breathing against an obstructed airway generates increased negative intra-thoracic pressures and a greater likelihood of overcoming the protective role of the esophageal sphincters. Reflux events could then irritate the laryngeal mucosa, causing edema and thereby worsening airway collapse. Chronic reflux may also contribute to decreased laryngeal sensation, further exacerbating the risk for choking and aspiration. There is some evidence that acid suppression can improve laryngeal sensation [14,15]. Some clinicians have therefore advocated for routine pH studies in children with laryngomalacia [16]. However, a recent systematic review of 27 studies evaluating the relationship between laryngomalacia and acid reflux supported the presence of co-existence between the two entities, but found only limited evidence to indicate a causal relationship. Additionally, the authors concluded that the lack of consistency in type of therapy employed, method of diagnosis and objective outcome measures precluded meaningful meta-analysis of treatment outcomes [17]. It therefore remains controversial whether routine evaluation for reflux disease is indicated.

The incidence of SALs in children with laryngomalacia also remains a topic of debate. Rates of SALs ranging from 12%-64% have been reported, most commonly tracheomalacia, subglottic stenosis and vocal cord paralysis [18–21]. The clinical significance of secondary airway lesions is also unclear. Mancuso reported that only 4.7% of patients with laryngomalacia and SALs required additional intervention [20]. Conversely, a report of 200 infants demonstrated SALs in over half (51.7%) of the subjects. Although lesions were more prevalent in the children with severe disease (79%), children with mild to moderate disease were more likely to require surgical intervention; in the author's opinion underscoring the clinical importance of timely diagnosis and appropriate intervention [22]. One explanation for these apparent contradictions is that the higher incidence of SALs in some reports reflects skewed patient cohorts of children with increased risk for airway abnormalities from other causes. Support for that explanation was seen in a recent report of a large cohort of patients undergoing laryngoscopy and bronchoscopy at a paediatric tertiary care center, including 108 patients consecutively diagnosed with laryngomalacia. Children with disorders known to likely affect the airway including cardiac or large vessel malformations, prematurity, prolonged or repeated intubations, prior airway surgery or acute infectious processes were excluded. Synchronous airway lesions were detected in only 7.7% of the 91 remaining patients [23].

Given this uncertainty in both the prevalence and clinical significance of SALs, it therefore remains controversial whether or not additional diagnostic procedures to evaluate for synchronous airway lesions are routinely indicated. Magnified airway fluoroscopy and barium swallow studies can non-invasively evaluate for the presence of secondary lesions or gross aspiration and reflux, but are associated with a not insignificant dose of radiation [5]. Rigid direct laryngoscopy and bronchoscopy can be used to evaluate SALs and also allows for closer inspection to rule out laryngeal clefts and more subtle abnormalities, but requires general anesthesia and has a potential risk for perforation or airway obstruction. One commonly employed clinical approach is therefore to routinely perform rigid bronchoscopy only on children undergoing concurrent supraglottoplasty.

Polysomnography may also be considered when nocturnal hypoxemia or severe obstructive sleep apnea due to laryngomalacia is suspected and may provide useful clinical information regarding the need for more aggressive intervention. An increased rate of central sleep apneas (46%) has been reported with laryngomalacia, most notably in children with neurological disorders, hypotonia or other syndromes [24]. Similarly, echocardiograms may be

Table 1
Laryngomalacia Severity Scale*

Severity Level	Respiratory Symptoms	Feeding symptoms
Mild	Inspiratory stridor Average resting SpO_2 98-100%	Occasional cough or regurgitation
Moderate	Inspiratory stridor Average resting SpO_2 ~96%	Frequent regurgitation or other feeding issues
Severe	Inspiratory stridor with cyanosis or apnea Average resting SpO_2 ~86%	Failure to thrive or aspiration

Derived from text descriptions by Thompson, DM and colleagues [11].

indicated in patients with a history of congenital heart defects to assess the extent of cardiac dysfunction and cardiac contribution to hypoxemia, both to assess the risk of additional peri-operative morbidity and to determine the likelihood of residual hypoxemia unrelated to the laryngomalacia [5].

The need for additional diagnostic studies or procedures is thus best determined by the treating physicians based on clinical presentation, fiberoptic findings, extent of feeding difficulty and response to conservative management. The presence of associated syndromes or co-morbidities should also be considered.

Atypical Presentations

Although laryngomalacia most often presents during infancy, occasionally symptoms are present only sporadically or have onset later in life. In state dependent laryngomalacia, children present with exclusively nocturnal symptoms and may initially undergo adenotonsillectomy. When symptoms persist, sleep endoscopy may reveal supraglottic collapse consistent with laryngomalacia [25,26]. Laryngomalacia only apparent during exercise can also be seen in older children and may be misdiagnosed as paradoxical vocal cord dysfunction. Flexible laryngoscopy during exercise can differentiate between the two conditions [27].

TREATMENT OPTIONS

Conservative and Medical Treatment

Children with intermittent or mild to moderate inspiratory stridor and no associated feeding difficulties can generally be managed by observation after definitive diagnosis. They should be carefully monitored for appropriate weight gain and worsening of respiratory or feeding symptoms.

In children with mild to moderate respiratory disease and mild feeding difficulties, conservative management and positional therapy is often effective as well. Feeding interventions may include the use of thickened formula or breast milk, slower paced feedings done in an upright position, and medications to treat possible reflux disease. In many children symptoms resolve by one year of age (average 7.6 months) [2] with resolution in the remaining children most commonly seen by 18-24 months. Of note, several studies have shown persistence of subtle inspiratory airflow limitation in some largely asymptomatic older children diagnosed with laryngomalacia as infants [28,29].

Surgical Treatment

In the smaller group of children with laryngomalacia who fail to respond to conservative treatment or in those with more severe respiratory or feeding difficulties upon presentation, surgical intervention is often recommended. Potential indications for surgery are listed in Table 2.

Sporadic reports of partial epiglottectomy or resection of AE folds for laryngomalacia appeared in the 1920's; however, tracheotomy remained the mainstay of surgical treatment for another 60 years. The introduction of improved microsurgical instruments and techniques created renewed interest in supraglottoplasty, including division of the AE folds and resection of redundant supra-arytenoid mucosa with otologic instruments [30] or the CO_2 laser [31]. With the advent of microlaryngeal instruments and advancements in fiberoptic technology, transoral supraglottoplasty gained widespread acceptance and essentially supplanted tracheotomy for treatment of severe symptomatic laryngomalacia [32–34].

The overarching goal of supraglottoplasty is to reduce or stabilize laryngeal tissue, thereby preventing inspiratory collapse and airway obstruction. The procedure is typically performed under sedation with spontaneous breathing after suspension of the larynx. Additional oxygen can be insufflated via an endotracheal tube in the oral cavity as needed. Jet ventilation and intermittent endotracheal intubation can also be employed for airway management. A combination of partial epiglottectomy, division of AE folds and removal of redundant mucosa is performed as indicated by the anatomical abnormalities seen on flexible fiberoptic evaluation and intra-operative findings (Figure 3). Surgery can be performed using microlaryngeal instruments [34], micro-debrider [35,36] or CO_2 laser [31]. Similar success rates have been reported for each [37,38], therefore instrumentation and technique is generally determined by surgeon preference and training. Enthusiasm for the use of lasers may have been somewhat tempered by sporadic reports of airway fires.

Table 2
Frequently Used Clinical Indications for Consideration of Surgical Intervention.

Respiratory	Feeding
Stridor with respiratory distress	Episodic cyanosis with feeding
Dyspnea with retractions	Recurrent aspiration pneumonia
Pectus excavatum	Failure to thrive
Pulmonary hypertension	
Cor pulmonale	
Severe obstructive sleep apnea	

Epiglottopexy may be necessary in patients with obstruction due to posterior collapse of the epiglottis. Theoretical concerns of aspiration have not been supported in reports of patients undergoing excision of epiglottic mucosa, even when done in conjunction with suturing of the epiglottis to the tongue musculature [39,40]. Improvement in stridor and weight gain was also reported by Whymark in 73% of 58 children with severe laryngomalacia undergoing isolated epiglottopexy, regardless of the anatomical pattern of collapse [40].

Post-Operative Care

Aggressive medical anti-reflux therapy and head of bed elevation are recommended to minimize edema and decrease risks of scar tissue or granuloma formation from exposure of raw mucosal surfaces to gastric acid. A short course of systemic steroids is generally administered to reduce edema and airway obstruction [5]. Children may require post-operative intubation, but can potentially be extubated shortly after surgery or on the first post-operative day, depending on age, severity of disease and extent of symptomatic improvement seen [5].

Although children are typically admitted to a monitored hospital bed post-operatively, a recent report of 65 otherwise healthy children undergoing cold-steel supraglottoplasty for severe laryngomalacia suggested that post-operative intubation or intensive care monitoring may not be routinely necessary in that population [41].

Surgical Success Rates and Complications

Surgical success as indicated by significant improvement or complete resolution of symptoms is reported in over half to 95% of patients undergoing supraglottoplasty in several large cohorts [1,32,34,42,43]. In a recent systematic review of 8 studies reporting surgical outcomes after supraglottoplasty, Preciado and Zalzal reported a higher risk ratio of surgical failure (7.14) in children with comorbidities such as neurologic and cardiac disease or severe GERD compared to those with isolated disease [44]. Persistent respiratory or feeding difficulties have also been reported in

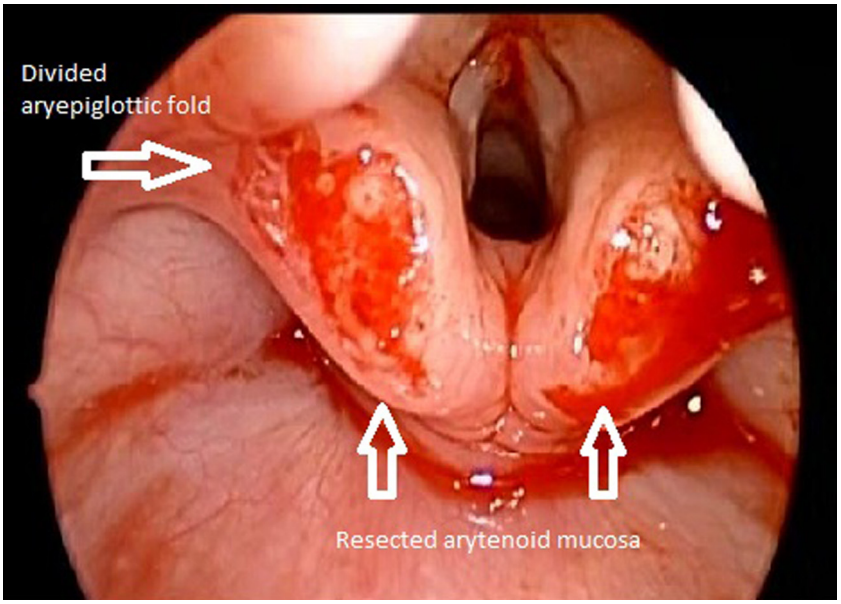

Figure 3. Intraoperative view of a larynx following supraglottoplasty. The aryepiglottic folds have been divided, and the redundant arytenoid mucosa removed. The interarytenoid mucosa has been preserved to prevent postoperative scarring.

some children post-operatively [11], especially in premature or neurologically affected children [45,46] with an increased risk ratio for persistent or significant aspiration of 4.3 in children with co-morbidities [44]. Other surgical complications such as airway stenosis, granuloma formation, or airway fires have been rarely reported as well [37].

Concerns of airway obstruction or post-operative aspiration or stenosis have prompted trials of unilateral supraglottoplasty [42,47]. In a comparison of 106 patients undergoing unilateral or bilateral supraglottoplasty for severe laryngomalacia, Reddy reported a 95.7% success rate with a low complications rate (8.5%) for the unilateral procedure. Contralateral procedures were required for 14.9% of patients initially undergoing unilateral resection [42].

Tracheotomy is now used infrequently and generally reserved for children with either persistent severe disease despite supraglottoplasty or synchronous airway lesions. Although an effective treatment for airway obstruction, complications of paediatric tracheotomy can include bleeding, tracheoesophageal fistula, accidental decannulation or tube occlusion and have been reported to occur in as many as 43-77% of children [48,49].

Alternative treatment options

Although surgical intervention is now considered the mainstay of treatment for severe laryngomalacia, alternative treatments may be effective in selected cases. A recent retrospective study compared 17 infants managed with supraglottoplasty to severity matched controls treated conservatively with acid suppression, high calorie diets and swallowing therapy. The groups showed equivalent weigh gain over a 2-month period and at their final visit. Only one child required additional surgical intervention (tracheotomy and gastrostomy tube placement). [50]

Continuous positive airway pressure (CPAP) therapy or non-invasive ventilation or has been used successfully in some children with severe laryngomalacia and respiratory distress or obstructive sleep apnea, generally in the context of awaiting surgery, or for children who were not surgical candidates or failed supraglottoplasty [51,52]. Noninvasive ventilation in infants can be associated with mid-face retrusion [53], so careful monitoring and comparison of risk/benefit ratio to surgery is recommended.

CONCLUSIONS

Laryngomalacia is a common cause of stridor and feeding difficulties in neonates and infants. A definitive diagnosis can be made with flexible fiberoptic laryngoscopy in most children, but additional diagnostic studies and procedures may be indicated, especially when co-morbidities are present or suspected.

The majority of children with mild-moderate disease can be successfully managed with observation alone or in conjunction with conservative measures. In these children symptom resolution in often seen by one year of age and rarely persists after 24 months. The approximately 5%-20% of children with severe symptomatic disease often benefit significantly from supraglottoplasty, with reported surgical success rates approaching 95% in some series. Tracheotomy is therefore currently only rarely performed. Treatment options such as non-invasive ventilation may also be considered in some cases. However, given the low complication rate of supraglottoplasty and numerous reports of benefit on a variety of outcome measures, this option may be best reserved for children with persistent disease after surgery, synchronous airway lesions, or co-morbidities precluding surgical intervention.

PRACTICE POINTS

- Laryngomalacia is the most common cause of stridor in infants.
- Definitive diagnosis can generally be made by flexible fiberoptic laryngoscopy without sedation.
- Most children can be managed conservatively with close monitoring.
- Supraglottoplasty successful eliminates symptoms in most otherwise healthy children with severe disease.

RESEARCH DIRECTIONS

- Determine if treatment of reflux disease influences laryngomalacia symptom resolution.
- Investigations into the role of non-surgical therapy for children with severe laryngomalacia.

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