Surgery for Pediatric Sleep Apnea

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The pathologies responsible for sleep-related breathing disorders (SRBD) in children are more diverse than those in adults. Although most affected adults and older children experience obstruction at the pharyngeal level, often caused by hyperplasia of the tonsils and adenoid and pharyngeal soft tissues, younger individuals may be affected at a variety of sites in the upper respiratory tract. In small children, the distance between these sites may be quite small, resulting in stertor or stridor or both, and the source of the noisy breathing may be difficult to localize.

Generally speaking, SRBD are characterized by episodic obstruction of airflow through the upper airway during sleep. In children, SRBD may result from decreased caliber of the airway caused by nasal obstruction in an obligate nasal breather, compromised skeletal anatomy, excessively compliant or hyperplastic pharyngeal or laryngeal soft tissues, or neuromuscular compromise, complicated by the diminished muscle tone and neurophysiologic changes that typically accompany sleep. Attempts to overcome the obstruction by increasing respiratory effort often exaggerate collapse of the airway, resulting in a paradoxical increase in resistance to airflow. The physiologic sequelae may include hypoxemia, hypercapnia, and acidosis, which in turn signal central and peripheral chemoreceptors and baroreceptors to initiate the arousals and sudden pharyngeal dilation that characterize SRBD.

Successful management of sleep apnea in children depends on accurate identification of the site of obstruction and the severity of obstruction. Only then can appropriate surgical and nonsurgical remedies be considered.
Diagnosis of sleep-related breathing disorders in children

With the exception of acute life-threatening events usually caused by reflux-induced laryngospasm, the presenting symptom in pediatric SRBD is noisy breathing. Stridor, a term used to describe turbulent airflow through the larynx and lower sites in the airway, is rare because lesions in these areas are not often affected by the dynamic changes that occur during sleep. Conversely, stertor, a term used to describe sonorous breathing in the upper airways, is quite common. In most studies, snoring occurs during sleep in 3% to 12% of children [1], although some studies suggest prevalence as high as 27% [2]. Only those with hypoventilation, apnea, hypoxemia, or repeated arousals, however, are considered to have SRBD.

In its mildest form, SRBD presents as upper airway resistance syndrome. Affected children demonstrate episodic arousals resulting from partial obstruction of the upper airway, associated with symptoms of heroic snoring, mouth breathing, sleep pauses or breathholding, gasping, perspiration, and enuresis. Daytime manifestations of sleep disturbance include morning headache, dry mouth, halitosis, and most significantly behavioral and neuropsychological disorders [3–6]. Hypersomnia may occur in older children and adolescents. Other signs and symptoms include audible breathing with open mouth posture, hyponasal speech, and chronic nasal obstruction with or without rhinorrhea. Approximately 40% of children who snore demonstrate more significant degrees of obstruction characteristic of obstructive hypopnea syndrome or obstructive sleep apnea syndrome as defined later [1]. The most severely affected patients may develop cor pulmonale, right ventricular hypertrophy, congestive heart failure, alveolar hypoventilation, pulmonary hypertension, pulmonary edema, or failure to thrive, and are at risk for permanent neurologic damage and even death.

Physical examination of children with SRBD should include assessment of the patient’s weight and body habitus, a complete examination of the head and neck with attention to potential sites of obstruction, and auscultation of the patient’s heart and lungs. Findings of nasal dyspnea or mouth breathing, hyponasal speech, mandibular hypoplasia, drooling, neuromuscular deficit, and tonsillar hyperplasia all suggest some degree of upper airway obstruction. Fiberoptic assessment of the nasal vault, the adenoid pad, and the distal pharynx and larynx may be useful in selected cases. Ancillary studies including chest radiography and electrocardiography should be performed in severely obstructed children. In many cases of nasal obstruction in infants and young children, CT scanning is desirable to define the bony anatomy and to assess the relationship of nasal masses to the sinonasal tract and the central nervous system. At some institutions, cross-table lateral fluoroscopy may be performed during sleep to aid in localizing the site of obstruction.

When a history of severe symptoms of sleep disturbance correlates with obvious physical findings of airway obstruction, additional studies to
establish a patient’s candidacy for surgical intervention may be superfluous. Studies suggest, however, that in most cases accurate diagnosis of SRBD cannot be established solely on the basis of a history and physical examination [7–14]. SRBD occurs primarily during REM sleep when children are less likely to be observed by their parents [15], and in many cases of upper airway resistance syndrome and obstructive hypopnea syndrome parents may misinterpret the symptoms only as snoring in the absence of obstruction. In addition, although hyperplasia of the tonsils and adenoid likely predispose to airway obstruction, airway dynamics during sleep cannot be determined by static examination in the office setting. Furthermore, fiberoptic assessment of the airway is useful in determining anatomic obstruction but offers a distorted wide-angle view of obstructing tissues and does not demonstrate the dynamics of the nasopharynx during sleep. Similarly, radiographic assessment of the adenoid tissue and tongue base may be difficult to interpret [16–19]. In such cases, polysomnography remains the gold standard for objective correlation of ventilatory abnormalities with sleep-disordered breathing [8]. This test and its interpretation are described in greater detail elsewhere in this issue.

Unfortunately, the expense and scheduling difficulties associated with polysomnography make this a cumbersome method of assessment in many otolaryngology practices. Other techniques of assessment including audiotaping [9,11], videotaping [20], and home polysomnography [21] have demonstrated favorable results, but require further study. Abbreviated polysomnography (ie, overnight oximetry or nap polysomnography) has demonstrated a high positive predictive value and a low negative predictive value, suggesting that patients with negative results may still require additional studies [22–24].

Causes of sleep-related breathing disorders in children

Causes of SRBD in children may be grouped on the basis of age, simplifying the differential diagnosis for a given patient (Box 1). Neonates and infants rarely have significant lymphoid hyperplasia, and SRBD in these children are usually related to their immature respiratory physiology or to congenital obstructing lesions. In premature babies, neural pathways that control ventilation, coordination of the larynx and diaphragm, and chemoreceptor responses are not yet fully developed. In such children, hypventilation, central apnea, and periodic breathing are common, resulting in reflex bradycardia. Hypoxemia and hypercapnia, which are less common because of the short duration of the apneic events, do not reliably evoke compensatory mechanisms. Apnea in infants may also be associated with gastroesophageal reflux, either as a direct result of soiling of the upper airway or because of vagally mediated reflexes that inhibit inspiration. In such cases, management by medical therapy or Nissen fundoplication may be warranted.
Because babies depend primarily on nasal breathing, obstruction of the nose or nasopharynx has more significance than in older children. Common causes include neonatal rhinitis, pyriform aperture stenosis, choanal atresia, dacryocystoceles, and nasal-choanal stenosis related to craniofacial conditions, such as Apert’s syndrome or Crouzon’s disease. Dermoids, teratomas, gliomas, and encephaloceles of the nose and nasopharynx are seen less frequently. Oropharyngeal obstruction in this age group is usually related to micrognathia or macroglossia. Micrognathia may be syndromic, as in children with Treacher Collins or Nager syndromes, or developmental, as in Pierre Robin syndrome. Relative macroglossia is common in Down syndrome and Beckwith-Wiedemann syndrome. Venous and lymphatic malformations of the pharynx and tongue and congenital cysts of the vallecula and tongue may also cause obstruction in this age group (Fig. 1). Laryngeal abnormalities, such as laryngomalacia, more often result in severe stridor while awake rather than in collapse of soft tissues during sleep. Neuromuscular disorders, which may be complicated by impaired pharyngeal tone, impaired excursion of the diaphragm, or effects of medical therapy, begin to cause

<table>
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<th>Box 1. Causes of sleep-related breathing disorders in children</th>
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<td><strong>Neonates and infants</strong></td>
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<td>Nasal aplasia, stenosis, or atresia</td>
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<td>Nasal or nasopharyngeal masses</td>
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<td>Craniofacial anomalies</td>
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<td>Hypoplastic mandible (Pierre Robin, Nager, or Treacher</td>
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<td>Collins syndromes)</td>
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<td>Hypoplastic maxilla (Apert’s syndrome, Crouzon’s disease)</td>
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<td>Macroglossia (Beckwith-Wiedemann syndrome)</td>
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<td>Vascular malformations of tongue and pharynx</td>
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<td>Congenital cysts of the vallecula and tongue</td>
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<td>Neuromuscular disorders</td>
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<td><strong>Toddlers and older children</strong></td>
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<td>Rhinitis, nasal polyposis, septal deviation</td>
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<td>Syndromic narrowing of nasopharynx (Hunter’s, Hurler’s, or</td>
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<td>Down syndromes; achondroplasia)</td>
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<td>Adenotonsillar hyperplasia</td>
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<td>Obesity</td>
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<td>Macroglossia (Down syndrome)</td>
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<td>Vascular malformations of tongue and pharynx</td>
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858 DARROW
obstruction in this age group and often progress as the child ages because of adenotonsillar enlargement.

Toddlers and older children are more affected during sleep by disorders that have had an opportunity to progress. Hyperplasia of the tonsils and adenoid is unquestionably the most common cause of upper airway obstruction in children resulting in sleep-disordered breathing. Severe allergic rhinitis may also develop in children, causing airway obstruction or complicating obstruction caused by other causes. Sinonasal polyposis caused by cystic fibrosis may appear in children in this age group. Similarly, weight gain becomes an issue in older children, and the accumulation of fat in the fascial planes surrounding the pharynx of obese individuals may be a cause of surgical failure following adenotonsillectomy. Some children are affected by syndromes involving progressive reduction of the pharyngeal airway, such as Down syndrome, achondroplasia, and the mucopolysaccharidoses (Hunter’s and Hurler’s syndromes). In the latter group, surgical intervention may actually precipitate deposition of mucopolysaccharide.

In adolescence, lymphoid hyperplasia becomes a less important cause of SRBD as the pharynx increases in size and the tonsils and adenoid recede. As in adults, sleep-disordered breathing is more commonly associated with redundant pharyngeal tissues, obesity, macroglossia, and septal deviation. Progression of neuromuscular disorders may also necessitate surgical intervention in this age group.

Iatrogenic stenosis of the nasopharynx following adenotonsillectomy, uvulopalatopharyngoplasty, or surgery for cleft palate or velopharyngeal insufficiency may result in significant sleep apnea. Corrective surgical intervention for this disorder is often complicated by recurrence.
Management of sleep-related breathing disorders in children

Nonsurgical management

Treatment of SRBD in children is tailored to the etiology of the airway obstruction. Medical management, such as thioxanthines and methylphenidate, may be useful in cases of central apnea. Pharmacotherapy may also be considered in less severe cases of obstructive apnea, or when surgical intervention does not address the pathology. Examples of such disorders include neonatal rhinitis, allergic rhinitis, and acute tonsillitis. In cases of chronic upper airway obstruction, mechanical correction by prostheses, positive airway pressure, or weight loss may be worth consideration. In most patients, however, such as those with obesity or neuromuscular disorders in which airway dynamics are affected, surgical management is generally considered before use of positive airway pressure or oral prostheses, because these interventions are rarely tolerated in children and are often ineffective. Such methods of management should be entertained, however, to address residual obstruction following surgery. Rarely, in the most severe or refractory cases, tracheotomy must be considered.

Surgical management

Preoperative planning is an essential component of the surgical management of patients with SRBD. Postoperative respiratory distress is common after surgery for SRBD because of effects of anesthesia, bleeding, edema, and residual airway compromise. Patients at greatest risk include those with severe obstructive sleep apnea syndrome; diminished neuromuscular tone (ie, cerebral palsy); morbid obesity; skeletal and craniofacial abnormalities, such as hypoplasia of the midface or mandible or nasopharyngeal vault; and very young children (younger than age 2–3 years) [24–28]. As a result, high-risk individuals who are undergoing even routine procedures, such as adenotonsillectomy, should be admitted to a high-visibility bed in the hospital with continuous cardiac and oxygen saturation monitoring. Intraoperative use of steroids and postoperative placement of nasopharyngeal airways may reduce the risk of airway compromise after surgery. Narcotics and sedatives should be used sparingly in severely obstructed children. Obese patients and those with reduced neuromuscular tone may benefit from airway support with positive airway pressure. In the most extreme cases, overnight endotracheal intubation may be desirable.

Nasal and nasopharyngeal obstruction

SRBD caused by nasal and nasopharyngeal masses is best addressed by removal of the mass. Depending on the pathology, the procedure may be as simple as a transoral, retropalatal approach for adenoidectomy or marsupialization of nasolacrimal duct cysts, or as complex as an anterior craniofacial approach for encephalocele. Nasal and nasopharyngeal neoplasms
may require aggressive resection, and preoperative embolization (juvenile nasopharyngeal angiofibroma) or postoperative radiation therapy or chemotherapy (malignancies).

Bilateral choanal atresia and stenosis of the pyriform aperture are causes of obstructive apnea in neonates and require early intervention (Fig. 2). Such infants can be temporized with oropharyngeal airways, but should not leave an intensive care setting until a secure airway is established by tracheotomy or repair of the bony defect. Timing of surgery is controversial; early repair with avoidance of tracheotomy is always desirable; however, children several weeks to several months old better tolerate bleeding and better accommodate instruments used in the nasal cavity.

Although choanal atresia may be approached by either the transpalatal or the transnasal route, improvements in endoscopic and powered instrumentation have made the transnasal approach the first choice for most otolaryngologists [29,30]. In small children, the procedure is best performed using a small rigid rod-lens telescope and a drill with a protected shaft. Microdebriders designed for intranasal surgery (Fig. 3) are well-suited for this purpose. A 120-degree telescope placed in the mouth with the palate retracted affords the surgeon a view of the nasopharynx so that a urethral sound may be safely passed through the atretic plate. After creation of mucosal flaps with a sickle knife or ablation of the mucosa with the aid of a fiber-delivered laser, the microdebrider can be fitted with a small round bur to initiate bone removal, and subsequently with choanal atresia or Silver Bullet (Medtronic/Xomed, Jacksonville, Florida) burs to expand the opening (Fig. 4). Standard suction blades (2.9 or 3.5 mm) used for sinus surgery facilitate the removal of soft tissue and thin bone. Back-biting forceps are used to remove the posterior portion of the vomer. The opened choanae may be treated with mitomycin C to reduce the risk of restenosis [31], and stenting for several weeks using endotracheal tubes or Albouker-type stent may be indicated in some cases. In cases of pyriform aperture stenosis, the

![Fig. 2. Comparison of CT scans of patients with choanal atresia (A) and pyriform aperture stenosis (B, arrows).](image)
offending bone may be approached through a sublabial approach and re-
duced using similar instrumentation [32,33].

Nasopharyngeal stenosis, once a common complication of syphilis, may
result as a complication of adenotonsillectomy, uvulopalatopharyngoplasty,

Fig. 3. The Straight Shot microdebrider (Medtronic/Xomed, Jacksonville, Florida) facilitates
choanal atresia surgery by removing bone and soft tissue without injury to the nasal vestibule.

Fig. 4. Drilling of the atretic plate may be accomplished with a pediatric round bur (top),
followed by a choanal atresia bur (center), or Silver Bullet blade (bottom).
or surgery for cleft palate or velopharyngeal insufficiency. This disorder often causes obstruction of the upper airway that is even more significant than the disorder the original surgery was intended to correct. Typically, cicatrix forms circumferentially in the nasopharynx as a result of removal of excessive removal of mucosa from opposing surfaces. Simple release of the scarred area results in recurrence, and treatment must include the movement of fresh, well-vascularized tissue to cover the denuded bed. A variety of techniques has been recommended, including Z-plasty [34], laterally based pharyngeal flaps (Fig. 5) [35], other advancement and rotation flaps [36–38], and radial forearm and jejunal free flaps [38,39]. Many authors advocate the use of intralesional steroids and topical application of mitomycin C to the surgical site to reduce the risk of recurrence. Postoperative stenting with nasopharyngeal airways or oropharyngeal prostheses [40] is mandatory, although the necessary duration of such stenting is controversial.

Adenotonsillar hyperplasia and oropharyngeal obstruction

Adenotonsillectomy is generally considered first-line therapy in most patients with SRBD, providing they have at least mild adenotonsillar hyperplasia. Improvements in snoring and polysomnography may be anticipated postoperatively in such patients [12,13,41–46]. Even obese children seem to have reduced obstruction after surgery [47–49]; however, available studies lack long-term follow-up and symptoms may return in those who do not additionally pursue weight loss. Children with SRBD who exhibit abnormalities in body growth preoperatively often demonstrate increased body mass after surgery [50–52]. Improvement following adenotonsillectomy surgery has also been demonstrated in children with preoperative enuresis [53–56], orthodontic abnormalities [57], and behavioral issues [3–6,58–62] before surgery, including those who are obese [63,64]. Validated surveys suggest an overall improvement in quality of life after adenotonsillectomy [49,65,66].

Several new techniques of tonsillectomy and adenoidectomy have been proposed in recent years as technology has evolved. For decades, guillotine and cold steel removal of the tonsils were fraught with complications of bleeding and postoperative pain. The use of electrocautery in these procedures reduced the problem of surgical blood loss considerably and decreased operating time, but postoperative pain remained a significant morbidity [67,68].

Initial reports of tonsillectomy using lasers yielded variable and occasionally disappointing results [69–72]. With the report by Krespi and Ling [73] of serial tonsillectomy with carbon-dioxide laser in the outpatient setting, however, came the notion that partial tonsillectomy was safe and less painful than traditional tonsillectomy for patients with tonsil hyperplasia. It is theorized that the exposure of muscle resulting from removal of the tonsil capsule is the cause of pain associated with tonsillectomy, and that
Fig. 5. Laterally based pharyngeal flap for correction of nasopharyngeal stenosis. (A) A lateral incision is made from velopharyngeal opening into lateral scar on one side (top) and deepened (bottom). (B) Mucosal flaps are elevated from the scar inferolaterally and the scar is excised. (C) A laterally based posterior pharyngeal flap is incised incorporating a back cut (top), then elevated with the underlying muscle (center). Points A1 and B1 are closed to points A and B, respectively, covering the denuded area (bottom). (From Cotton RT, Nasopharyngeal stenosis. Arch Otolaryngol 1985;111:146–48; with permission. Copyright © 1985, American Medical Association. All rights reserved.)
leaving some small portion of the tonsil behind may vastly diminish this sequelae [74]. Proposed many years ago, the technique had been abandoned because of the risk of tonsil regrowth at a time when most such procedures were performed for recurring infection. Studies suggest that single-stage intracapsular tonsillectomy, or “tonsillotomy,” using the carbon-dioxide laser is safe, rapid, and effective with little loss of blood [75,76]. The microdebrider has been a more popular instrument for this procedure, however, given its greater efficiency and lower cost. Randomized studies comparing microdebrider intracapsular tonsillectomy with complete electrocautery tonsillectomy generally suggest a modest advantage in pain reduction, particularly otalgia, and return to normal activity; other outcomes yielded less consistent results [77–80]. The procedure involves a slight increase in duration and blood loss.

Other technologies developed over the last 20 years have competed for supremacy in adenotonsillectomy with the promises of decreased pain, decreased bleeding, and decreased operative time. No one device seems to have definitively accomplished these goals. The Harmonic scalpel (Ethicon Endo-Surgery, Cincinnati, Ohio) is an instrument that uses ultrasonic technology to cut and coagulate with minimal tissue damage. Recent randomized studies of tonsillectomy using this device suggest that there is no advantage in pain reduction or hemorrhage rate, and that surgical time may be somewhat longer and the cost of the disposable blade is high [80–82]. Radiofrequency devices, such as the Somnoplasty system (Somnus Medical Technologies, Sunnyvale, California) and the ArthroCare Coblation system (ArthroCare, Sunnyvale, California) have been studied in small trials that suggest modest reduction in pain compared with electrocautery, with further decrease in postoperative pain when the tonsil is reduced rather than excised [47,83–90]. There is some controversy about increased hemorrhage rates using this technology [91,92].

Techniques of adenoidectomy include curettage, suction electrocautery ablation, and removal by power-assisted devices. Traditional curettage is inexpensive but is the least precise of these techniques and is associated with hemorrhage that must be controlled before leaving the operating room. Electrocautery dissection, by definition, is associated with less bleeding and is also a precise and inexpensive device [93–95]. High settings are required on the cautery device, however, with the potential for thermal injury to deep structures. Surgical times have been variable. Studies of power-assisted (microdebrider) techniques have demonstrated excellent precision with rapid removal of tissue and minimal additional time for cautery; however, the disposable blades add significant expense [96,97].

Uvulopalatopharyngoplasty is not commonly performed in children, perhaps because most children with sleep apnea do not demonstrate the redundant tissue found in adults with similar symptoms. Several studies have demonstrated that the procedure is efficacious in the most difficult-to-treat patients with SRBD, particularly those with obesity [98], neurologic
impairment [99–101], or Down syndrome [102–104]. These reports are retrospective, however, and it remains unclear whether resection of the palate and uvula add significantly to tonsillectomy with plication of the tonsil pillars, which is usually performed simultaneously. In addition, nasopharyngeal stenosis remains a significant risk when the procedure is performed at the same time as adenoidectomy [38,105].

Macroglossia and the ptotic tongue

Children with macroglossia generally have Beckwith-Wiedemann syndrome (macroglossia, omphalocele, visceromegaly, cytomegaly of the adrenal cortex); Down syndrome; or a vascular malformation of the tongue. Complications of macroglossia include aberrant dental eruption and malocclusion, maldevelopment of the maxilla and mandible, excessive drying of the tongue with ulceration, and airway obstruction. Unfortunately, surgical reduction of the tongue is generally effective only for the first three indications, and less so for airway obstruction. The procedure usually consists of a resection of the lingual margin or a wedge resection with or without aggressive resection at the foramen cecum [106], and fails to address obstruction at the distal oropharynx and tongue base (Fig. 6). As a result, airway obstruction persists in many children undergoing tongue reduction for macroglossia [107]. Regrowth of tongue tissue following the procedure has also been reported [108].

Other methods of managing macroglossia include suture suspension of the tongue and radiofrequency ablation. Successful use of the tongue suspension suture technique has been reported in a single pediatric case [109], but anecdotally the procedure is not well tolerated. To date, only case reports document the success of radiofrequency ablation for pediatric macroglossia caused by Down syndrome (E.A. Mair, personal communication, 2006).

Vascular malformations of the tongue are generally of lymphatic or venous origin. Lymphatic malformations that are limited to the superficial layers of the tongue (lymphangioma circumscriptum) may be ablated using a carbon-dioxide laser. Microcystic disease causing the tongue to be both wide and thick, however, is extremely difficult to treat. Limited success has been reported using radiofrequency and coblation technology [110,111]. Many such patients retain a tracheotomy indefinitely. Conversely, venous malformations of the tongue may be reduced considerably using a combination of superficial and intralesional neodymium:yttrium-aluminum-garnet laser therapy, alcohol sclerosis, or excision [112].

Ductal cysts of the vallecula may present with sleep-disordered breathing in neonates (see Fig. 1). These lesions are thought to result from mucous gland obstruction, but the etiology has not been definitively elucidated. The diagnosis may be difficult to make endoscopically because of the position of the mass. Lateral radiograph of the upper airway may be useful when the diagnosis is suspected. The lesion is managed by marsupialization using
cold steel, laser, or microdebrider; laser applied to the base helps to control hemorrhage and theoretically reduces the risk of recurrence.

Hypoplasia of the midface and mandible

Upper airway obstruction caused by hypoplasia of the midface and mandible is usually associated with craniofacial syndromes. Micrognathia caused by Pierre Robin syndrome often improves within the first 2 years of life without surgical intervention for the mandible. In cases of mild airway obstruction, children with competent caretakers may be managed by prone positioning and nasopharyngeal stenting by nasal trumpet or similar device [113]. When symptoms are more severe, temporary repositioning of
the ptotic tongue by labioglossopexy (Fig. 7) has been advocated [114]. Results from this procedure are variable, however, and the procedure carries the risks of dehiscence, tongue lacerations, and deformation of the lip and speech impairment caused by scar formation [115]. Subperiosteal release
of the floor of the mouth has also been reported but has not been used widely. Temporary tracheotomy seems to be the most reliable and least morbid means of airway management providing the patient shows signs of mandibular “catch-up” growth within the first few months. When this is not the case, distraction osteogenesis should be considered.

First described in 1969 by Ilizarov and Lediaev [116] in the treatment of limb length discrepancies, osteotomy with distraction of bone is now widely accepted as the procedure of choice in the early management of airway obstruction caused by craniofacial disproportion [117–120]. The procedure takes advantage of the rapid healing and capacity for growth in the pediatric skeleton. Distraction osteogenesis has been used for over a decade to advance the mandible in cases of retrognathia and micrognathia, but indications have expanded to include neuromuscular disorders. With modifications to the expansion devices, distraction of the midface is also beginning to replace Lefort osteotomies with bone grafting [120,121].

Before surgery, all candidates for mandibular distraction undergo airway endoscopy and craniofacial assessment by three-dimensional CT scanning. Airway patency is estimated in relaxed and jaw-thrust positions, and precise bony measurements are taken from the scan.

Distraction osteogenesis is divided into four phases: (1) surgery, (2) distraction, (3) consolidation, and (4) removal. The surgical approach recommended is illustrated in Fig. 8. After a lag phase of 24 to 72 hours, distraction is started. Distraction may progress at a rate of 1 to 2 mm per day, with adjustments of 1 mm every 12 to 24 hours. Once the desired length of the mandible has been achieved, adequacy of the airway is verified by flexible or rigid laryngoscopy before consolidation. In children who already have a tracheostomy, downsizing and bedside occlusion can be performed. The consolidation phase is approximately 8 weeks, but should last at least two times as long as the distraction period. The hardware may be left in place during this time. The final stage is removal of the hardware and minor scar revision. Avoidance of or decannulation from tracheotomy in

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**Fig. 7. Labioglossopexy for glossoptosis.** Modified labioglossopexy. This technique, described by Routledge, incorporates muscle into the lip-tongue adhesion. (A) After T-shaped incisions are made on the anterior ventral tongue and lower lip, the wound edges on both incisions are undermined to create mucosal flaps and the underlying tongue and orbicularis oris muscles are exposed. (B) A small periosteal elevator is used to tunnel along the anterior aspect of the mandible and to detach the genioglossus muscle. (C, D) A spinal needle passed through the soft tissue along the anterior and posterior surfaces of the mandible through the skin of the mentum facilitates placement of a circummandibular stay suture passed through muscle. (E) The two ends of the suture are then placed into the tongue muscles in a location that allows approximation of the muscle directly to the alveolar ridge incision. (F) The ventral tongue mucosal flaps are then matched to the flaps of the lower lip and approximated using a 4-0 chromic gut suture. (From Schraff S, Darrow DH. Labioglossopexy and epiglottopexy. Operative Techniques in Otolaryngology-Head and Neck Surgery 2005;16:203–8; with permission.)
appropriately selected patients undergoing distraction of the mandible is greater than 80% [118,119,121].

References


