A 4-year-old boy presented for evaluation of his “abnormal voice.” His mother reports that since he has been able to speak he has never made clear “s” and “p” sounds. She reports that to most people he is unintelligible. She is seeking options for therapy, but currently lives on a Caribbean island with minimal access to speech services or surgical care. The child has no other medical problems, feeds well, and has no previous surgical history. His examination shows a healthy energetic boy with no evidence of craniofacial dysmorphisms. However, he demonstrates markedly hypernasal speech. Fiberoptic examination demonstrates a short palate with decent lateral wall motion. Nasometry is consistent with marked nasal air escape. Given his anatomic deficit, surgical management was offered. In discussing the potential risks and benefits of each surgical option with his mother, she provided additional history that suggested he might have some degree of sleep apnea. She gave support to the notion that, were he to develop worse sleep apnea postoperatively, there would be no access on the island to anyone with expertise in diagnosing and managing such a condition. Given the history, a sphincter pharyngoplasty was offered in place of a posterior pharyngeal flap. The child underwent surgery uneventfully and noticed immediate improvement. Six months later his results were maintained.

The complex neuromuscular functions that regulate human speech are not limited to the larynx. The sphincteric interaction of the palate (velum) within the pharynx is critical to the production of intelligible speech. Velopharyngeal insufficiency (VPI), or the inability to effectively seal the nasopharynx,
results in loss of resonant control of speech and in some cases, optimal intraoral pressure to achieve orally directed speech sounds. Given that the nasopharynx is effectively closed during the vast majority of speech, this can significantly impact speech intelligibility. A lack of speech intelligibility has an obvious detrimental effect to affected children, but even mild cases of VPI can alter a child’s effective communication and their well-being as speech provides a bridge to the people around us. The etiology of VPI varies from residual speech patterns after cleft palate repair to congenital anomalies of the soft palate (e.g., shortness, submucous cleft) as well as weakness or motor planning difficulties.1 Subsequently, the approaches to assessment and intervention are variable and often need to be tailored to the individual child.

**SEMANTICS**

Terminology used within the VPI literature is limited by redundancy and inconsistencies. In addition to velopharyngeal insufficiency, commonly used terms include velopharyngeal dysfunction, velopharyngeal inadequacy, and velopharyngeal incompetence. These terms are often used interchangeably. When specific terminology is used, variations of the classification introduced by Trost in 1981 seem to be the most common.2 In the classification, an all encompassing term velopharyngeal inadequacy is used to describe velopharyngeal mislearning (faulty learning of articulation patterns), velopharyngeal incompetence (neurologic dysfunction leading to impaired motor control of the palate), and velopharyngeal insufficiency (an anatomic deficiency of insufficient tissue for closure). A similar, widely used all encompassing term is velopharyngeal dysfunction (VPD).3 For the purposes of this chapter, VPI is used to connote velopharyngeal inadequacy.

**PERTINENT ANATOMY**

A brief review of anatomy is requisite to understanding the problem of VPI and the potential implications regarding evaluation and treatment. In general terms, the velopharyngeal port is a sphincter that regulates airflow through the nasopharynx. The degree of regulation manifests in the production (or lack thereof) of nasal resonance. In simple terms, six muscles constitute the sphincter. These include the levator veli palatini, tensor veli palatini, palatoglossus, palatopharyngeus, muscular uvula, and superior pharyngeal constrictor. All except for the superior constrictor comprise the soft palate, also known as the velum. Anatomically, the soft palate is located at the posterior aspect of the maxilla protruding from the hard palate. The Latin term velum refers to a “ship’s sail” and connotes the flat sheet-like shape of the soft palate as it protrudes posteriorly. By separating the oropharynx from the nasopharynx, the palate has both an oral and nasal surface.

Regarding the musculature, motor control is primarily mediated through branches of cranial nerve X except for the tensor veli palatini which is innervated by a motor branch of cranial nerve V. The paired levator palatini serve as the primary muscle mass of the soft palate and form a sling suspended from the skull base.4 The muscle serves to elevate the palate in a posterior direction. This motion is counteracted by the action of the palatoglossus (anterior tonsillar pillar) and the palatopharyngeus (posterior tonsillar pillar). Although the levator veli palatini provides the muscular
mass of the velum, the tensor veli palatini contributes the majority of the fibrous component referred to as the palatal aponeurosis. The primary action of the tensor veli palatini is to facilitate middle ear aeration and overall has a minimal effect on velopharyngeal closure. The muscular uvula tenses the palate as well as providing a bulge on the posterior nasal surface of the palate which has been postulated to be instrumental in tight velopharyngeal closure. The superior pharyngeal constrictor serves to provide lateral wall motion of the nasopharynx to close the velopharyngeal port. Additionally, it may contribute to the presence of Passavant's ridge, a transverse mucosal bulge along the posterior pharyngeal wall noted in 20% of the population.

From a functional standpoint, an interesting distinction is made between the physiology involved in closing the nasopharynx during swallowing versus speech exercises. A common situation is seen when children have evidence of severe VPI with speech, but exhibit no nasal regurgitation during swallowing. Shprintzen and colleagues classified differences in pneumatic (speech, blowing, and whistling) and nonpneumatic (gagging and swallowing) closure mechanisms based on videofluoroscopic findings. Furthermore, an electromyographic (EMG) study of levator function during speech, blowing, and swallowing suggests that different muscle types are activated during swallowing exercises as compared to speech and blowing exercises. By determining the mean power frequencies of EMG signals, Nohara et al. concluded that pneumatic activities tend to activate slow-twitch motor units while swallowing tends to trigger fast twitch motor units. This work is corroborated by the hypothesis that the human pharyngeal constrictors possess a subspecialized slow twitch inner layer of muscle fibers that appears to be related to speech and respiration. Ultimately the complex neuromuscular interaction and subspecialization of muscle fibers highlights the importance of approaching VPI as more than a simple anatomic deficit and realizing that the manifestations of VPI can result from a variety of insults.

Closure Patterns

The relatively simplistic discussion of the musculature involved in velopharyngeal closure described above fails to reveal the high degree of coordination, complexity, and variation involved. The sum motion is one in which the palate elevates posteriorly and contacts the pharyngeal wall circumferentially. On a lateral view, the palate appears to flex like a knee due to the bulge of the uvula maximizing contact with the posterior pharyngeal wall (Fig 16–1). Perhaps a
better way to look at velopharyngeal anatomy is through closure patterns. In 1973, Skolnick and associates used videofluoroscopy to delineate four patterns of velopharyngeal closure. The most commonly observed pattern is the situation in which the posterior surface of the velum comes into broad apposition with the posterior pharyngeal wall in the absence of lateral pharyngeal wall motion. Two circular patterns of closure are described. The first pattern involves a combination of lateral wall motion and posterior velar movement to achieve velopharyngeal closure. A secondary circular pattern with posterior pharyngeal motion (Passavant’s ridge) is described. However, this motion pattern must be interpreted with caution as Passavant’s ridge does not always correspond to the level of closure. The least common closure pattern is referred to as sagittal and demonstrates minimal velar movement combined with medial apposition of the lateral pharyngeal walls. An assessment of closure patterns is instrumental in characterizing the nature and location of the velopharyngeal air escape. Such knowledge is critical in selecting operative procedures to effectively seal the gap.

Normal Versus Abnormal Speech

Etiology and Pathophysiology

VPI is most commonly seen in children with associated craniofacial developmental anomalies of which cleft palate is the most common. Despite successful palatoplasty, post repair prevalence of VPI has been reported to be 20 to 50%. A special case is the submucosal (occult) cleft palate. In this situation, no overt cleft is seen, but a failure of the midline fusion of the velar muscles is present often manifesting as a bifid uvula, hard palate notch, or a bluish line of a visible diastasis (Fig 16–2). The
majority of these children will have no speech deficits during their lifetime. However, a subset will present with VPI often after adenotonsillar surgery. In a review of 126 children with VPI after adenoidectomy, 26% were noted to have a previously unidentified submucosal cleft palate or bifid uvula. In a different study, 55% of children with VPI in the absence of an overt bony cleft were noted to have a submucous cleft on endoscopic examination.

**Associated Syndromes**

Over 200 syndromes have been described where cleft palate is a reported manifestation. Any such syndrome can be associated with VPI. Of special note is velocardiofacial syndrome which typically does not manifest an overt palatal cleft. The syndrome was first described in 1977 by Shprintzen and colleagues. The syndrome has a wide spectrum of phenotypes including congenital cardiac anomalies, VPI, and characteristic facial dysmorphisms. The prevalence in the United States is estimated to be 1:2000. The difficulty lies in the wide variability of presentations and propensity to be under-diagnosed. Proper diagnosis is essential in that patients with VCFS must be screened for potentially lethal cardiac anomalies. From a surgical standpoint, there have been a number of reports of carotid artery medialization which may possibly represent hazardous surgical anatomy (Fig 16–3). Additionally, surgical outcomes for VPI have been reported to be inferior to the results achieved in children without VCFS.

**Postadenoidectomy**

VPI manifesting after adenoidectomy is relatively rare and generally of short duration, with most cases resolving within 6 weeks. Given the bulk of adenoid tissue, many children produce velopharyngeal closure by
approaching the velum to their adenoid pad. In most children, removal of the adenoid pad is of no consequence because their velum has adequate length to reach the posterior pharyngeal wall. However, in select children, the new dynamics of velopharyngeal closure do not allow adequate apposition. Permanent VPI after adenoidectomy requiring intervention is reported to occur in approximately 1:1500 adenoidectomies. In retrospect, many children have suggestions of marginal velopharyngeal competence including physical stigmata of a submucosal cleft, preoperative hypernasality or regurgitation (Table 16–1). In a review of 23 children with VPI after adenoidectomy, 14 children were found to carry the VCFS genotype. In situations where an adenoidectomy appears to be indicated in a child with features concerning for marginal velopharyngeal competence, a superior pole adenoidectomy can be performed in which the inferior aspect of the adenoid pad is maintained to prevent the development of VPI.

**Other Causes**

VPI has been noted in a variety of other settings. Any surgery that involves orthognathic maxillary advancement (often performed in children with craniofacial abnormalities) by definition puts a child at risk for developing VPI. Hypertrophied tonsils have been associated with clinical VPI and resolution has been documented after tonsillectomy. Additionally, neuromuscular disorders resulting in poor control of pharyngeal musculature can result in hypernasality and dysarthria.

**DIAGNOSTIC EVALUATION**

As delineated above, VPI represents a complex problem with a variety of manifestations. The degree of complexity mandates a multidisciplinary approach to the diagnosis and treatment of affected children. Often these children are best served in the setting of a tertiary care referral center with coordinated access to speech pathologists, surgeons, dentists, audiologists, and social workers.

**History**

Evaluation of a child with suspected VPI starts by simply listening with a keen ear. Although children are often referred for grossly abnormal speech, a great deal can be learned by listening to the child speak. Using standard phrases weighted with sibilants and plosives will help to uncover the extent of VPI. A comprehensive history is imperative for all children. Particular emphasis on any developmental anomalies, past medical history and past surgical history may yield clues to syndromic associations or other problems that can be seen in the setting of VPI. Eliciting any history of hearing loss or other anomalies that potentially increase the child's communication difficulties is essential. A developmental and psychological history is useful in determining the extent of disability imparted by the communication difficulties.

---

**Table 16–1. Physical Examination Findings for a Submucosal Cleft Palate**

| Prevention of Postadenoidectomy VPI: Recognize the Signs of a Submucosal Cleft |
|---------------------------------|-------------------------------|
| bifid uvula                     | hard palate notch             |
|                                | bluish line of a visible diastasis |
Physical Examination

A comprehensive physical examination is requisite in all children with VPI. All children must be assessed for the presence of syndromic stigmata, craniofacial dysmorphisms and the presence of cardiac abnormalities. A thorough head and neck examination includes an assessment of the middle ear status. An oral exam is performed to identify the presence of a cleft and status of repair. As described below, flexible nasopharyngoscopy has proven to be a well tolerated and invaluable tool in examining and formulating a treatment plan for these children.

A further note on orofacial examination is necessary at this point. The complete evaluation consists of close intraoral examination with attention to oromotor skills, the occlusal and dental status as well as direct visualization and palpation of the velum. Facial examination during speech in relation to characteristic grimaces and gestures are often noted.

Perceptual Evaluation

Several perceptual evaluation scales have been developed and validated. One of the most commonly used is that of McWilliams and Phillips which is sometimes referred to as the Pittsburgh Weighted Speech Scale. This weighted scale rates five components of speech including nasal emission, facial grimace, nasality, phonation, and articulation (Fig 16–4). Points are assigned for each subgroup and summed to give an overall score that can be used to track outcomes.

Nasometry

Nasometry is based on the measurement of nasal acoustic energy within speech.
WEIGHTED SPEECH SCORE: VPI SCALE

<table>
<thead>
<tr>
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<tr>
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<tr>
<td>3</td>
<td></td>
<td>Significantly reduced intraoral pressure</td>
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<tr>
<td>4</td>
<td></td>
<td>Compensatory errors with reduced intraoral air pressure, eg. Glottal stops, pharyngeal fricatives, pharyngeal stops, nasal snorts, implosions, etc.</td>
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QUALITY: LARYNGEAL RESONANCE

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QUALITY: NASAL RESONANCE

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<td>1</td>
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</tr>
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FACIAL GRIMACE

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<tr>
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TOTAL SCORE

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<td>Inconsistently competent</td>
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<td>Borderline valving mechanism</td>
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<tr>
<td>7+</td>
<td>Incompetent valving mechanism</td>
</tr>
</tbody>
</table>

Fig 16–4. Perceptual weighted speech score used at Massachusetts General Hospital. Adapted from McWilliams and Phillips.26
Multiview Fluoroscopy

Multiview fluoroscopy was for many years the primary means of assessing velopharyngeal closure. Three views are traditionally used after instilling a small amount of high-density barium into the child’s nose to coat the nasopharynx. The anteroposterior view allows assessment of lateral pharyngeal wall motion (Fig 16–5). The lateral view allows visualization of palatal motion and the posterior pharyngeal wall (see Fig 16–1). The closure pattern of the sphincter is viewed directly in the base view (Fig 16–6). Videofluoroscopy allows excellent visualization of the shape of the velum and angle of elevation in lateral view and may serve as a better tolerated alternative for children who are noncompliant with nasendoscopy. The requirement of ionizing radiation in addition to potential difficulties in standard positioning with resultant child compliance issues are potential limitations of the study. An important concept is that often videofluoroscopy and nasopharyngoscopy provide complementary information.

Grading and Standardization of Velopharyngeal Closure Measurements

In 1990, an international working group of clinicians and researchers headed by Karen Golding-Kushner reported a standardized grading scale for reporting findings on nasopharyngoscopy and multiview fluoroscopy. The scale serves to outline both quantitative and qualitative scoring to accurately describe and grade the anatomic defects associated with VPI.

Fig 16–5. Anteroposterior videofluoroscopy demonstrating visualization of lateral wall motion.

Fig 16–6. Base view videofluoroscopy demonstrating closure pattern.
Nasopharyngoscopy, Multiview Fluoroscopy, or Both?

Over time, much has been written about the merits and disadvantages of both nasopharyngoscopy and multiview fluoroscopy. Both are used to accurately assess velopharyngeal anatomy to assist in developing a treatment plan, particularly surgical methods. Nasopharyngoscopy allows an excellent view of velopharyngeal closure patterns, but can be limited by optical distortion and tolerance by the child undergoing the exam. Multiview fluoroscopy allows an excellent view of lateral wall motion as well as closure patterns. As stated above, the closure patterns of the velopharynx were initially described based on fluoroscopic studies. Difficulties arise in interpreting anatomic findings in the presence of multiple shadows. Additionally, postsurgical examination particularly in the setting of a pharyngeal flap is quite difficult with fluoroscopy, but is easily visualized directly with nasopharyngoscopy. A recent review suggests that both modalities provide complementary data, but that nasopharyngoscopy may provide a higher correlation with VPI severity. Currently, our practice is to perform flexible nasopharyngoscopy on all children to visualize anatomy and assist in surgical planning and proceed to multiview fluoroscopy in children where additional information may prove useful, particularly in children under six years of age who have limited cooperation for a functional endoscopic assessment.

TREATMENT: BASIC TENETS

Prior to surgical repair of a cleft palate or primary VPI, a speech-language pathologist with specialized training can help guide parents to elicit sound play with their infant, expand consonant repertoires, and to minimize patterns of glottal stops.

As language and speech emerge for the toddler and preschool age child, it is important to discern if speech errors are developmental, obligatory, or compensatory. When children with cleft or noncleft velopharyngeal problems display articulation errors and resonance abnormalities, the developmentally appropriate articulation issues are addressed first. It is important to remediate these developmental speech errors as well as establish accurate placement of the articulators and manner of production (eg, fricative versus stop consonants), even when the anatomy prohibits the ability to achieve an orally produced sound. This is especially true for children under four years of age with a cleft palate who are often too young for consideration of a secondary surgery.

Behavioral therapy with a speech-language pathologist can be helpful in mild VPI and phoneme specific VPI. Speech/resonance therapy is not indicated when: (a) nasal emissions are present in all non-nasal consonants with subsequent hypernasality related to a short or poor moving palate or excessively deep pharynx, (b) nasal air loss related to a palatal fistula, or (c) articulation errors related to severe dental malocclusions that require physical management. Speech/resonance therapy cannot work against atypical anatomy and if attempted may cause undue frustration to the child.

Perhaps the primary concern for every child, parent, and VPI surgeon is to avoid operating when a child has a functional speech abnormality that can be masking as what appears to be VPI secondary to anatomic deficit. A thorough evaluation by a speech and language pathologist is often necessary to accurately diagnose such disorders preoperatively. As described below, comprehensive therapy often involves much more than simply filling the anatomic defect.
Speech Therapy: Resonance Therapy

Resonance therapy is helpful in certain conditions: mild velopharyngeal dysfunction that results in inconsistent nasal air emissions related to articulation errors and in the postoperative period. Short-term speech therapy preoperatively is helpful to establish accurate patterns so that the child can experience maximum success following surgery. Also, speech therapy may be considered for young children with a repaired cleft palate who are too young for secondary surgery but who have either difficulties with accurate articulation placement or have compensatory strategies considered as speech errors, such as glottal stops. Treatment approaches generally include establishing auditory discrimination of nasal and non-nasal speech productions, maximizing oral airflow for non-nasal speech sounds, facilitating accurate articulation placement, production, and manner; and diminishing deviant compensatory speech patterns, such as glottal stops. Treatment approaches may include articulation strategies to foster oral airflow, such as a prolonged plosive sound “t” to glide into a sibilant “s,” whispered speech with initial sounds “h” or “w” paired with low front vowels (e.g., “haha” or “wah wah”). Low resistance blowing toys can be helpful for the concept of oral airflow, but should not be used to “strengthen” the palate muscle as research does not support that an “exercise model” results in improved palate motion. Other approaches that may help with improved resonance balance include: vowel prolongation, increased mouth opening, and increased vocal loudness. In addition, visual and auditory feedback in therapy can offer additional modalities to help the child see or hear the degree of nasal air escape. Feedback can be seen via fogging on a nasal mirror, use of a SeeScape® device which uses a nasal tip to capture nasal airflow and provides the visual correlation of an object moving up a tube to reflect degree of flow, the new Oral and Nasal Listener® device with connected dual stethoscopes to provide auditory feedback, or a computer program using a nasometer to display nasal airflow in graphic form.

Of note, resonance therapy will not be helpful for moderate to severe VPI when the physical ability of the palate to achieve closure during speech is not possible. This would include unintelligible speech related to hypernasality and velopharyngeal incompetence, inability to achieve non-nasal consonants because of nasal air leakage and poor intraoral pressure.

Obturators and Prostheses

In some children, the use of a dental appliance to serve as a palatal lift or nasopharyngeal obturator may serve as a useful therapy alternative. Palatal lifts serve to elevate the neurogenic palate that has reduced motion or decreased accurate timing of soft palate elevation to achieve VP closure. Generally such children will have adequate velar length, but poor muscle tone. In contrast, speech bulbs or obturators are fashioned to fill the open space or gap between the soft palate and posterior pharyngeal wall in cases of insufficient palatal length (Fig 16–7). The lateral and posterior walls of the pharynx can then close against the obturator. Ideally, a speech appliance (either lift or bulb) provides the closure between the soft palate and pharyngeal wall to remediate nasal emissions and/or hypernasality associated with VPI. In general, prosthetic management of VPI is not generally a first-line approach due to compliance issues and the need for adequate stable dentition. However, such devices can be useful when secondary surgical
management, such as a pharyngeal flap, is contraindicated as in the case of a child with potential surgical comorbidities such as severe obstructive sleep apnea or cardiac anomalies. The devices can often serve as a temporary approach until surgery can be completed, or to offer insight if surgery will be beneficial.43

A team approach for speech appliance selection and fitting is useful. In general, the team should consist of a speech language pathologist, dental specialist, and orthodontist or prosthodontist to maximize successful outcomes.43 Some studies have documented improved VP muscle function following use of speech appliances in electromyography measures, such as increased activation signal of the levator veli palatini muscle.41

Careful selection of patients is requisite for success. Potential candidates include children with wide clefts in whom a lack of available tissue may compromise potential repair techniques, children with significant neuromuscular deficits of the soft palate or when surgery is contraindicated or delayed for any reason.44 In general, the limitations of such devices are realized through noncompliance. Extensive dental caries precludes the use of such devices as well.44

Surgical Treatment

Surgical treatment is the cornerstone of effective therapy for the anatomic defect associated with VPI. A variety of techniques have been developed over time to address the various configurations of closure patterns and degree of difficulties experienced by individual children. Most surgeons accept that a basic tenet of VPI surgery is that procedures must be tailored to the specific difficulty and anatomic deficiency present in each child.

The timing of such procedures depends on a variety of factors including age at diagnosis, etiology of VPI, access to trained therapists and neurocognitive development. In general, as discussed above, adequate diagnosis of VPI often does not occur until the child is approximately 3 to 4 years of age. Once diagnosed, most surgical procedures can be safely performed in children as young as 3 years old. A special note regarding selection of procedure type is the presence of baseline obstructive sleep apnea. As procedures designed to address VPI constrict the nasopharyngeal airway by definition, the theoretical possibility of exacerbating or introducing obstructive sleep apnea must be considered.

Posterior Pharyngeal Flap

Efforts to lessen the nasal emission of VPI were first described by Passavant in 1865 when he reported adhesion of the soft palate to the posterior pharyngeal wall.45 This was subsequently followed in 1875 when Schoenborn described the inferiorly based posterior pharyngeal flap followed by his introduction of a superior based flap 10 years later.46 The procedure has subsequently undergone numerous modifications since that time, but the principle remains the same. The goal of a posterior pharyngeal flap...
A flap is to effectively obturate the nasopharynx with a biologic obturator. The procedure involves creating a flap of tissue from the posterior pharyngeal wall that is raised from an inferior point superiorly where it remains attached to the posterior pharynx. The elevated inferior aspect is subsequently secured to the nasal surface of the soft palate. This can be accomplished either with or without splitting the soft palate. Once completed, the central region of the nasopharynx is obturated by the tissue, whereas lateral ports for air escape remain open to allow an attenuated degree of nasal transmission (Fig 16–8).

The development of the procedure over time has placed attention to the proper construction of the lateral ports. A prevailing concept is that children with some degree of lateral wall motion may benefit most from a pharyngeal flap as the existing lateral wall motion may be used to control the release of air through the ports.47

**Sphincter Pharyngoplasty**

In distinction to the static obturator created by a pharyngeal flap, the sphincter pharyngoplasty operation was developed in an effort to recreate a dynamic sphincter. First introduced in 1950 by Hynes with further modifications by Orticochea, Jackson, and others, the sphincter pharyngoplasty involves elevating two lateral superiorly based flaps from the region of the posterior tonsillar pillars.48–50 A transverse incision is made in the posterior pharyngeal wall mucosa, and the flaps are rotated 90 degrees and subsequently inset into the transverse incision potentially placing dynamic muscle (palatopharyngeus) into an orientation to create a dynamic sphincteric effect (Fig 16–9). A study comparing pre and postoperative operative videofluoroscopy suggested that there is some degree of dynamism after sphincter pharyngoplasty, but that it is difficult to quantify.51 Ultimately, sphincter pharyngoplasty is generally pursued in the setting of a child with adynamic lateral pharyngeal walls.

**Posterior Wall Augmentation**

In some children with a mild to moderate degree of VPI and a clearly evident small velopharyngeal gap, posterior pharyngeal wall augmentation may provide significant speech improvement. The concept involves placing the augmentation material in a location that allows adequate velopharyngeal closure by displacing the posterior pharyngeal wall anteriorly to allow contact with the soft palate. A variety of materials have been advocated including cartilage, fat, fascia, paraffin, silicone, acellular dermis, polytetrafluoroethylene, and calcium hydroxylapatite (CaHA).4,52–56 Placement methods have included direct incision over the pharyngeal mucosa, transcervical approaches, and injection. Teflon is associated with an unclear safety profile and migration leading to a sharp decrease in its use in recent years.4 Recently, our center has had a favorable experience with CaHA which serves as a stable, easily placed injectable augmentation.
agent (Fig 16–10). To date, we have used CaHA augmentation in 12 patients. Eight children demonstrated success defined as normalized nasometry and improved perceptual scores at 3 months. Four children have been followed for over 24 months and have demonstrated sustained success. Three of the 4 failures occurred very early in our experience and it became evident that the technique is both operator and patient dependent. From a technique standpoint, a minimum of 2 to 3 mL of CaHA must be injected. This is performed under direct visualization using a 120-degree endoscope with a soft palate retractor. Of note, we have had no cases of CaHA migration. In our experience, older children with mild to moderate VPI with a clear anatomic deficit seem to benefit most from the procedure.

An alternative method of posterior wall augmentation is elevating a superiorly based posterior pharyngeal wall flap and rolling it onto itself instead of attaching it to the soft palate as in typical pharyngeal flap surgery. This creates a mound of tissue that ultimately scars and provides for a contact point in the soft palate. Patient selection is critical as this method is only appropriate in children with small gaps. A particular advantage with injection methods is the ability to precisely locate the area of deficiency and to endoscopically target only the area that requires treatment.

Palatoplasty Methods

In some children, the configuration of their palate or previous surgeries may make palato-
plasty techniques more useful. In particular, children with submucous cleft palate or congenitally short palate and associated VPI may benefit from a palatal lengthening procedure such as a Furlow palatoplasty or V-Y push-back palatoplasty. Both of these methods serve to effectively lengthen the soft palate. The Furlow method involves using opposing Z-plasties whereas the V-Y method uses soft tissue elevated from the hard palate.

**Special Case: Unilateral Deficits**

Special consideration must be given in the setting of VPI in children with unilateral deficits as is commonly seen with hemifacial microsomia or unilateral neurologic injury. In these children, the anatomic defect results in a unilateral escape of air on the affected side. Surgical therapy can be accomplished with unilateral sphincter pharyngoplasty techniques, offset superior based pharyngeal flaps or possibly directed posterior wall augmentation. The decision on the best procedure is dictated by the child’s anatomy, underlying features and the experience of the surgeon. The situation clearly demonstrates the need to address VPI on an individual case by case basis.

**Tonsillectomy**

A rarely described, but clinically important cause of VPI is obstructed velar closure secondary to hypertrophic tonsils. Tonsillectomy can be curative in such children. In such children examination will demonstrate significant tonsillar hypertrophy, but confirmation requires an endoscopic or fluoroscopic examination to determine the presence of the velopharyngeal gap and to visualize the role that the tonsils play in contributing to the overall gap dimensions.

**Surgical Outcomes**

Each of the described methods has been shown to be effective in representative case series. Definitions of success vary and the heterogeneity of the problem leads to preoperative characteristics that are not uniform in studies addressing surgical outcomes. In general, success rates described as resolution of VPI vary from 62 to 98% with most accounts being in the realm of 75% resolution. Of note, several studies have looked to differentiate success rates between pharyngeal flaps and sphincter pharyngoplasty. Unfortunately, the relative rarity of the problem coupled with different techniques among different surgeons clouds the literature. An underpowered mult center trial in 2005 suggested that outcomes were similar.

Perhaps a greater concern might be the risk of complications between the various procedures. Moderate to severe bleeding seen after both pharyngeal flap surgery and sphincter pharyngoplasty is generally rare, but may occasionally require transfusion. As described above, prudence in detecting medialized carotid arteries is requisite in children with velocardiofacial syndrome. Complications associated with posterior wall augmentation procedures are related to the material used. Extrusion, infection, resorption and migration are all possibilities and occur at varying rates. Our material of choice, calcium hydroxylapatite, has not demonstrated any such complications to date.

The development of obstructive sleep apnea is likely one of the most worrisome complications associated with the surgical management of VPI. Obstructive sleep apnea is almost exclusively seen in pharyngeal flap surgery and several postoperative deaths have been reported. Recent attention to the subject has suggested that careful preoperative airway evaluation and consideration of preoperative tonsillectomy may be useful in preventing untoward outcomes.

When considering patient selection for various procedures, a certain degree of tailoring is necessary. A combination of the child’s anatomy, neurocognitive development, social situation, and access to therapy coupled with the surgeon’s experience are all factors in selecting the appropriate procedure for each child.
FUTURE DIRECTIONS

The management of velopharyngeal insufficiency continues to be an evolving field. Recent advances in evaluation include the widespread use and acceptance of nasal endoscopy. Of recent note, the utility of magnetic resonance imaging (MRI) as an evaluation tool has emerged as stronger magnets and imaging algorithms have allowed the development of cine MRI sequences which provide high-resolution detailed velopharyngeal movement visualized without ionizing radiation. Further developments in surgical technique including the novel materials for posterior wall augmentation as well as alternative procedures such as cerclage pharyngoplasty and creation of a palatopharyngeal sling have been described and represent exciting advances in the field.

CONCLUSIONS

Overall, the evaluation and management of VPI remains both challenging and rewarding. The heterogeneity of the problem leads to a wide variety of manifestations and therapies. The care of these children requires an individualized approach to each patient in a multidisciplinary fashion. Fortunately, given the opportunity, most children can ultimately achieve intelligible speech and experience minimal vocal disability over the long term.

REFERENCES


