What’s New in Cleft Palate and Velopharyngeal Dysfunction Management?

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Learning Objectives: After studying this article, the participant should be able to: 1. Have a clear understanding of the evolution of concepts of velopharyngeal dysfunction, especially as it relates to patients with a cleft palate. 2. Explain the subjective and objective evaluation of speech in children with velopharyngeal dysfunction. 3. On the basis of these diagnostic findings, be able to classify types of velopharyngeal dysfunction. 4. Develop a safe, evidence-based, patient-customized treatment plan for velopharyngeal dysfunction founded on objective considerations.

Summary: Velopharyngeal dysfunction is improper function of the dynamic structures that work to control the velopharyngeal sphincter. Approximately 30 percent of patients having undergone cleft palate repair require secondary surgery for velopharyngeal dysfunction. A multidisciplinary team using multimodal instruments to evaluate velopharyngeal function and speech should manage these patients. Instruments may include perceptual speech analysis, video nasopharyngeal endoscopy, multiview speech videofluoroscopy, nasometry, pressure-flow, and magnetic resonance imaging. Velopharyngeal dysfunction may be amenable to surgical or nonsurgical treatment methods or a combination of each. Nonsurgical management may include speech therapy or prosthetic devices. Surgical interventions could include palatal re-repair with repositioning of levator veli palatini muscles, posterior pharyngeal flap, sphincter pharyngoplasty, or soft palate or posterior wall augmentation. Treatment interventions should be based on objective assessment and rating of the movement of lateral and posterior pharyngeal walls and the palate to optimize speech outcomes. Treatment should be tailored to specific anatomical and physiologic findings and the overall needs of the patient. (Plast. Reconstr. Surg. 139: 1343e, 2017.)

Velopharyngeal dysfunction results from inadequate function of dynamic structures that work to control the velopharyngeal sphincter (formed by the soft palate, the lateral pharyngeal walls, and the posterior pharyngeal wall), which separates the nasal cavity from the oral cavity during speech.¹ The velopharyngeal sphincter is also often referred to as the velopharyngeal port, valve, portal, or passage, but will hereafter be described as the sphincter. The levator veli palatini, tensor veli palatini, palatoglossus, palatopharyngeus, musculus uvulae, salpingopharyngeus, and superior pharyngeal constrictors all play a part in the function of the velopharyngeal sphincter.¹ Together, they aid in manipulating air pressure and sound emanating from the respiratory tract into intelligible speech by controlling the shape and size of, and directing flow of air between, the oral and nasal resonating cavities. Dysfunction of this system may result in hypernasality, nasal air emission, decreased intraoral air pressure for oral pressure consonants, reduced speech loudness, nostril or facial grimacing, and hyperfunctional phona- tory changes.² Although there are many causes

Disclosure: Dr. Losee receives royalties from the publication of Comprehensive Cleft Care, for which he is an editor. The authors have no other disclosures.

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Received for publication May 6, 2016; accepted November 21, 2016.
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DOI: 10.1097/PRS.0000000000003335
of velopharyngeal dysfunction, the focus of this article is that as a result of cleft palate. Approximately 30 percent of patients having undergone cleft palate repair require secondary surgery for velopharyngeal dysfunction. Velopharyngeal dysfunction has been codified previously, with multiple published reviews from past and present. In fact, there is very little that is truly “new” in the management and treatment of velopharyngeal dysfunction, especially in the cleft palate patient. That which is new includes evolving diagnostic tools, outcome data following surgical interventions, and evolved surgical techniques. As such, our goal is to present a review of established diagnostic and management techniques, present more recent outcome data to support their use, and present surgical techniques that may be on the horizon.

**CLASIFICATION OF VELOPHARYNGEAL DYSFUNCTION**

Differential causes of velopharyngeal dysfunction in the cleft palate patient include velopharyngeal insufficiency, velopharyngeal incompetency, and mislearning, with management varying depending on cause (Fig. 1). Of note, an oronasal fistula may cause abnormal nasal air emission and reduced velopharyngeal sphincter closure in the absence of true velopharyngeal dysfunction.

Velopharyngeal insufficiency is a subset of velopharyngeal dysfunction secondary to insufficient tissue or mechanical restriction resulting from an unrepaired cleft palate, palatopharyngeal disproportion, or a previously repaired cleft palate where the soft palate may be too short or constrained by a significant amount of scar tissue.

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**Fig. 1.** Velopharyngeal dysfunction classification. The differential diagnosis of velopharyngeal dysfunction includes velopharyngeal insufficiency (VPI), velopharyngeal incompetency, or mislearning (orange boxes). Potential causes of nasal air emission (NAE) in a patient with a cleft palate are in the green boxes. Causes in blue boxes are typically not found in patients with a cleft palate. (Reprinted with permission from Hopper RA, Tse R, Smartt J, Swanson J, Kinter S. Cleft palate repair and velopharyngeal dysfunction. *Plast Reconstr Surg.* 2014;133:852e–864e.)
or where the levator veli palatini muscles have not been properly reoriented. Other causes of velopharyngeal insufficiency include submucous cleft palate, velar dysplasia, deep pharynx, irregular adenoids, adenoid hypertrophy, adenoidectomy, hypertrophic tonsils, maxillary advancement, posttonsillectomy, and oral or pharyngeal cavities.1

All patients with an anatomical cause of velopharyngeal dysfunction will present with compensatory misarticulations, which may persist following anatomical repair. It is therefore important to be able to distinguish between compensatory misarticulations versus mislearning misarticulations. Compensatory misarticulations develop spontaneously to compensate for reduced intraoral air pressure because of abnormal anatomy, whereas mislearning misarticulations result from abnormal use of the velopharyngeal mechanism despite the absence of other abnormality. One should also consider hearing impairment as a cause of velopharyngeal mislearning. A thorough auditory evaluation is therefore essential for all patients that present with a speech disorder.

**DIAGNOSING VELOPHARYNGEAL DYSFUNCTION**

Patients with velopharyngeal dysfunction should be managed by a multidisciplinary team, using multimodal instruments to evaluate preoperative and postoperative speech outcomes. This has been advocated in an effort to standardize reporting of speech outcomes in cleft palate patients, and to customize treatment algorithms for specific patients. The speech pathologist is perhaps the most integral part of the multidisciplinary team at this stage of the cleft palate patient’s journey. Diagnostic results should be rigorously reviewed and consensus established as to the optimum course of management. Especially critical is distinguishing between abnormal speech that is a result of velopharyngeal sphincter dysfunction versus behavioral speech function. Many professionals may be able to determine whether speech “sounds normal”; however, the speech pathologist is the most qualified team member to differentiate between a speech abnormality secondary to a structural anomaly that would benefit from surgical intervention versus that which would benefit from behavioral speech therapy.

**Perceptual Speech Analysis**

After a thorough history and physical examination, perceptual speech analysis is first performed by the trained ear of a certified speech-language pathologist. Speech samples are obtained through a structured formalized assessment protocol and inclusion of spontaneous speech rating. Assessment includes sampling of all speech sounds. Specific attention is made to the production of pressure sounds, including plosives, fricatives, affricatives, and nasal consonants (Table 1). Misarticulations are analyzed for developmental type errors, compensatory maladaptive errors, and those that may be attributable to oral cavity or dental structure abnormalities. Resonance patterns, presence of abnormal audible and visible nasal air emission, and maladaptive nostril or facial grimacing are also ascertained.9

Detailed methods of perceptual speech analysis are beyond the scope of this article. In brief, one must first determine whether the patient’s speech abnormality is a result of velopharyngeal dysfunction with abnormal resonance and nasal air emission, or an abnormality of speech sound learning, or both. On establishing the cause of velopharyngeal dysfunction, the utility of further diagnostic imaging may be determined. Resonance, which is a descriptor of where sound moves and reverberates throughout the vocal tract, is assessed using voiced (resonating) sounds, including vowels, nasal consonants, and vocalic consonants. Abnormal closure of the nasal valve can result in abnormal resonance, and may be clinically evidenced by hypernasality, hyponasality, cul-de-sac resonance, or a combination of these.

In addition, audible nasal air emission or nasal turbulence with or without nostril/facial grimacing may be present. Hypernasality (rhinolalia

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**Table 1. Definitions of Specific Pressure Phonemes and Speech Characteristics**

<table>
<thead>
<tr>
<th>Phoneme</th>
<th>Speech Characteristics</th>
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<tbody>
<tr>
<td>Plosives</td>
<td>Consonants in which the vocal tract is blocked so that all airflow ceases. The occlusion may be made with the tongue blade (/t/, /d/) or body (/k/, /g/), lips (/p/, /b/), or glottis.</td>
</tr>
<tr>
<td>Fricatives</td>
<td>Consonants produced by forcing air through a narrow channel made by placing two articulators close together. These may be the lower lip against the upper teeth, in the case of /f/; the back of the tongue against the soft palate; or the side of the tongue against the molars.</td>
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<tr>
<td>Affricatives</td>
<td>A consonant that begins as a stop and releases as a fricative.</td>
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<tr>
<td>Misarticulations</td>
<td>Generic term for any deviation of speech sound production (articulation), which is characterized by distortion, omission, or substitution or addition of phonemes.</td>
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aperta) results from increased vocal resonation through the nose during speech production because of inadequate or incomplete closure of the velopharyngeal sphincter. Conversely, hyponasality (rhinolalia aperta) results from a lack or reduction of nasal resonance. Audible nasal emission and nasal turbulence or “rustling” occurs when air is lost through the velopharyngeal sphincter during productions of oral pressure consonants. The airflow may result in “bubbling” of nasal secretions or vibration of the tissues in the velopharyngeal sphincter, resulting in the characteristic acoustically turbulent air and resultant speech distortion. This can be correlated with visible nasal air escape, detected with the assistance of a mirror held under the nares, which would fog. Facial grimacing is a compensatory action used to narrow the external nares to decrease nasal air emission during nonnasal speech.

Articulation assessment is a difficult part of perceptual speech evaluation, and is used to determine the status of the patient’s speech errors. This is important because obligatory errors are caused by structural or neurogenic problems, such as fistulas or velopharyngeal dysfunction, and would require surgical correction, whereas compensatory articulation errors are learned articulation errors that are developed in early speech acquisition because of an inability to generate adequate intraoral air pressure for normal production of pressure consonants.

Velopharyngeal mislearning includes these compensatory errors and learned phoneme-specific nasal air emission with particular speech sounds, most often /s/ and /z/, but at times including other fricatives and sometimes affricates. All of these learned errors are corrected through speech therapy only. Within the office setting, articulation evaluation may be performed by having the patient produce a conversational speech sample and structured speech tasks. There is no standardized perceptual acoustic evaluation protocol that is uniformly used among all speech-language pathologists, despite the recommendations of the International Working Group. Perceptual analysis may be supplemented with the use of the Pittsburgh Weighted Speech Scale, which is used in many clinics to report the severity of velopharyngeal dysfunction.10,11

Video Nasopharyngeal Endoscopy

Video nasopharyngeal endoscopy uses a magnified high-quality view to provide direct visualization of the entire vocal tract during speech production. Since its earliest use and introduction by Pigott et al. in 1969, video nasopharyngeal endoscopy technology has advanced significantly and become one of the two primary state-of-the-art tools for examination of the upper vocal tract during speech.12,13 Video nasopharyngeal endoscopy provides optimal viewing of the velopharyngeal sphincter by enabling direct visualization of the degree of closure, the position and function of the levator musculature, the length and quality of the soft palate, and the degree of motion of the lateral pharyngeal walls and posterior pharynx.14 This is performed while a speech-language pathologist guides the patient through repetition of a standardized speech sample tailored to their abilities. Video nasopharyngeal endoscopy also allows for examination of the entire vocal tract at different levels and from different angles, and for visualization of the larynx to assist in identifying vocal fold abnormality and the presence of hyperfunctional phonatory disorders often associated with velopharyngeal insufficiency. This plays an important role when determining the appropriate treatment algorithm, as surgical methods of correction should be based on specific patterns of closure.15 A limitation of video nasopharyngeal endoscopy is the fact that it is not possible to quantitatively measure pertinent anatomical findings, such as gap size, as image size changes dramatically with scope position. Video nasopharyngeal endoscopy may also be a very uncomfortable procedure for pediatric patients, especially in the hands of an inexperienced endoscopist. (See Video, Supplemental Digital Content 1, which displays a video tutorial of velopharyngeal assessment using the Pittsburgh Weighted Speech Scale. This video is available in the “Related Videos” section of the full-text article on PRSJournal.com or, for Ovid users, at http://links.lww.com/PRS/C168.)

Recent advances in video nasopharyngeal endoscopy include three-dimensional imaging, its use in detecting syndromic cleft palate diagnoses, and its use while the patient is under mild sedation.16–19 At present, video nasopharyngeal endoscopy imaging is predominantly two-dimensional. A single view (sagittal) and velar overlapping preclude optimum observation of lateral pharyngeal wall motion. More recently, three-dimensional conceptualization of the velopharyngeal sphincter during speech using coronal, sagittal, and axial planes has been promoted.16,17 One recent case report highlighted the use of video nasopharyngeal endoscopy for detecting pulsations on the lateral and posterior pharyngeal walls, which prompted workup for 22q11.2 microdeletion.
syndrome. Given that 22q11.2 microdeletion syndrome is the most common syndrome associated with cleft palate and velopharyngeal insufficiency, this report highlights an important clinical finding that may affect workup and management of patients with velopharyngeal dysfunction. In the pediatric patient, compliance during a video nasopharyngeal endoscopy study is often challenging. A recent study assessed whether postponing video nasopharyngeal endoscopy until the patient was in the operating room and under the effect of preoperative light sedation could result in similar or even better analysis than performing the procedure awake. The authors found that procedure compliance and patient comfort were improved, and the diagnostic findings dictated surgical procedures that completely corrected hypernasality in 90 percent of cases.

Multiview Speech Videofluoroscopy

Multiview speech videofluoroscopy provides two-dimensional visualization of the velopharyngeal sphincter in motion during speech by creating serial radiographs through tissues. First described by Skolnick in 1970, the procedure is flexible in that information can be obtained regarding multiple anatomical and physiologic correlates even without contrast. Velar motion, adenoid size, and cranial base angle are easily ascertained. Lateral pharyngeal wall motion can also be accurately ascertained even in a very young patient. If tolerable, high-density contrast material (barium) may be syringe-injected transnasally during the examination to coat the tissues of the velopharyngeal sphincter, allowing a base view to be obtained with good visualization of gap size and closure patterns. In collaboration with a radiologist, the patient is guided by a speech-language pathologist through repetition of a standardized speech sample personalized to their abilities. This procedure is typically performed in both the lateral and anteroposterior views, providing images of the posterior pharyngeal wall and Passavant ridge. (See Video, Supplemental Digital Content 2, which displays a multiview speech videofluoroscopy examination of a patient with velopharyngeal insufficiency. This video is available in the “Related Videos” section of the full-text article on PRSJournal.com or, for Ovid users, at http://links.lww.com/PRS/C169.)
Multiview speech videofluoroscopy tends to be better tolerated than video nasopharyngeal endoscopy, and is often preferentially used in younger children who are unlikely to cooperate for a video nasopharyngeal endoscopic examination. However, multiview speech videofluoroscopy may oversimplify the dynamic velopharyngeal sphincter and therefore make patterns of closure more difficult to assess. The procedure also necessitates some exposure to radiation and, like video nasopharyngeal endoscopy, is limited by the patient’s ability to cooperate. A recent advance is improved standardization of objective measures when using multiview speech videofluoroscopy to assess velopharyngeal dysfunction. With significant reliability, multiview speech videofluoroscopy has been shown to provide real-size measurements by a ratio of selected distance markings and pixels and therefore deliver better quantitative data regarding closure patterns.

Multiview speech videofluoroscopy and video nasopharyngeal endoscopy are the two primary state-of-the-art tools for examination of the upper vocal tract during speech, and are often used in conjunction to maximize objective evidence required to progress through one’s treatment algorithm decision tree. These studies should be video-recorded with sound so they may be reviewed by a multidisciplinary team. The importance of a speech-language pathologist cannot be emphasized enough, along with their selection of conversational speech sample and structured informal speech tasks. By optimally using both multiview speech videofluoroscopy and video nasopharyngeal endoscopy, surgical treatment may be customized individually and speech outcomes significantly improved.

Nasometry

Nasometry is an objective, indirect, computer-aided test used to measure air escaping past the velum and through the nose (nasal emission). It provides a measurement of the modulation of the velopharyngeal sphincter, and allows for reproducible calculation of the ratio between nasal and oral sound emissions (nasalance). These ratios are compared with normative values and may also be compared preoperatively and postoperatively. Nasometry does not provide any data regarding the localization or quantification of velopharyngeal sphincter gap size. For example, nasal air emission may be the result of an oronasal fistula versus velopharyngeal insufficiency but objectively would produce similar nasalance. There have not been any recent advances in use of this diagnostic modality. Although nasometry may not be suited to diagnosing the cause of velopharyngeal dysfunction, it may provide a standard objective measure with which to compare preoperative and postoperative speech outcomes.

Magnetic Resonance Imaging

Magnetic resonance imaging has recently been promoted for evaluation of the velopharynx. Magnetic resonance imaging does not require radiation exposure and provides the ability to acquire high-quality, reproducible, static and dynamic imaging of velopharyngeal structures. Function may be assessed under direct visualization of the velopharynx and the direction and insertion of distal muscular fibers of the levator veli palatini. Although a two- or three-dimensional magnetic resonance imaging sequence may provide better analyses and more precise measurements, it remains cost prohibitive.

TREATMENT OF VELOPHARYNGEAL DYSFUNCTION

Management of velopharyngeal dysfunction is dependent on specific cause and subsequent customization of treatment to optimize speech outcomes. Treatment may be nonsurgical (speech therapy or prosthetic devices), surgical, or a combination of the two. The key to choosing the right therapy is proper use and analysis of velopharyngeal dysfunction diagnostic modalities described previously.

Nonsurgical Treatment

Prosthetic options may be used as a temporary or permanent solution for nonsurgical candidates. Devices are customized and provide palatal lift, obturation, or a combination of both. Palatal lifts aid the soft palate in velopharyngeal sphincter closure by pushing the soft palate cranially, and are often used in cases of hypomobility or paralysis. Obturators are used to occlude either oronasal fistulas or unrepaired palatal clefts. Speech bulbs can be used to occlude persistent velopharyngeal defects after inadequate palatal repair when further surgery is contraindicated or undesired.

Although speech therapy may be beneficial for all patients with velopharyngeal dysfunction, it is the sole therapy for velopharyngeal mislearning. In cases where patients have already acquired speech, those with velopharyngeal insufficiency benefit from speech therapy postoperatively in helping them to learn how to use their “new anatomy.”
Surgical Treatment

Surgical approaches to correction of velopharyngeal dysfunction may be divided into broad groups that either correct muscle function (palatal re-repair with repositioning of the levator veli palatini), compensate for poor function by narrowing the velopharyngeal sphincter (posterior pharyngeal flap, sphincter pharyngoplasty, or posterior wall and/or soft palate augmentation), or both (V-Y pushback, Furlow double-opposing Z-plasty). Hereafter, we will elaborate on the three most widely used methods: posterior pharyngeal flap, sphincter pharyngoplasty, and palatal re-repair.

We will touch briefly on more recent studies using fat grafting for posterior wall and/or soft palate augmentation.

Posterior Pharyngeal Flap

The posterior pharyngeal flap is one of the oldest and most commonly used surgical techniques for treatment of velopharyngeal dysfunction. Its evolution dates back to 1865, when Passavant first performed a surgical technique that sutured the posterior border of the soft palate to the posterior pharyngeal wall, and Schoenborn in 1875 who performed an inferiorly based flap. More recently, the technique was popularized in the United States by Padgett in the 1930s and Hogan in the 1970s. In connecting the posterior pharynx to the soft palate, a musculomucosal bridge is created, dividing the velopharyngeal sphincter into two smaller ports, decreasing airflow during speech. Success relies on adequate mobility of the lateral pharyngeal walls to close the resulting two lateral velopharyngeal sphincters. Debate continues regarding inferiorly based versus superiorly based flaps; however, speech outcomes are not significantly different with either technique.

The superiorly based flap is preferentially used at our institution, because it provides an unobstructed view of the donor site during harvest, does not tether the soft palate inferiorly, and allows for harvest of greater length. The surgical technique has not varied considerably from that popularized by Hogan (Fig. 2); however, some variations include not splitting the palate in the midline, not lining the flap with nasal mucosa from the soft palate, and performing a “through-and-through” dissection of the soft palate for flap inset. Smartt et al. have recently advanced the modality of this surgery by exploring the use of robotic surgical telemanipulation systems to perform a Hogan-style posterior pharyngeal flap on a small series of cadaveric human specimens. They found the technique to be feasible and postulated that it may offer improved exposure and ergonomics compared with traditional surgery. The use of robotic surgical systems may therefore find a niche within intraoral cleft surgery in the coming years. No recent studies have shown one posterior pharyngeal flap technique to be superior to another with regard to reduction of complications or improvement in speech outcomes. However, recent studies have shown longevity in improvement of speech following takedown for posterior pharyngeal flap for obstructive sleep apnea. The mechanism by which this occurs may include stretching of the soft palate and/or a thicker posterior pad after flap takedown. There is significant potential morbidity associated with pharyngoplasty, and although the most comprehensive reviews of complication rates are now dated, a recent study using the 2012 American College of Surgeons National Surgical Quality Improvement Program Pediatric database identified the overall perioperative complication rate for posterior pharyngeal flap surgery to be low (5.3 percent), and identified patients with underlying cardiac risk factors, severe American Society of Anesthesiologists Physical Status class, and asthma as having heightened risk profiles.

Sphincter Pharyngoplasty

The sphincter pharyngoplasty has undergone incremental evolution since its first introduction. The surgical method still includes elevation of thick vertically oriented posterior tonsillar pillar flaps (all of which include the palatopharyngeus muscle) and transposing them 90 degrees medially to a horizontal position, against the posterior pharyngeal wall (Fig. 3). Recent advancements include augmentation of the muscle sphincter created by the posterior tonsillar pillar flaps with the longus capitis muscle, cerclage of the sphincter pharyngoplasty using polypropylene sutures, and placing the pharyngoplasty higher in the pharynx. Similar to posterior pharyngeal flaps, the modality of surgery has also recently been explored, with cadaveric studies investigating the feasibility of transnasal endoscopy–assisted pharyngoplasty. Like the posterior pharyngeal flap, obstructive sleep apnea remains a significant morbidity associated with sphincter pharyngoplasty, and parents should be counseled regarding the diagnosis and treatment of this potential complication.

Palatal Re-Repair with Reorientation of the Levator Veli Palatini

Palatal re-repair has been advocated for the secondary correction of velopharyngeal dysfunction.
insufficiency in patients who initially underwent a “straight-line palatoplasty” and/or demonstrate anterior insertion of the levator veli palatini. The method of re-repair may be debated (Furlow double-opposing Z-plasty versus aggressive intravelar veloplasty), but both emphasize the importance of correction of the abnormal position of the levator veli palatini, suturing of these divided muscle bellies, and removal of scar tissue. Correctly positioning the levator veli palatini is the most important factor in terms of functional speech outcomes in palatoplasty. At our institution, the Furlow double-opposing Z-plasty is the preferred first-line intervention for velopharyngeal insufficiency in a previously repaired cleft palate. The Furlow double-opposing Z-plasty has been shown to be efficacious as a secondary treatment for velopharyngeal dysfunction resulting from a previously repaired cleft. The geometric design of the Furlow double-opposing Z-plasty is in achievement of its primary goal of overlapping the levator veli palatini muscle bellies and placing them under “functional tension,” bringing the tip of each posteriorly based musculomucosal flap to the base of the contralateral levator veli palatini muscle belly as it exits the skull base (Fig. 4). In doing so, one achieves a precisely transverse orientation of the levator veli palatini muscles, displacing them anatomically to the middle 50 percent of the velum. There are three functional benefits

Fig. 2. Posterior pharyngeal flap. Before any infiltration or incision, examination and palpation of the posterior pharyngeal wall should be performed to identify medialization of the carotid arteries. Analgesic/epinephrine infiltrate may be used to hydrodissect the submucosal layer of the posterior pharyngeal wall. (Above, left) Marked borders of the proposed flap, with distal demarcation that may taper inferiorly to a rounded or triangular point corresponding to the site of attachment to the soft palate. The midline has been split and retraction sutures placed. (Above, center) The white prevertebral fascial plane determines the depth of the dissection of the posterior pharyngeal wall. The flap incorporates the muscle of the posterior pharyngeal wall. (Above, right) Sagittal view of the posterior pharyngeal flap raised cephalad (arrow). (Below, left) Closure of the flap donor site with bites of the prevertebral fascia incorporated to eliminate webbing and close the dead space. (Below, second from left) Insetting of the pharyngeal flap. (Below, second from right) Closure of the soft palate and approximation of the nasal mucosal flaps in the midline. (Below, right) Sagittal view of the inset and closure of the nasal mucosal lining. Design of the palatal inset will vary with technique, but will ultimately result in bridging of the velum and posterior pharyngeal wall as illustrated. The oral cavity is irrigated and suctioned dry. Alternatively, the donor site may be left to close by means of secondary intention. (Reprinted with permission from Wong KW, Klaiman PG, Forrest CR. Posterior pharyngeal flaps. In: Losee JE, Kirschner RE, eds. Comprehensive Cleft Care. 2nd ed. Boca Raton, Fla: CRC Press; 2015:1133–1156.)
of Furlow double-opposing Z-plasty: (1) lengthening of the velum with Z-plasties of both the nasal and oral mucosa; (2) reorientation of the levator veli palatini muscles, resulting in the greatest degree of overlap under “functional tension”; and (3) a pharyngoplasty effect through narrowing of the velopharyngeal sphincter as a result of the nasal lining Z-plasty. Although this technique was originally proposed as a method of primary cleft repair, it has become a very effective method of correction of velopharyngeal insufficiency after primary cleft repair, as it not only provides considerable palatal lengthening, but also corrects the abnormal orientation of the levator veli palatini muscles. There is mounting evidence that the Furlow double-opposing Z-plasty offers superior outcomes when compared with posterior pharyngeal flaps and sphincter pharyngoplasties. Recent studies address the debate as to whether Furlow double-opposing Z-plasty or intravelar veloplasty produces superior speech results. That being said, surgeon comfort will ultimately dictate which technique is used and will produce the best results in their hands.

**Augmentation of the Posterior Pharyngeal Wall and Soft Palate**

Augmentation of the posterior pharyngeal wall has a long history and has used a wide range of substances. With higher extrusion rates experienced with synthetic materials, more recently, autologous tissues such as fat and cartilage have become the materials of choice.

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**Fig. 3.** Sphincter pharyngoplasty. *(Above, left)* The optimal insertion level in the posterior pharyngeal wall for the posterior tonsillar pillar myomucosal flap is determined preoperatively using lateral speech fluoroscopy. The dotted line represents the velum, which is displaced within the posterior pharynx to expose the inferior nasopharynx and velopharynx for the surgical approach. *(Above, right)* Attention is first directed to the junction of the ventral surface of the posterior tonsillar pillar and the tonsillar bed, where the mucosa is incised. A unipedicled, superiorly based myomucosal flap is developed from the posterior pharyngeal wall insertion site superiorly to an inferior length equal to the transverse width of the insertion site. This flap includes the palatopharyngeus muscle to achieve optimal function and flap survival. The superior aspect of the flap is preserved as its base, and the inferior aspect is divided. The flap is elevated until the posterior pharyngeal wall insertion site is reached. The same procedure is then repeated for the opposite pillar. *(Below, left)* The mucosa at the posterior pharyngeal wall insertion site is cut, connecting the superior aspects of each posterior pillar myomucosal flap donor site as a U. Only the mucosa is cut, with a minimum of underlying muscle. *(Below, center)* The posterior pillar flaps are rotated 90 degrees and inset into the posterior pharyngeal wall mucosa defect and to each other in a Z pattern. *(Below, right)* The lateral pharyngeal wall donor sites are then repaired. (Reprinted from Marsh JL, Gage EA. Sphincter pharyngoplasty. In: Losee JE, Kirschner RE, eds. Comprehensive Cleft Care. 2nd ed. Boca Raton, Fla: CRC Press; 2015:1157–1170.)
Fig. 4. Furlow double-opposing Z-plasty. In using the double-opposing Z-plasty for correction of velopharyngeal insufficiency, the procedure is not all that different from that in primary cleft palate repair, with design based on palate anatomy, not geometry. (Above, left) Traditionally, the posteriorly based oral musculomucosal flap is elevated first. The clefted levator muscle is carefully detached from its hard palate attachment and from the nasal mucosa. Scar may complicate the medial aspect of this dissection. When the lateral extent of the dissection nears the hamulus, the palate muscles are bluntly pushed posteriorly, not laterally, from the superior constrictor, leaving the levator as a distinct muscle bundle coming into the flap from between the nasal mucosa and the superior constrictor at the posterior margin of the eustachian orifice. (Above, center) The lateral limb incision for the anteriorly based oral mucosal flap is made from the base of the uvula to just lateral to the hamulus, taking care to expose the muscle without cutting it. As the flap is elevated, care is taken to separate the mucosa from the underlying muscle. As the dissection approaches the base of the flap along the posterior edge of the hard palate, the plane should be deepened to the back of the hard palate and carefully detached from it, without damaging the greater palatine vessels. (Above, right) The anteriorly based nasal mucosal flap is incised from the base of the uvula to the superior constrictor at the point of entry of the levator. (Below, left) The posteriorly based nasal musculomucosal flap is then created by incising the nasal mucosa at 3 to 4 mm from the posterior edge of the hard palate toward the eustachian orifice for approximately 1 cm. With the tip of the flap pulled transversely, the levator muscle is released carefully from the new free margin of the nasal mucosal incision, and the lateral limb incision is extended if necessary until the tip of the flap will reach the end of the contralateral nasal mucosal flap lateral limb incision. This brings the distal end of the levator muscle against the contralateral superior constrictor and immediately under the contralateral levator. (Below, center) Flaps are then inset, beginning with the nasal musculomucosal flap, bringing the tip of the levator muscle to the contralateral superior constrictor. (Below, right) The tip of the oral musculomucosal flap is positioned at the point along the lateral limb incision over the contralateral levator muscle belly, just posterior to the hamulus, orienting the levator transversely to complete the overlapping levator sling. (Reprinted with permission from Kaye A, Kirschner RE. The Furlow double-opposing Z-plasty repair for cleft palate. In: Losee JE, Kirschner RE, eds. Comprehensive Cleft Care. 2nd ed. Boca Raton, Fla: CRC Press; 2015:943–958; and Kao MC, Sie KC. Correction of velopharyngeal dysfunction by double-opposing Z-plasty. In: Losee JE, Kirschner RE, eds. Comprehensive Cleft Care. 2nd ed. Boca Raton, Fla: CRC Press; 2015:1125–1132.)
Solid data regarding the long-term outcomes of fat or cartilaginous augmentation are lacking, with observational results varying depending on assessment modality, and objective measures such as nasalance and fat graft “take” being reported inconsistently. With only a small number of serious complications being reported, including fat embolism resulting in stroke and fat hypertrophy resulting in obstructive sleep apnea, the safety of fat augmentation remains unproven. Retrospective studies of isolated posterior pharyngeal wall augmentation reveal varied results that range from complete resorption of graft to complete resolution of hypernasality. Boneti et al. performed augmentation of the nasal surface of the palate in 46 patients. The recorded volume of fat grafted averaged 2.4 ± 1.1 ml. Of 34 patients with adequate speech follow-up, including Pittsburgh Weighted Speech Scale assessment, the average preoperative score of 8.17 ± 3.59 was reduced to 5.17 ± 3.14 postoperatively. Although 26 of 34 patients (76.5 percent) had an improvement in their Pittsburgh Weighted Speech Scale score, what is not provided in this study is whether any of these patients required additional surgical intervention because of persistent dysfunction and a lack of significant enough improvement with augmentation alone. At this time, augmentation of the posterior pharyngeal wall and/or soft palate may best be reserved for patients with small velopharyngeal sphincter closure defects; however, questions remain regarding ideal graft volume and location. Standardized assessment methods and comparison studies against established velopharyngoplasty techniques are still needed.

**TREATMENT ALGORITHM**

With improved diagnostic modalities and ability to objectively assess the degree of velopharyngeal insufficiency, it is clear that a “one-size-fits-all” approach to surgical correction does not produce optimal results. Anatomical and neurologic considerations must be appreciated, in addition to velopharyngeal sphincter size and surgeon expertise. The pattern of velopharyngeal sphincter closure is important in determining the optimum surgical approach. Posterior pharyngeal flaps have proved superior in cases of circular or sagittal closure, and sphincter pharyngoplasty has proved superior in cases of coronal closure patterns and patients with preexisting obstructive sleep apnea.

At the Pittsburgh Cleft Craniofacial Center, we use video nasopharyngeal endoscopy, multiview speech videofluoroscopy, and perceptual speech analysis together to diagnose the cause of a patient’s velopharyngeal dysfunction. In patients with a cleft palate previously repaired with a straight-line technique, and/or where there is evidence of persistent abnormal orientation of the levator veli palatini (vaulted V-shaped pattern of velar elevation), our preferred first-line intervention is to perform a “conversion” Furlow double-opposing Z-plasty. Only after this first intervention is a posterior pharyngeal flap (in cases of circular or sagittal closure patterns) or sphincter pharyngoplasty (in cases of coronal closure patterns) explored. Put alternatively, the ideal posterior pharyngeal flap candidate is one with active lateral pharyngeal wall motion and a large defect, whereas the ideal sphincter pharyngoplasty is one with poor lateral pharyngeal wall motion and a small defect. Given limited objective outcome data, we have not currently incorporated posterior wall and/or soft palate augmentation into our treatment algorithm.

Regardless of one’s treatment algorithm, established and emerging diagnostic modalities should be used to provide objective assessment and rating of the movement of lateral and posterior pharyngeal wall and palate. In this way, treatment interventions can be tailored to the specific needs of the patient, and speech outcomes can be optimized.

**REFERENCES**


