SCHOOLS

Evaluation and Treatment of Resonance Disorders

Ann W. Kummer
Children's Hospital Medical Center, Cincinnati, OH
Linda Lee
University of Cincinnati, OH

Resonance is the quality of the voice that results from sound vibrations in the pharynx, oral cavity, and nasal cavity. The relative balance of sound vibration in these anatomical cavities determines whether the quality of the voice is perceived as normal or deviant due to a type of "nasality."

NORMAL RESONANCE AND VELOPHARYNGEAL FUNCTION

Sound energy begins when the vocal folds vibrate, producing sound. The sound energy travels in a superior direction through a series of interconnected resonators that include the pharynx, the oral cavity, and the nasal cavity. The size and shape of the resonating cavities directly affect the perceived resonance and voice quality. The velopharyngeal mechanism is responsible for regulating and directing the transmission of sound energy and air pressure in the oral and nasal cavities.

ABSTRACT: Resonance disorders can be caused by a variety of structural abnormalities in the resonating chambers for speech, or by velopharyngeal dysfunction. These abnormalities may result in hypernasality, hypo- or denasality, or cul-de-sac resonance. Resonance disorders are commonly seen in patients with craniofacial anomalies, particularly a history of cleft palate. The appropriate evaluation of a resonance disorder includes a speech pathology evaluation, and may require a videofluoroscopic speech study or nasopharyngoscopy assessment. Treatment may include surgery or the use of prosthetic devices, and usually speech therapy. Given the complexity of these disorders in regard to evaluation and treatment, the patient is best served by an interdisciplinary craniofacial anomaly team.

KEY WORDS: resonance, cleft lip/palate, hypernasality, velopharyngeal insufficiency

During the production of oral sounds, the velopharyngeal mechanism functions as a valve by closing the nasal cavity. This redirects acoustic energy anteriorly into the oral cavity for the production of oral sounds. Therefore, the primary sound resonators for oral phonemes are the oral cavity and the pharynx.

For nasal consonants (m, n, ng), the velopharyngeal port remains open to allow sound transmission into the nasal cavity, which is the primary resonating chamber for these sounds. Very little sound energy resonates in the oral cavity during the production of nasal sounds. This is due to the fact that the acoustic energy begins by traveling in a superior direction toward the nasal cavity, and continues without significant obstruction, which would redirect the sound energy. In addition, the lowered position of the velum restricts sound energy from entering the oral cavity to a great degree. For normal speech and resonance, velopharyngeal closure should be complete during the production of oral sounds; and for nasal sounds, sound energy should be relatively unimpeded through the pharynx and nasal cavity (Moller & Starr, 1993).

Normal resonance is highly dependent on normal velopharyngeal structures and function. The velopharyngeal structures include the velum, the lateral pharyngeal walls, and the posterior pharyngeal wall. Velopharyngeal closure is accomplished by the coordinated movement of all of these structures.

During normal speech, the velum moves in a superior and posterior direction with a type of "knee" action in order to achieve closure against the posterior pharyngeal wall. The posterior pharyngeal wall often moves anteriorly in order to assist in achieving contact. The lateral pharyngeal walls move medially to close against the velum, or in some cases, to meet in midline behind the velum. Through the coordinated action of these structures, velopharyngeal closure occurs as a valve or sphincter.

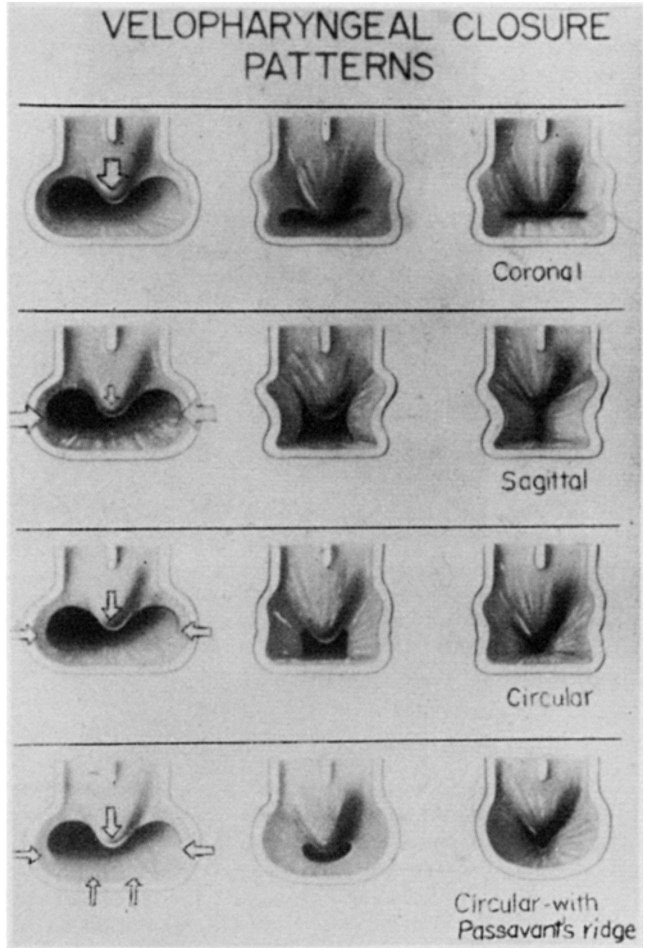
Velopharyngeal closure occurs not only for speech, but also for other pneumatic activities such as sucking, blowing, and whistling. However, the position and degree of closure differ for all these activities. In fact, the point of contact and degree of closure even vary with different phonemes and with different phonetic environments (Flowers & Morris, 1973; McWilliams & Bradley, 1965; Moll, 1962; Shprintzen, McCall, Skolnick, & Lencione, 1975).

Velopharyngeal closure also occurs with nonpneumatic activities such as gagging, swallowing, and vomiting. This type of closure is greatly different from that noted with pneumatic activities in that it is usually very high in the nasopharynx and more exaggerated. Closure may be complete for nonpneumatic activities, but insufficient for speech or other pneumatic activities (Shprintzen et al., 1975).

In addition to variability in movement patterns with different pneumatic and nonpneumatic activities, there is also variability in the closure pattern between individuals. Different basic closure patterns occur among normal speakers due to variances in the relative contribution of the velum, lateral pharyngeal walls, and posterior pharyngeal wall in achieving closure. Siegel-Sadewitz and Shprintzen (1982) presented an artist's interpretation of the four types of velopharyngeal valving patterns, which is helpful in highlighting their differences (see Figure 1).

Witzel and Posnick (1989) reported that in a group of 246 clients, 68% showed a coronal pattern of closure, with most of the activity occurring due to movement of the velum and posterior pharyngeal wall. The lateral pharyngeal walls contribute little to closure in these cases. A circular pattern of closure was noted in 23% of the clients, where all structures contribute equally, so that a "purse-string" or sphincter type pattern is noted. A sagittal pattern was noted in 4% of their clients. This closure pattern is due to the medial movement of the lateral pharyngeal walls, with little contribution of the velum or posterior pharyngeal wall. Finally, 5% of the clients demonstrated a pattern with a Passavant's ridge on the posterior pharyngeal wall. These variations of normal closure are important to recognize, particularly in the evaluation process, because the basic pattern of closure can impact the type of surgical or prosthetic intervention that is planned (Siegel-Sadewitz & Shprintzen, 1982; Skolnick, McCall, & Barnes, 1973).

Figure 1. Normal patterns of velopharyngeal closure.



Reprinted with permission from Siegel-Sadewitz, V. L., & Shprintzen, R. J. (1982). Nasopharyngoscopy of the normal velopharyngeal sphincter: An experiment of biofeedback. *Cleft Palate Journal, 19*(3), 194–200.

RESONANCE DISORDERS

A resonance disorder can occur when the velopharyngeal mechanism does not function adequately to prevent the transmission of sound into the nasal cavity. Resonance can also be abnormal when there is a blockage in the nasopharynx so that sound transmission is impeded during passage into the nasal cavity for nasal phonemes. Anything that disrupts the normal balance of oral and nasal resonance can result in a resonance disorder.

Hypernasality

Hypernasality is a resonance disorder due to velopharyngeal inadequacy (VPI). As a result of an inadequate velopharyngeal valve, sound resonates into the nasal cavity inappropriately, which affects the quality of speech. Hypernasality is particularly perceptible on vowel sounds because these sounds are voiced and relatively long in duration. However, hypernasality can best be judged in connected speech. Hypernasality due to VPI must be distinguished from the "nasal" speech that is associated with some regional dialects. This type of resonance would not be considered abnormal unless it is deviant from others with that dialect.

In addition to the hypernasal resonance, VPI can also cause audible nasal air emission during consonant production. As the client attempts to build up air pressure in the oral cavity for pressure-sensitive sounds (plosives, fricatives, and affricates), air pressure leaks through the valve and is emitted nasally. A nasal rustle, which is also referred to as turbulence, is a very loud and distracting form of nasal emission. It is felt to be the result of a large amount of air being forced through a small velopharyngeal opening, causing a friction sound (Kummer & Neale, 1989; Kummer, Curtis, Wiggs, Lee, & Strife, 1992). Nasal emission can be phoneme-specific and due to faulty articulation rather than VPI. For example, the child may produce pharyngeal fricatives with accompanying nasal air emission as a substitution for sibilant sounds. Changing articulatory placement in this case often results in an elimination of the nasal air emission.

When air pressure is leaked through the velopharyngeal valve, this may also reduce the amount of air pressure that is available for consonant production. As a result, consonants may be weak in pressure and intensity, or may be omitted completely (Baken, 1987; McWilliams, Morris, & Shelton, 1990).

Compensatory articulation productions are often acquired when intra-oral air pressure is inadequate for normal speech. The client learns to articulate using air pressure that is available in the pharynx. Therefore, common compensatory productions include glottal stops, pharyngeal stops, and pharyngeal fricatives. Often, these compensatory articulation productions are co-articulated with the normal articulatory placement. Other compensatory articulation productions have also been described (Trost, 1981).

Velopharyngeal inadequacy may be due to anatomical deficiencies or physiological deficiencies. The term velopharyngeal insufficiency refers to anatomical deficits that would cause the velum to be short relative to the posterior pharyngeal wall. Velopharyngeal incompetence refers to physiological deficiencies, causing poor movement of the velopharyngeal structures. In practice, the term velopharyngeal insufficiency is used most often to refer to all types of valving disorders (Loney & Bloem, 1987; Trost-Cardamone, 1989).

Velopharyngeal insufficiency may be noted in clients with a history of cleft palate, despite the surgical repair. In many cases, a submucous cleft palate can also result in a short palate. Some clients demonstrate congenital palatal insufficiency (CPI) for a variety of reasons, including a deep pharynx or cranial base abnormalities (McWilliams et al., 1990; Peterson-Falzone, 1985). Velopharyngeal insufficiency may occur after an adenoidectomy (Andreassen, Leeper, & MacRae, 1991; Kummer, Myer, Smith, & Shott, 1993; Van Gelder, 1974), especially if closure was achieved against the adenoid pad or was tenuous from the start.

In clients with a history of cleft palate, a Le Fort I maxillary advancement procedure is commonly performed to correct midface deficiency. This procedure can result in velopharyngeal insufficiency because the velum can move anteriorly with the maxilla (Kummer, Strife, Grau, Creaghead, & Lee, 1989; Witzel & Munro, 1977). Finally, large tonsils can intrude into the nasopharynx and thus interfere with velopharyngeal closure (Kummer, Billmire & Myer, 1993).

Velopharyngeal incompetence can occur in clients with submucous cleft palate due to abnormal muscle insertion in the velum. It can also occur despite a cleft palate repair due to poor muscle function. Velopharyngeal incompetence can be noted in clients with oral-motor dysfunction, as in a dysarthria. Characteristics of neurological dysfunction include slowness, weakness, and incoordination of palatal movements (Yorkston, Beukelman, & Bell, 1988). In clients with either congenital or acquired cranial nerve damage, specific velopharyngeal paralysis or paresis (usually unilateral) can occur in the absence of other oral-motor deficits. Regardless of the cause, inadequate velopharyngeal closure will cause hypernasality.

Hyponasality and Denasality

Hyponasality occurs when there is a reduction in nasal resonance due to blockage in the nasopharynx or in the nasal cavity. If the nasal cavity is completely occluded, resonance would be denasal. Hyponasality and denasality affect the quality of vowels, but particularly the production of the nasal consonants (m, n, and ng). When nasal resonance is eliminated for the nasal consonants, these consonants sound similar to their oral phoneme cognates (b, d, and g).

The cause of hyponasality or denasality is always obstruction somewhere in the nasopharynx or nasal cavity. This obstruction may be due to an enlarged adenoid pad, swelling of the nasal passages secondary to allergic rhinitis or the common cold, a deviated septum, choanal atresia, a stenotic naris, midface deficiency, and others. Because the cause of reduced nasal resonance is strictly obstruction, further evaluation and treatment should be performed by a physician.

Cul-de-Sac Resonance

Cul-de-sac resonance occurs when the transmission of acoustic energy is trapped in a blind pouch with only one outlet. The speech is perceived as muffled and has been described as "potato-in-the-mouth" speech (Finkelstein, Bar-Ziv, Nachmani, Berger, & Ophir, 1993). This can occur, for example, in clients with very large tonsils and adenoid pad (Kummer et al., 1993; Shprintzen, Sher, & Croft, 1986). As the sound energy travels superiorly, the sound may be blocked from the nasal cavity by the adenoid pad. The tonsils can also restrict sound transmission into the oral cavity. As a result, the sound energy is blocked and vibration occurs primarily in the pharynx. Resonance can also be perceived as cul-de-sac when there is VPI and anterior blockage of the nasal cavity. This blockage could be due to a deviated septum, nasal polyps, or stenotic nares. This type of resonance disorder requires medical intervention to eliminate the source of blockage.

Mixed Resonance

Some clients demonstrate a combination of hyper- and hyponasality. These two resonance characteristics are not mutually exclusive. Mixed hyper-hyponasality can occur when there is velopharyngeal insufficiency in addition to significant nasal airway blockage. In this case, hypernasality may be the predominate characteristic of connected speech, but hyponasality is noted on the nasal consonants.

This can also occur in clients with oral-motor disorders due to inappropriate timing of the upward or downward movement of the velum for speech (Netsell, 1969).

EVALUATION OF RESONANCE DISORDERS

Perceptual Evaluation

The evaluation of a resonance disorder must begin with a speech pathology evaluation. The perceptual assessment should determine whether resonance is normal or abnormal. Resonance can be said to be abnormal if the quality or intelligibility of speech is affected by inappropriate transmission of acoustic energy in the vocal tract.

The speech evaluation often begins with the single word articulation test. The Iowa Pressure Articulation Test, a part of the Templin-Darley Tests of Articulation (Templin & Darley, 1960), was developed specifically for testing clients with suspected VPI (Morris, Spriestersbach, & Darley, 1961). It is loaded with high pressure consonants, making it sensitive to resonance disorders; however, any articulation test can be used.

The examiner should inventory all articulation errors that are not age-appropriate. Particular attention should be paid to the focus of articulation. Patients with velopharyngeal insufficiency often demonstrate compensatory articulation productions by making use of the air stream in the pharynx before it is lost through the velopharyngeal port. These sounds can be articulated with what appears to be normal placement, but actually is not. For example, the client may appear to be producing a normal /p/ phoneme with bilabial closure, while co-articulating the plosive portion with a glottal stop. It is very important to make a distinction between articulation errors due to faulty placement only versus those associated with velopharyngeal valving problems.

In addition to articulation errors, the examiner should evaluate the adequacy of intra-oral air pressure. If consonants are weak in intensity, it can be assumed that intra-oral air pressure is compromised due to velopharyngeal insufficiency. The examiner should also note the occurrence of audible nasal air emission (including nasal rustle) during the production of pressure-sensitive phonemes. Each occurrence of nasal emission during phoneme production should be noted on the articulation test.

Assessing stimulability is an important component of the evaluation. The client may be stimulable for a reduction or elimination of nasal air emission with a change in articulatory placement. This may be a good prognostic indicator for improvement or correction with therapy. It may also suggest that the client demonstrates "functional" hypernasality or phoneme-specific nasal emission. This may be the result of articulation errors or the faulty learning of movement patterns, rather than a primary velopharyngeal disorder.

An evaluation of resonance in spontaneous connected speech is very important because it cannot be adequately assessed with single words or even short utterances. Overall resonance can be rated on a simple scale as either denasal, hyponasal, normal, or hypernasal to a mild, moderate, or severe degree. The clinician should be sure to make a judgement as to whether there is any evidence of cul-de-sac nasality or mixed resonance.

Connected speech increases the demands on the velopharyngeal valving system to achieve and maintain closure. The examiner may note an increase in hypernasality and nasal emission in connected speech when compared to single words. An increase in articulation errors is also common during the production of continuous utterances.

Although perceptual assessment of resonance is critically important, it is understandably difficult for the untrained ear. The use of training tapes for judgments of speech characteristics (Subtelny, Orlando, & Whitehead, 1981) or collaboration with more experienced professionals may help to establish intra- and interjudge agreement. Supplemental tests (to be discussed later) may also be helpful. Finally, these perceptual judgements may be used in combination with more direct measures of VPI using instrumentation.

In addition to resonance, phonation should always be assessed. Breathiness or hoarseness may indicate the presence of vocal nodules that are commonly found in clients with mild velopharyngeal insufficiency. In an attempt to compensate for the effects of VPI, these children may demonstrate laryngeal hyperfunction. In addition, compensatory valving activities and the use of glottal stops may also contribute to the development of nodules (McWilliams, Bluestone, & Musgrave, 1969; McWilliams, Lavorato, & Bluestone, 1973).

At this point in the evaluation, the clinician may have an impression of the resonance characteristics of speech. However, supplemental tests are often needed in order to more clearly identify the degree of hypernasality and the occurrence of nasal emission.

The following informal speech tests may be helpful in that they are sensitive to velopharyngeal valving problems:

1. Have the child produce pressure-sensitive phonemes (plosives, fricatives, affricates) in a repetitive manner (pa, pa, pa, pa, etc.).
2. Have the child repeat sentences that are loaded with pressure-sensitive phonemes. It can be particularly helpful if these sentences contain similar phonemes in terms of articulatory placement. Sample sentences might include:
   A. Popeye plays baseball.
   B. Take Teddy to town.
   C. Give Kate the cake.
   D. Fred has five fish.
   E. Sissy sees the sun in the sky.
   F. I eat cherries and cheese.
   G. John told a joke to Jim.
3. Have the child count from 1 to 20 and then 60 to 70. The sixties can be particularly diagnostic because these numbers contain a combination of sibilants, velar plosives, and alveolar plosives. These sounds require a buildup and continuation of intra-oral air pressure that can particularly tax the velopharyngeal mechanism.

Using these informal tests, the examiner should listen for nasal air emission, including nasal rustle (turbulence). It is particularly important to note whether nasal air emission occurs on specific phonemes, or whether it occurs on all pressure-sensitive sounds. The examiner should feel the sides of the nares as the child repeats the pressure-sensitive sounds. (It is important to eliminate nasal phonemes from the speech sample for obvious reasons.) If vibration is felt, this could indicate nasal emission or hypernasality.

In addition to listening and feeling for nasal emission, the examiner can actually see nasal emission by using an "air paddle" (Bzoch, 1989). An air paddle can be cut from a piece of paper and placed underneath the nares during speech. If the paddle moves during the production of pressure-sensitive sounds, this indicates that there is nasal air emission. The use of a cold mirror held under the nares during speech has been used in the past to evaluate nasal emission based on condensation. However, this is not a very practical technique because it is hard to have a cold mirror available, and the mirror fogs as soon as the client breathes.

Another informal test that is helpful in evaluating resonance is to have the child produce a vowel or repeat a sentence that is completely devoid of nasal consonants. The child should then repeat the same utterances with the nares occluded. In normal speech, there should be no perceptible difference in the quality of the production because the nasal cavity is already closed by the velopharyngeal mechanism. If there is a difference in quality with closure of the nasal cavity at the nares, this suggests that resonance is hypernasal because there is sound resonating in the nasal cavity. If resonance is perceived as abnormal, but closure of the nares results in no change in quality, this can suggest either cul-de-sac resonance or hyponasality.

To rule out hyponasality or denasality, the examiner can have the child produce nasal sounds repetitively or sentences loaded with nasal consonants. If the nasal phonemes are distorted or sound closer to their oral cognates, hypo- or denasality due to upper airway obstruction is suggested. (Mouth breathing is also indicative of airway obstruction.)

Instrumental Assessment

Some hospitals and clinics, particularly those associated with a craniofacial center, have the advantage of a variety of instruments to assess resonance, air flow, and air pressure. Aerodynamic data can be obtained through instrumentation and is used to estimate velopharyngeal orifice size and the relationship between nasal air flow and the ability to generate oral air pressure (Smith & Weinberg, 1980; Warren, 1979; Warren, 1988; Warren & DuBois, 1964).

One instrument that is commonly used in the clinical setting is the nasometer (Kay Elemetrics, Pine Brook, NJ). The nasometer is a computer-based instrument that is designed to be used with either an IBM-compatible or Apple personal computer (see Figure 2). The nasometer consists of a headset that has directional microphones for the nose and mouth. These microphones are separated by a baffle that rests against the upper lip. The microphones

Figure 2. Use of the nasometer in the evaluation of resonance.

pick up acoustic energy from the nasal and oral cavities. The nasometer then computes the ratio of nasal acoustic energy to total (nasal plus oral) acoustic energy and displays this in real time. In this way, an average "nasalance" score can be computed for a given speech segment. When one of the standardized passages is used, the nasalance score can be compared to normative data.

This instrument can be very useful in a clinical examination because it provides objective information regarding resonance and nasality (Dalston, Warren, & Dalston, 1991b). However, the examiner must interpret the scores based on knowledge regarding resonance and articulation. A combination of hyponasality and nasal emission can affect the nasalance score to a significant degree (Dalston, Warren, & Dalston, 1991a).

Intra-Oral Examination

An intra-oral examination should always be done as part of the resonance evaluation. The examiner should be aware, however, that an intra-oral view is not adequate for a judgement regarding velopharyngeal function. Closure occurs behind the velum and is above the level of the oral cavity, usually on the plane of the hard palate. In addition, the examiner cannot see the point of maximum lateral pharyngeal wall movement from an intra-oral perspective.

In an intra-oral examination, the clinician can determine palatal and velar integrity. The presence and location of a palatal fistula should always be noted because a large fistula (especially one in a posterior position) can cause hypernasality and nasal emission. The examiner should judge the relative length of the velum because a very short velum may suggest velopharyngeal insufficiency. Velar mobility during phonation should be observed. The velum should raise and the velar "dimple" should be back approximately 80% of the length of the soft palate (Mason & Simon, 1977). Poor velar mobility or asymmetrical movement may suggest VPI. Dental occlusion should be assessed, especially in clients with a history of cleft palate, because a crossbite or malocclusion often affect articulation.

If there is no history of cleft palate, the examiner should look for signs of a submucous cleft. These signs may include a bifid or hypoplastic uvula; a bluish, transparent appearing velum; or a V-shape in the hard palate. In palpating the posterior nasal spine, the examiner may feel a notch in the bony structure, which would suggest a submucous cleft. During phonation, the velum often appears to "tent up" in an inverted V-shape when there is a submucous cleft that extends through the velum.

FOLLOW-UP

Once the speech pathology evaluation is completed, the examiner must make a decision as to whether to recommend speech therapy or to refer for further evaluation. If the child demonstrates a moderate degree of hypernasality or nasal emission, or if these characteristics are mild but very consistent, speech therapy alone may not be appropriate. Instead, direct evaluation of velopharyngeal function should be done through either videofluoroscopy, nasopharyngoscopy, or both.

Videoflouroscopic Speech Study

A videofluoroscopic speech study is a radiographic evaluation that allows the direct visualization of all aspects of the velopharyngeal sphincter during speech (Skolnick, 1970). In order to determine the optimal surgical or prosthetic treatment for the client, it is important to assess both the anatomic and physiologic abnormalities causing velopharyngeal insufficiency. During the speech study, the client is asked to repeat standard sentences so that the velopharyngeal structures can be observed during connected speech. Because multiple views are used, the examiner can evaluate the motion of the velum and posterior pharyngeal wall, and then assess the movement of the lateral pharyngeal walls.

Using multiview videofluoroscopy, the examiner can confirm the presence of the velopharyngeal opening and determine the size and relative shape of that opening. The cause of VPI can also be differentiated between a short velum, poor velar movement, and/or poor lateral pharyngeal wall motion. For an excellent overview of the videofluoroscopy technique for speech studies, please refer to the book by Skolnick & Cohn (1989).

Nasopharyngoscopy (Endoscopy)

Nasopharyngoscopy is an endoscopic technique that can be a useful tool in evaluating velopharyngeal function (D'Antonio, Muntz, Marsh, Marty-Grames, & Backensto-Marsh, 1988; Watterson & McFarlane, 1990). This technique allows direct observation of the velopharyngeal portal during speech. This procedure can be performed by a physician or a well-trained speech-language pathologist.

The nasopharyngoscopy procedure requires the introduction of a topical anesthetic, such as xylocaine, into the nasal cavity. Once numbing has occurred, the nasopharyngoscope is passed through the middle meatus and back to the area of velopharyngeal closure. Through this procedure, the examiner can view the nasal aspect of the velum, the posterior pharyngeal wall, and the lateral pharyngeal walls. The adenoid pad can be easily seen through this technique. So that the velopharyngeal function can be directly observed, the client is asked to repeat sentences. The entire procedure is usually videotaped to allow for an in-depth analysis at a later time.

TREATMENT OF RESONANCE DISORDERS

When the abnormal resonance is caused by a blockage somewhere in the resonating chambers, as in denasality, hyponasality, and cul-de-sac nasality, medical intervention is required. This could simply involve antihistamine/decongestant therapy. However, surgical intervention may be indicated, such as removing the adenoid pad or tonsils, or straightening a deviated septum. Speech therapy is rarely required for these types of disorders.

The treatment of hypernasality secondary to velopharyngeal insufficiency may include surgical intervention, a prosthetic device, or speech therapy. It should be noted that changing velopharyngeal structure with surgery or a prosthesis does not change function. Therefore, speech therapy is indicated in most cases.

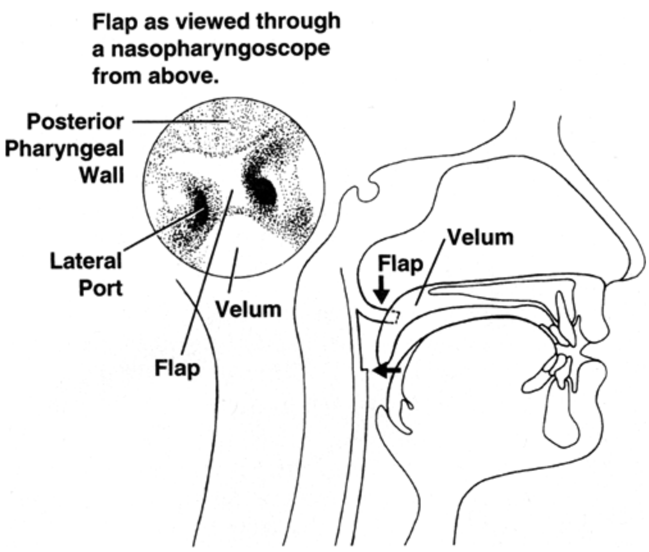
Surgical Intervention for Velopharyngeal Insufficiency

Surgical intervention is indicated whenever the hypernasality is caused by a structural or physiological abnormality that renders the client unable to achieve normal velopharyngeal closure. If the client was born with a cleft of the palate, obviously this needs to be repaired before normal velopharyngeal function can be expected. Most surgeons repair the palate around the age of 12 months (Cooper, Harding, Krogman, Mazaheri, & Millard, 1979; Grabb, Rosenstein, & Bzoch, 1971). If the client was born with a submucous cleft palate and has characteristics of VPI, the speech pathologist and surgeon may opt to try a primary palate repair first before considering secondary surgical procedures designed to correct VPI.

An oronasal fistula is an opening in the hard palate or velum that occurs occasionally after palate repair. A fistula can occur during attempts to normalize occlusion through maxillary expansion in clients with a history of cleft palate. If the fistula causes hypernasality or nasal emission, surgical repair is indicated. The examiner should carefully evaluate whether the hypernasality is due to the fistula or VPI so that the appropriate surgical intervention is recommended. An easy way to assess this is to occlude the fistula with chewing gum, and then evaluate whether there is a change in resonance and nasal emission.

If the hypernasality is due to VPI, surgical intervention is often in the form of a superiorly based pharyngeal flap (see Figure 3). This procedure involves the creation of a

Figure 3. A superiorly based pharyngeal flap.



soft tissue flap from the posterior pharyngeal wall, which is then sutured into the velum. This results in partial occlusion of the velopharyngeal space. Lateral ports on either side of the flap remain open for normal nasal breathing but, during speech, the lateral walls move in to close around the flap (Cooper et al., 1979; Grabb et al., 1971; McWilliams et al., 1990).

Other surgical options for correction of VPI include a sphincteroplasty. This surgery attempts to create a dynamic sphincter in the pharynx by repositioning the palatopharyngeus muscles (Jackson & Silverton, 1977; Orticochea, 1968; Riski, Serafin, Riefkohl, & Georgiade, 1984). In cases of very mild VPI, an option may be a form of pharyngeal augmentation, such as a teflon injection (Smith & McCabe, 1977; Sturim & Jacob, 1972).

Prosthetic Management

When surgery for the correction of VPI is not an option because of medical or psychological reasons, prosthetic management should be considered (Posnick, 1977) A palatal obturator can be used to cover an open defect such as an unrepaired cleft or a fistula. In cases where the velum is long enough to achieve closure, but does not move well, a palatal lift can be used. This is particularly effective for dysarthric clients, when hypernasality is a primary contributor to intelligibility deficits and articulation, phonation, and respiration are not severely compromised (see Dworkin & Johns, 1980; Johns, 1990; Riski & Gordon, 1979; Schweiger, Netsell, & Sommerfield, 1970; or Yorkston et al., 1988 for further guidelines). Finally, when the velum is too short to close completely against the posterior pharyngeal wall, a speech bulb obturator can be considered. The bulb serves to fill in the pharyngeal space for speech.

Although a prosthesis is appropriate for some clients, it has some distinct disadvantages. Unlike surgery, a prosthesis is not a permanent correction. It usually needs to be removed at night and during eating. It can cause ulceration of the mucosa, making it uncomfortable to wear. As a result, compliance can be a problem. Finally, in young children, the prosthesis needs to be remade periodically to accompany normal growth.

Speech Therapy

Compensatory articulation productions can be successfully eliminated through articulation therapy. Hypernasality, nasal air emission, and weak consonants usually require surgical correction of VPI before therapy can be successful. Therapy can be effective in improving or correcting these characteristics *only* under the following conditions:

- The characteristic is mild.
- The characteristic is inconsistent.
- The child is stimulable for a reduction or elimination of the characteristic.
- The characteristic is due to faulty articulation (i.e. nasal air emission with pharyngeal fricatives, or nasality due to an associated /ng/ tongue position with an anterior phoneme, such as /l/).
- The characteristic is associated with oral-motor dysfunction or dysarthria.
- The characteristic occurs primarily when the child is tired.
- The velopharyngeal opening is slight or inconsistent, as demonstrated by videofluoroscopy or nasopharyngoscopy.
- A pharyngeal flap, sphincteroplasty, or pharyngeal augmentation has been done and the client needs therapy to increase lateral pharyngeal wall motion or to improve the function of the revised structures.

If the child demonstrates a moderate degree of hypernasality or nasal emission, or if these characteristics are consistent, speech therapy is not appropriate. Instead, further evaluation of velopharyngeal function should be done through videofluoroscopy or nasopharyngoscopy. Following those assessments, surgical intervention should be considered. Once the VPI is corrected surgically, speech therapy may be appropriate to correct the function of the mechanism (Trost-Cardamone & Bernthal, 1993).

Whenever possible, therapy should incorporate the use of visual or auditory biofeedback. This can greatly facilitate progress (Moller & Starr, 1993). The nasometer is an excellent tool for providing visual feedback regarding oral-nasal resonance and nasal emission. Therefore, it can be very useful in the treatment process (see Nasometer Manual, Kay Elemetrics, Pine Brook, NJ).

In addition to the use of the nasometer, there are other therapy techniques that can be effective in treating the various characteristics of velopharyngeal insufficiency. Kuehn (1991) reported case studies where continuous positive airway pressure (CPAP) was used as a treatment for velopharyngeal insufficiency. The CPAP instrument delivers a continuous flow of air into the nasal airway via a mask and hose that is connected to a flow generator. In therapy, the client attempts to block the flow of air through resistance of the velopharyngeal muscles during speech tasks. In Kuehn's study, subjective measures of nasal resonance indicated improvement for three out of four subjects, suggesting that velopharyngeal musculature was strengthened and function was improved.

If speech therapy is indicated, the following techniques are offered for use with a child; however, they can be equally effective with adults. In the absence of efficacy studies, these techniques are offered as clinical suggestions that could be tried with this population.

1. Hypernasality

Although therapy for hypernasality has been done for years, it tends to be ineffective because the cause of hypernasality is usually a velopharyngeal opening (McWilliams et al., 1990). Therefore, surgical intervention is typically required. However, there are some techniques that can encourage oral resonance. These could be tried if there is a doubt regarding the need for surgery, particularly if there is an oral-motor component to the hypernasality. These techniques are most appropriate for clients with hypernasality due to dysarthria.

Therapy Suggestions

- **Discrimination training:** Have the child listen to hypernasal speech and to normal oral speech as both are simulated by the clinician or presented through samples on a tape recorder.
- **Nasal/oral contrasts:** Have the child try to raise and lower the velum during the production of [a] to produce nasal/oral contrasts, as in [ng-a, ng-a]. This will also increase velar sensation and control.
- **Simulate denasality:** Have the child pretend to be "stopped up" with a severe cold and speak accordingly. Gradually eliminate the denasality to a more oral resonance.
- **Increase oral activity and volume:** Increasing oral activity can increase oral resonance, because increasing anterior oral activity increases posterior oral (velar) movement and alters the path of least resistance for the air flow. Increasing volume tends to increase oral activity, as can changing the rate of speech. A wider mouth opening can further promote oral resonance. The ultimate goal, however, is a normal degree of oral activity, rate, and volume.
- **Tactile feedback:** Have the child lightly touch the side of the nose to feel for vibration during the production of repetitive nasal phonemes, such as "mamama." Compare this with the production of oral sounds (plosives, fricatives, or affricates with vowels), such as "papapa." If vibration is still felt, have the child try to eliminate this vibration as various vowels and voiced consonants in syllables are attempted.
- **Tongue blade manipulation:** Raise the velum mechanically with a tongue blade as the child is producing vowel sounds. Then have the child attempt to raise the velum without assistance to match that sound.
- **Yawn technique:** Have the child yawn in order to forcibly lower the back of the tongue and raise the velum. Then use this movement with the production of vowel sounds and anterior consonants, keeping that same movement in mind.

2. Nasal Air Emission/Nasal Rustle (Turbulence)

Nasal air emission responds to therapy if it is inconsistent or phoneme-specific. A nasal rustle (turbulence) often responds well to therapy because it is often caused by a small velopharyngeal gap.

Therapy Suggestions

- **Auditory feedback:** Make the child aware of the nasal emission or rustle by simulating this characteristic or by having the child listen to and identify samples of nasal emission on a tape recorder.
- **Tactile feedback:** Have the child feel the sides of the nose for vibration during the repetitive production of pressure-sensitive phonemes or during the production of sentences with these sounds (no nasals). Ask the child to carefully produce these sounds or sentences without the vibration.
- **Visual feedback:** The See-Scape (Speech Bin: Vero Beach, FL) is a simple instrument for detecting nasal air emission during speech. It provides immediate visual feedback by causing a float to rise in a plastic tube when emission occurs. If instrumental biofeedback is not available, place a piece of paper (preferably in the shape of a paddle) under the nares during the production of repetitive pressure-sensitive phonemes or sentences. This helps the child see the nasal emission as the paddle moves. Ask the child to produce the same utterances without moving the air paddle.
- **Cul-de-sac technique:** Have the child pinch the nostrils during the production of pressure sounds to eliminate the nasal emission. Next, try to produce the sounds in the same way with the nostrils open.
- **Light, quick contacts:** Ask the child to produce light, quick contacts during the production of pressure-sensitive phonemes. This helps to eliminate the backup of air pressure in the nasopharynx and can reduce the occurrence of nasal emission.

3. Weak Consonants

When intra-oral breath pressure is inadequate due to a leak in pressure, consonants can be weak in intensity or even omitted.

Therapy Suggestions

- **Visual feedback:** Place a paper paddle in front of the child's mouth during the production of pressure-sensitive phonemes. Have the child try to produce the sounds with enough pressure to force the air paddle to move.
- **Tactile feedback:** Place the child's hand in front of the clinician's mouth as plosives are produced in a forceful manner. Point out the air pressure as each sound is produced. Repeat the process in front of the child's mouth.

- **Increase volume and oral activity:** Have the child increase volume and oral activity to increase the force of articulation and to increase velar movement.

4. **Compensatory Articulation Productions**

If the child is unable to build up air pressure in the oral cavity to produce sounds normally, he or she may learn to produce sounds in an alternate way by using the air pressure in the pharynx. A common compensatory articulation production, often substituted for plosives, is the glottal stop. This sound is produced at the level of the glottis and may be co-articulated with appropriate oral placement. Another common compensatory production is the pharyngeal plosive, which is produced with the base of the tongue articulating against the posterior pharyngeal wall. Sibilant phonemes are often substituted by a pharyngeal fricative, which is produced by retracting the back of the tongue to cause a friction sound between the tongue and the pharynx.

Therapy Suggestions

- **Glottal stops as a substitution for plosives:** Produce voiced and voiceless plosives slowly with an aspirate /h/, or whisper to eliminate the glottal stop. Modify voice onset time by delaying the voicing on the voiced plosive or delaying voicing on the vowel that follows a voiceless plosive.
- **Pharyngeal plosives as a substitution for plosives:** Work on the placement of bilabial and lingual-alveolar plosives first. Once these are mastered, work on velar plosives. Establish placement for velar plosives by starting with an /ng/. Then have the child use more force with the back of the tongue to produce the plosive.
- **Pharyngeal fricatives as a substitution for sibilant sounds:** Have the child produce sibilant sounds with the nares occluded and then open to get the feel for oral rather than pharyngeal air flow. Work on /s/ by having the child produce a hard /t/ with the teeth closed. Increase the duration of the production until it becomes /ts/. Finally, eliminate the /t/ component. Work on the /sh/ sound by having the child do a big sigh with the teeth closed. Try to increase the force of oral air pressure and then shape the lip position. Work on the /ch/ sound by going from a /t/ with the teeth closed or trying a loud sneeze sound with the teeth closed. Once this is mastered, add the voiced component for the /j/ sound.
- **For a nasal /l/ or ng/l substitution:** Ask the child to produce a yawn to get the base of the tongue down and the velum up. With the yawn, have the tongue tip go up to produce the /l/. Gradually extinguish the use of the yawn.

CONCLUSION

Speech therapy is often recommended when a client has disordered resonance. However, it is important to remember that speech therapy cannot change structure; surgical intervention is needed to correct VPI. On the other hand, surgery cannot change function. Therefore, the child may need to be taught appropriate articulatory placement and oral air flow after surgical intervention.

In all cases, therapy should continue as long as the child is making progress. If the child continues to have characteristics of VPI after a few months of therapy, the child should be referred for further evaluation of velopharyngeal function and for consideration of surgical intervention or revision.

Ideally, referral should be made to a craniofacial anomaly team for evaluation and treatment recommendations. This ensures that the client will receive appropriate services by professionals who are knowledgeable and experienced in dealing with a variety of resonance disorders. If there is no team in the area, the Cleft Palate Foundation of the American Cleft Palate-Craniofacial Association (1218 Grandview Avenue, Pittsburgh, PA 15211) can assist in finding appropriate professionals to provide service. The Foundation also has literature and other resources for parents and professionals.

REFERENCES

Andreassen, M. L., Leeper, H. A., & MacRae, D. L. (1991). Changes in vocal resonance and nasalization following adenoidectomy in normal children: Preliminary findings. *Journal of Otolaryngology, 20,* 237–242.

Baken, R. J. (1987). *Clinical measurement of speech and voice.* Boston, MA: College-Hill Press.

Bzoch, K. R. (1989). *Communicative disorders related to cleft lip and palate* (3rd ed.). Boston, MA: College-Hill Press.

Cooper, H. K., Harding, R. L., Krogman, W. M., Mazaheri, M., & Millard, R. T. (Eds.). (1979). *Cleft palate and cleft lip: A team approach to clinical management and rehabilitation of the patient.* Philadelphia, PA: W.B. Saunders.

Dalston, R. M., Warren, D. W., & Dalston, E. T. (1991a). A preliminary investigation concerning the use of nasometry in identifying patients with hyponasality and/or nasal airway impairment. *Journal of Speech and Hearing Research, 34,* 11–18.

Dalston, R. M., Warren, D. W., & Dalston, E. T. (1991b). Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. *Cleft Palate-Craniofacial Journal, 28,* 184–189.

D'Antonio, L. L., Muntz, H. R., Marsh, J. L., Marty-Grames, L., & Backensto-Marsh, R. (1988). Practical application of flexible fiberoptic nasopharyngoscopy for evaluating velopharyngeal function. *Plastic and Reconstructive Surgery, 82,* 611–618.

Dworkin, J. P., & Johns, D. F. (1980). Management of velopharyngeal incompetence in dysarthria: A historical review. *Clinical Otolaryngology, 5,* 61–74.

Finkelstein, Y., Bar-Ziv, J., Nachmani, A., Berger, G., & Ophir, D. (1993). Peritonsillar abscess as a cause of transient velopharyngeal insufficiency. *Cleft Palate-Craniofacial Journal, 30,* 421–428.

Flowers, C. R., & Morris, H. L. (1973). Oral-pharyngeal movements during swallowing and speech. *Cleft Palate Journal, 10,* 180–190.

Grabb, W. C., Rosenstein, S. W., & Bzoch, K. (1971). *Cleft lip and palate.* Boston, MA: Little, Brown & Co.

Jackson, I. T., & Silverton, J. S. (1977). The sphincter pharyngoplasty as a secondary procedure in cleft palates. *Plastic and Reconstructive Surgery, 59,* 518–524.

Johns, D. F. (Ed.). (1990). *Clinical management of neurogenic communicative disorders.* Boston, MA: Little, Brown & Co.

Kuehn, D. P. (1991). New therapy for treating hypernasal speech using continuous positive airway pressure (CPAP). *Plastic and Reconstructive Surgery, 88,* 959–966.

Kummer, A. W., Billmire, D. A., & Myer, C. M. (1993). Hypertrophic tonsils: The effect on resonance and velopharyngeal closure. *Plastic and Reconstructive Surgery, 91,* 608–611.

Kummer, A. W., Curtis, C., Wiggs, M., Lee, L., & Strife, J. L. (1992). Comparison of velopharyngeal gap size in patients with hypernasality, hypernasality and nasal emission, or nasal turbulence (rustle) as the primary speech characteristic. *Cleft Palate-Craniofacial Journal, 29,* 152–156.

Kummer, A. W., Myer, C. M., Smith, M. E., & Shott, S. R. (1993). Changes in nasal resonance secondary to adenotonsillectomy. *American Journal of Otolaryngology, 14,* 285–290.

Kummer, A. W., & Neale, H. W. (1989). Changes in articulation and resonance after tongue flap closure of palatal fistulas: Case reports. *Cleft Palate Journal, 26,* 51–55.

Kummer, A. W., Strife, J. L., Grau, W. H., Creaghead, N. A., & Lee, L. (1989). The effects of Le Fort I osteotomy with maxillary movement on articulation, resonance, and velopharyngeal function. *Cleft Palate Journal, 26,* 193–199.

Loney, R. W., & Bloem, T. J. (1987). Velopharyngeal dysfunction: Recommendations for use of nomenclature. *Cleft Palate Journal, 24,* 334–335.

Mason, R. M., & Simon, C. (1977). Orofacial examination checklist. *Language, Speech and Hearing Services in Schools, 8,* 161–163.

McWilliams, B. J., Bluestone, C. D., & Musgrave, R. H. (1969). Diagnostic implications of vocal cord nodules in children with cleft palate. *Laryngoscope, 79,* 2072–2080.

McWilliams, B. J., & Bradley, D. P. (1965). Ratings of velopharyngeal closure during blowing and speech. *Cleft Palate Journal, 2,* 46–55.

McWilliams, B. J., Lavorato, A. S., & Bluestone, C. D. (1973). Vocal cord abnormalities in children with velopharyngeal valving problems. *Laryngoscope, 83,* 1745–1753.

McWilliams, B. J., Morris, H. L., & Shelton, R. L. (1990). *Cleft palate speech.* Philadelphia, PA: B.C. Decker.

Moll, K. L. (1962). Velopharyngeal closure on vowels. *Journal of Speech and Hearing Research, 5,* 30–37.

Moller, K. T., & Starr, C. D. (Eds.). (1993). *Cleft palate: Interdisciplinary issues and treatment.* Austin, TX: Pro-Ed.

Morris, H. L., Spriestersbach, D. C., & Darley, F. L. (1961). An articulation test for assessing competency of velopharyngeal closure. *Journal of Speech and Hearing Research, 4,* 48–55.

Netsell, R. (1969). Evaluation of velopharyngeal function in dysarthria. *Journal of Speech and Hearing Disorders, 34,* 113–122.

Orticochea, M. (1968). Construction of a dynamic muscle sphincter in cleft palates. *Plastic and Reconstructive Surgery, 41,* 323–327.

Peterson-Falzone, S. J. (1985). Velopharyngeal inadequacy in the absence of overt cleft palate. *Journal of Craniofacial Genetics and Developmental Biology, (Suppl. 1),* 97–124.

Posnick, W. R. (1977). Prosthetic management of palatopharyngeal incompetency for the pediatric patient. *Journal of Dentistry for Children, 44,* 117–121.

Riski, J. E., & Gordon, D. (1979). Prosthetic management of neurogenic velopharyngeal incompetency. *North Carolina Dental Journal, 62,* 24–26.

Riski, J. E., Serafin, D., Riefkohl, R., & Georgiade, G. S. (1984). A rationale for modifying the site of insertion of the Orticochea pharyngoplasty. *Plastic and Reconstructive Surgery, 73,* 882–894.

Schweiger, J., Netsell, R., & Sommerfield, R. (1970). Prosthetic management and speech improvements in individuals with dysarthria of the palate. *Journal of the American Dental Association, 80,* 1348–1353.

Shprintzen, R. J., McCall, G. N., Skolnick, M. L., & Lencione, R. M. (1975). Selective movement of the lateral aspects of the pharyngeal walls during velopharyngeal closure for speech, blowing, and whistling in normals. *Cleft Palate Journal, 12,* 51–58.

Shprintzen, R. J., Sher, A. E., & Croft, C. B. (1986). Hypernasal speech caused by tonsillar hypertrophy. *International Journal of Pediatric Otorhinolaryngology, 14,* 45–56.

Siegel-Sadewitz, V. L., & Shprintzen, R. J. (1982). Nasopharyngoscopy of the normal velopharyngeal sphincter: An experiment of biofeedback. *Cleft Palate Journal, 19,* 194–200.

Skolnick, M. L. (1970). Videofluoroscopic examination of the velopharyngeal portal during phonation in lateral and base projections—A new technique for studying the mechanics of closure. *Cleft Palate Journal, 7,* 803–816.

Skolnick, M. L., & Cohn, E. R. (1989). *Videofluoroscopic studies of speech in patients with cleft palate.* New York: Springer-Vergal.

Skolnick, M. L., McCall, G. N., & Barnes, M. (1973). The sphincteric mechanism of velopharyngeal closure. *Cleft Palate Journal, 10,* 286–305.

Smith, B., & Weinberg, B. (1980). Prediction of velopharyngeal orifice area: A re-examination of model experimentation. *Cleft Palate Journal, 17,* 277–282.

Smith, J. K., & McCabe, B. F. (1977). Teflon injection in the nasopharynx to improve velopharyngeal closure. *Annals of Otology, Rhinology, and Laryngology, 86,* 559–563.

Sturim, H. S., & Jacob, C. T. (1972). Use of teflon in hypernasal speech. *Rhode Island Medical Journal, 55,* 317–320.

Subtelny, J. D., Orlando, N. A., & Whitehead, R. L. (1981). *Speech and voice characteristics of the deaf.* Washington, DC: Alexander Graham Bell Association for the Deaf.

Templin, M. C., & Darley, F. L. (1960). *The Templin-Darley Tests of Articulation.* Iowa City: Bureau of Educational Research and Service, University of Iowa.

Trost, J. E. (1981). Articulatory additions to the classical descriptions of the speech of person with cleft palate. *Cleft Palate Journal, 18,* 193–203.

Trost-Cardamone, J. E. (1989). Coming to terms with VPI: A response to Loney and Bloem. *Cleft Palate Journal, 26,* 68–70.

Trost-Cardamone, J. E., & Bernthal, J. E. (1993). Articulation assessment procedures and treatment decisions. In K.T. Moller, & C.D. Starr (Eds.), *Cleft palate: Inter-disciplinary issues and treatment* (pp. 307–336). Austin, TX: Pro-Ed.

Van Gelder, L. (1974). Open nasal speech following adenoidectomy and tonsillectomy. *Journal of Communication Disorders, 7,* 263–267.

Warren, D. W. (1979). Perci: A method for rating palatal efficiency. *Cleft Palate Journal, 16,* 279–285.

Warren, D. W. (1988). Aerodynamics of speech. In N.J. Lass, L.V. McReynolds, J.L. Northern, & D.E. Yoder (Eds.), *Handbook of speech-language pathology and audiology* (pp. 191–214). Philadelphia, PA: B.C. Decker.

Warren, D. W., & DuBois, A. (1964). A pressure-flow technique for measuring velopharyngeal orifice area during continuous speech. *Cleft Palate Journal, 1,* 52–71.

Watterson, T. L., & McFarlane, S. C. (1990). Transnasal videoendoscopy of the velopharyngeal port mechanism. *Seminars in Speech and Language, 11,* 27–37.

Witzel, M. A., & Munro, I. R. (1977). Velopharyngeal insufficiency after maxillary advancement. *Cleft Palate Journal, 14,* 176–180.

Witzel, M. A., & Posnick, J. C. (1989). Patterns and location of velopharyngeal valving problems: Atypical findings of video nasopharyngoscopy. *Cleft Palate Journal, 26,* 63–67.

Yorkston, K. M., Beukelman, D. R., & Bell, K. R. (1988). *Clinical management of dysarthric speakers.* Boston, MA: College Hill Press.

Received January 3, 1994
Accepted August 25, 1994

Contact author: Ann W. Kummer, PhD, Director, Speech Pathology Department, Children's Hospital Medical Center, 3333 Burnet Avenue, Cincinnati, OH 45229-3039.