Resonance Disorders and Velopharyngeal Dysfunction: Evaluation and Treatment

Ann W. Kummer, PhD, CCC-SLP
Cincinnati Children’s Hospital Medical Center
Resonance Disorders and Velopharyngeal Dysfunction

- Normal resonance
- Normal velopharyngeal function
- Velopharyngeal dysfunction (VPD)
  - Velopharyngeal insufficiency (VPI)
  - Velopharyngeal incompetence (VPI)
- Abnormal resonance
- Effects of cleft palate and VPI on speech/resonance
- Velopharyngeal mislearning
Evaluation and Treatment

- Evaluation
  - Perceptual evaluation
  - Intra-oral evaluation

- Treatment
  - Surgical procedures
  - Prosthetic devices
  - Speech therapy

- Referrals
What is resonance for speech?

• Modification of the sound that is generated from the vocal cords
• Provides the *quality* of perceived sound during speech
What determines resonance for speech?

- Size and shape of the resonating cavities
  - pharyngeal cavity
  - oral cavity
  - nasal cavity
- Function of the velopharyngeal valve
Size and Shape of Cavities

Resonance is affected by the following:

- Length and volume of pharynx
- Size and shape of oral cavity
- Configuration of nasal cavity
Science Experiment
Science Experiment
Size and Shape of Cavities

- Shorter/smaller cavities: enhance higher formants
- Longer/larger cavities: enhance lower formants
Size and Shape of Cavities

• Differences between
  - children and adults
  - men and women
  - tall people and short people

• Makes voice quality unique to individual
Resonance and Vowels

- Vowels are resonance sounds
- They are produced by changing the size and shape of the oral (resonating) cavity
NORMAL VELOPHARYNGEAL FUNCTION
Structures Active in VP Closure

- Velum (Soft Palate)
- Lateral Pharyngeal Walls (LPWs)
- Posterior Pharyngeal Wall (PPW)
Velum: Rest
Velum (Soft Palate)

- Moves in a superior and posterior direction
- Has a type of “knee” action
- Moves toward the posterior pharyngeal wall
Velum: During Speech
Physics and Flow

- Water (and air) flow in a forward direction until something stops it.
- An obstructing object will redirect the flow.
Velopharyngeal Valve and Flow

- Due to the physics of airflow, even a small opening will be symptomatic for speech.
Lateral Pharyngeal Walls (LPWs)

- Move medially to close against the velum or in some cases, behind the velum
Posterior Pharyngeal Wall (PPW)

- Moves anteriorly toward the velum
- In some speakers, there’s a bulge called a Passavant’s ridge
Passavant’s Ridge
VP Valve during Speech

• Velopharyngeal valve is closed for oral sounds
  – Most consonants (air pressure sounds)
  – All vowels (resonance sounds)
• Velopharyngeal valve is open for nasal sounds (m, n, ng)
Purpose of VP Valve

- Directs transmission of sound energy and air flow in the oral and nasal cavities during speech
Video: Normal VP Closure (Videofluoroscopy)
Normal VP Closure
(Nasopharyngoscopy)
Video: Normal VP Closure
(Nasopharyngoscopy)
Variations in VP Closure

• Non-Pneumatic:
  – gagging, vomiting, swallowing

• Pneumatic:
  – blowing, whistling, speech (+ pressure)
  – sucking, kissing (- pressure)
Normal Velopharyngeal Function

Learning (Articulation)

Anatomy (Structure)       Physiology (Movement)
 ➢ VELOPHARYNGEAL DYSFUNCTION

Articulation/Speech Learning
(Velopharyngeal Mislearning)

Anatomy
(Velopharyngeal Insufficiency)

Physiology
(Velopharyngeal Incompetence)
VPI: Velopharyngeal Insufficiency and Incompetence
Velopharyngeal Insufficiency (VPI)
Video: VP Insufficiency
Video: VP Insufficiency
Causes of VP Insufficiency

- History of cleft palate or submucous cleft
- Deep pharynx
- Irregular adenoids
- Enlarged tonsils
History of Cleft Palate

• Velum may be too short or may be irregular following repair
Submucous Cleft
Nasal Surface
Deep Pharynx

• Can be due to cranial base or cervical spine anomalies (i.e., Klippel-Feil syndrome or craniosynostosis)
Adenoids

- Positioned in usual site of VP contact
- Closure is velo-adenoidal in kids
- Normal VP closure requires a tight seal
Irregular Adenoids

• Adenoid irregularity (marked indentation or protrusion) prevents a tight seal
• Can cause small gap and nasal emission
Video: Irregular Adenoids
Enlarged Tonsils

- Can extend into pharynx, interfering with LPW and velar movement or preventing a tight VP seal
VP Insufficiency
Following Surgery or Treatment

- Adenoidectomy
- Maxillary advancement
- Treatment of nasopharyngeal tumors
Adenoidectomy

• Sudden increase in the nasopharyngeal dimension can cause VPI
• Often temporary and resolves within 6 weeks
• Permanent VPI is a risk, especially with history of cleft or submucous cleft
VPI Post Adenoidectomy

- Caused by a change in the structure
- *Speech therapy CANNOT change structure*
- *Exercises don’t work* because the problem is not the muscles
- *Surgical correction is indicated*
Velopharyngeal Incompetence (VPI)
Video: VP Incompetence
(Note hypernasality)
Causes of VP Incompetence

• Velopharyngeal hypotonia, paralysis or paresis
• Neurological injury (i.e., TBI) or dysfunction (i.e., neuromuscular disorders)
  – Occurs as a characteristic of dysarthria
  – Velopharyngeal incoordination can occur with apraxia of speech
Video: Dysarthria

Case #1
Video: Apraxia
Abnormal Resonance

- Hypernasality
- Hyponasalidity (denasality)
- Cul de sac resonance
- Mixed resonance
Hypernasality

- Too much sound resonating in the nasal cavity
- Usually due to VPI or fistula
- Most perceptible on vowels
Hypernasality

- Voiced oral consonants become nasalized (m/b, n/d, etc.)
  - Obligatory distortion
- Other consonants may be substituted by nasals
  - Compensatory production
Hyponasality

• Not enough nasal resonance on nasal sounds (m, n, ng)
• Due to nasal obstruction
• Nasal phonemes sound similar to oral cognates (b/m, d/n, g/ng)
• Also noticeable on vowels
Cul de Sac Resonance

- Sound resonates in a cavity (oral, pharyngeal or nasal), but cannot get out
- Due to blockage in the vocal tract
Cul de Sac Resonance

- Voice sounds muffled and low in volume
- Sound is absorbed (like a sponge) in the cavity
Cul de Sac Resonance
Types and Causes

- **Oral** cul de sac resonance
- **Nasal** cul de sac resonance
- **Pharyngeal** cul de sac resonance
Oral Cul de Sac Resonance

• Sound stays in the oral cavity
• Due to small oral cavity size or small mouth opening (microstomia)
• Parents describe speech as “mumbling” (which is not opening the mouth very much)
• Speech is low in volume
To increase volume ...
Nasal Cul de Sac Resonance

- Sound is mostly in the nasal cavity
- Due to VPI and nasal obstruction from:
  - a deviated septum
  - stenotic nares
  - maxillary retruson
- Common with cleft palate and craniofacial anomalies
Pharyngeal Cul de Sac Resonance

• Sound stays in the pharynx
• Common in patients with very large tonsils
Pharyngeal Cul de Sac Resonance

- Has been called “potato-in-the-mouth” speech
- Enlarged tonsils are the “potatoes”
Enlarged Tonsils

- Tonsils block sound transmission to oral cavity
*Cul de Sac Residence*
Mixed Resonance

• Hypernasality/nasal emission on oral sounds and hyponasality on nasal sounds
• Due to VPI and obstruction or apraxia
Effects of Cleft Palate and VPI on Speech and Resonance

1. Abnormal resonance
   - Hypernasality due to VPI or fistula
   - Hyponasality or cul de sac resonance with cleft palate or craniofacial anomalies due to blockage
Effects of Cleft Palate and VPI on Speech and Resonance

2. Nasal air emission, which can cause…
   - Weak or omitted consonants
   - Short utterance length
   - Occasionally a nasal grimace
   - Compensatory articulation productions

3. Dysphonia
Nasal Air Emission

• Air leaks through the valve
• Occurs on high pressure consonants, particularly voiceless consonants
• Occurs with or without hypernasality
Types of Nasal Emission

- Large opening
- Small opening
  - Nasal Rustle (Turbulence)
Nasal Emission with Large Opening

- No impedance to airflow
- Soft, low intensity sound
- Affects articulation and utterance length
Nasal Emission with Large Opening

Can also cause:

• Weak or omitted consonants
• Short utterance length
• Occasionally a nasal grimace
• Compensatory articulation productions
Compensatory Productions for VPI or Fistula

• Manner of production is maintained
• Placement is in pharynx to take advantage of air pressure
• VP valve will be open, so there will be nasal emission
Compensatory Productions for Palatal Fistula

**Plosives (Stops)**
- **Velar** plosive (backing of anterior sounds)

**Fricatives**
- **Velar** fricative
Velar Fricative
Compensatory Productions for VPI

Plosives (Stops)
- Pharyngeal plosives
- Glottal stops

Fricatives
- Pharyngeal fricatives
- Posterior nasal fricatives
- Glottal fricative (/h/)
- Nasal sniff
Pharyngeal Plosive
Glottal Stop
Can be Co-Articulated

7.12 Glottal stop with coarticulated /+/- placement
Pharyngeal Fricative
Posterior Nasal Fricative

7.11 Posterior nasal fricative
Posterior Nasal Fricative

- Back of tongue articulates against velum
- Air pressure forced into pharynx
- VP valve opens for release of air pressure
- Causes phoneme-specific nasal air emission (PSNAE)
Glottal Fricative (/h/)

• Substituted for oral fricatives
Nasal Sniff

- Occurs as a substitution for sibilants, particularly /s/
- Usually occurs in the final word position
Compensatory Productions for VPI

- Are produce in the pharynx
- Production results in an open VP valve
- Nasal emission is due to production, so persists, even after surgery for VPI
- Speech therapy is needed postoperatively to correct placement (which will eliminate nasal emission)
Nasal Emission with Small Opening

- Air forced through the small opening causes friction and bubbling of secretions *(nasal rustle)*/ nasal turbulence
- Distortion is loud and distracting
- Has no effect on consonants or utterance length
Nasal Emission with Small Opening

- Occurs inconsistently
- Patient can usually close with effort
- Opening increases with motoric demands and fatigue
- Can correct “in therapy”- but child will not be able to maintain it
- Therefore, even a small structural gap will require surgical correction
Dysphonia

• Hoarseness
• Breathiness
• Abnormal pitch
Dysphonia

- Vocal cord nodules due to strain in the vocal tract with VPI
- Laryngeal anomalies with craniofacial syndromes
- Compensatory strategy
  - Breathiness and low volume mask hypernasality and nasal emission
Examples of Effect of Gap Size
Video: Large Gap

• Note: Nasal emission, weak consonants, short utterance length, nasal grimace
Video: Mid Sized Gap

• Note: Distortion is worse when opening becomes smaller
Video: Small Gap

- Note: Rustle (AKA Turbulence)
VELOPHARYNGEAL MISLEARNING
Velopharyngeal Mislearning

Causes:

• **Hearing Loss/Deafness**

• **Secondary to VPI**: Learned compensatory productions secondary to VPI

• **Mislearning**: Misarticulations that cause nasal emission unrelated to a VPI
Hearing Loss/Deafness

- Need auditory feedback because there is no tactile-kinesthetic feedback of VP movement
- Results in a mixture of hyper- and hyponasality
“Hypernasality” due to Misarticulations

- Nasalization of vowels
  - Back of tongue too high on vowels
  - Can be phoneme-specific on the high vowel /i/
“Hypernasality” due to Misarticulations

• Substitution of nasal consonants for oral consonants (i.e. ng/l, ng/r)
Nasal Emission due to Misarticulation

- Due to pharyngeal or posterior nasal fricatives
- Causes phoneme-specific nasal air emission (PSNAE)
- Usually occurs on sibilants, particularly s/z
- Child is usually stimulable
Video: PSNAE

Phoneme-Specific Nasal Air Emission (PSNAE)
Recommendations for VP Mislearning

• Speech therapy because this is an articulation disorder
• Surgery is NOT indicated!!!
• Differential diagnosis is very important!
Evaluation and Treatment:
using low-tech and “no tech” procedures
Evaluation of VP Function

• Child needs:
  – Connected speech
  – Ability to cooperate for stimulability testing and instrumental assessment
  – Big enough for a good airway
  – No recent airway concerns

• Usually around the age of 3
Caveat: Don’t wait too long!

- Critical period of brain development
- Need to intervene during critical period
Caveat: Don’t wait too long!

- Consequences of waiting too long
  - Correction will take longer
  - Prognosis is negatively affected
  - Can affect social and emotional development
What to Evaluate

• Speech sound production
• Airflow/air pressure and presence of nasal emission
• Resonance
• Voice (phonation)
Speech Sound Production

- Placement errors
- Phonological (pattern) errors
- Developmental errors
- Obligatory or compensatory errors
Obligatory Errors

Placement is correct, but structure is abnormal
• Nasalization of oral phonemes (m/b, n/d, ng/g)
• Nasal emission
  – Weak or omitted consonants
  – Short utterance length
Compensatory Errors

Placement is incorrect to compensate for abnormal structure

- Glottal stops
- Pharyngeal fricatives
- Pharyngeal plosives

Note: These misarticulations can also be due to mislearning in the absence of VPI
Nasal Emission

- Characteristics of a large gap versus small gap
Nasal Emission - Large Gap

- Nasal emission is barely audible or even inaudible
- Nasal emission causes:
  - Weak or omitted consonants
  - Short utterance length
  - Nasal grimace
Nasal Emission- Small Gap

- Usually in the form of a **nasal rustle**

Note: Nasal rustle can also be due to a misarticulation which causes phoneme-specific nasal air emission
Nasal Rustle
Can be structural or functional

**Structural Defect**
- Occurs inconsistently, but on all pressure sounds, including /p/, /t/ and /k/

**Functional Error**
- Occurs consistently, but only on certain sibilants (i.e. s/z)
Resonance

Need to determine the type:

• normal resonance
  – right balance of oral and nasal resonance
• hypernasality
• hyponasality
• cul de sac resonance
• mixed resonance
Resonance Severity

Rating scales:

• Seven point scale
• Normal, mild, moderate, severe
• Present or absent
Phonation

Evaluate for signs of dysphonia:

- Hoarseness
- Breathiness
- Low or high pitch
- Low intensity
How?
Speech Samples

• Single word articulation test
• NOT good!!!
Speech Samples

- Prolongation of sounds
- Repetition of syllables
- Counting
- Repetition of sentences with pressure-sensitive consonants
- Connected speech
Repetition of Single Sounds

- Oral sound to test hypernasality:
  - vowels, particularly /ah/ and /eee/
- Oral sounds to test nasal emission:
  - prolonged /s/
- Nasal sound to test hyponasality:
  - prolonged /m/
Repetition of Syllables

To test hypernasality or nasal emission, use oral consonants with high and low vowels:

• pa, pa, pa, pa… pi, pi, pi, pi…
• ta, ta, ta, ta… ti, ti, ti, ti…
• ka, ka, ka, ka… ki, ki, ki, ki…
• sa, sa, sa, sa… si, si, si, si…
• sha, sha, sha, sha… shi, shi, shi, shi…
Repetition of Syllables

To test hyponasality, use nasal sounds with high and low vowels:

- ma, ma, ma, ma…   mi, mi, mi, mi…
- na, na, na, na…   ni, ni, ni, ni…
Counting

To test nasal emission:

- Count from 60 to 70
- Repeat 60 or 66 over and over
  
  66 = SIKSTY SIKS

- Good combination of plosives and fricatives in blends
Counting

To test hyponasality:

• Count from 90 to 99
• Repeat 99 over and over
Repetition of Sentences

- p/b: Popeye plays baseball.
- t/d: Take Teddy to town. Do it for Daddy.
- k/g: Give Kate the cake. Go get the wagon.
- f/v: Fred has five fish. Drive the van.
- s/z: I see the sun in the sky.
- sh: She went shopping.
- ch: I ride a choo choo train.
- j: John told a joke to Jim.
- l: Look at the lady.
- r: Run down the road. I have a red fire truck.
- th: Thank you for the toothbrush.
- Blends: splash, sprinkle, street
Stimulability and Consistency

• Does change in placement change VP function?
• Stimulability is a good prognostic indicator for improvement or correction with therapy
Key to Perceptual Assessment

Listen very carefully!!!
Low-Tech/ “No-Tech” Procedures

Use same type of speech samples to...

» See
» Feel
» Hear
See: Mirror Test
See: Air Paddle
See: See-Scape
Feel: Sides of Nose
Hear: Nose Plugging

• Listen to oral sounds and sentences with nose open and then closed
• If there is a difference, there is an open VP valve
• If there is no difference, the test is inconclusive
Hear: Stethoscope

- Take off the drum
- Put the tip of the tube at the entrance of a nostril
- Listen for air or sound through the scope during oral sounds
Hear: Straw

- Same as stethoscope
- Straw is always available, cheap and disposable!
Hear: Listening Tube
Prediction of Gap Size based on perceptual features

→ Hypernasality, *inaudible* nasal emission, weak consonants, short utterance length, compensatory productions

→ Hypernasality, *audible* nasal emission, weak consonants, may have compensatory productions

→ Possibly mild hypernasality and audible nasal emission

→ Normal resonance, but inconsistent nasal rustle (turbulence)
INTRA-ORAL EVALUATION
Intra-Oral Evaluation

• Can evaluate oral structures and oral function
• Cannot evaluate velopharyngeal structure or VP function
• View is well below area of closure
Intra-Oral Evaluation

- Signs of a submucous cleft
- Position of the uvula during phonation
- Size of the tonsils
- Signs of upper airway obstruction
- Signs of oral-motor dysfunction
Intra-Oral Evaluation

- Need to see to the tip of the uvula
- Avoid using a tongue blade
Say “aaaah” as in “bat” and protrude the tongue
Aaaah
Video: Submucous Cleft
Submucous Cleft
Instrumental Evaluation of VP Function

- **Direct Procedures**
  - You can see it, but you can’t quantify it.
  - Videofluoroscopy and nasopharyngoscopy

- **Indirect Procedures**
  - You can quantify it, but you can’t see it
  - Aerodynamics (pressure-flow) and Nasometry
Nasometry (KayPentax)

- Analyzes **acoustic energy** from oral and nasal cavities
- Gives an **objective nasalance score**
Measured Value called “Nasalance”

• Computes a percentage of nasal acoustic energy in speech

Nasal Acoustic Energy
Total \((\text{nasal} + \text{oral})\) Acoustic Energy
SNAP Test: Sibilants Passage
Normal Speech
SNAP Test: Suzy Passage
Nasal Rustle
SNAP Test: Velars Passage
Nasal Rustle

![Graph showing nasal rustle over time.](image-url)
Need to Determine Probable Cause

- Velopharyngeal insufficiency (VPI)
- Velopharyngeal incompetence (VPI)
- Velopharyngeal mislearning
Velopharyngeal Insufficiency (structural abnormality)

- Surgery (speech therapy postoperatively)
- Prosthetics- speech bulb (if surgery is not an option)
- Speech therapy is appropriate AFTER the surgery to eliminate compensatory articulation errors

Note: Speech therapy CANNOT change abnormal structure!
Velopharyngeal Incompetence (neurophysiological cause)

- Surgery (speech therapy postoperatively)
- Prosthetics- palatal lift
- Speech therapy
Velopharyngeal Mislearning

- Speech therapy only
TREATMENT OF VPI

- Surgery
- Prosthetics
- Speech therapy
Surgery for VPI

- Pharyngeal augmentation
- Furlow Z plasty
- Sphincter pharyngoplasty
- Pharyngeal flap

Note: These do not always work the first time. May need revision or even re-do.
Factors in Surgical Procedure Selection

• **Cause:** irregular adenoids versus short velum
• **Size** of the opening
• **Risk** of airway obstruction
• **Location, Location, Location**

Need to find the hole and find the right procedure to fill it!
Prosthetic Devices

- Palatal lift
- Palatal obturator
- Speech bulb
Limitations of Prosthetic Devices

- Require insertion and removal
- Have to redo periodically due to growth
- Can be lost or damaged
- May be very uncomfortable
- Compliance is often poor
- Don’t permanently correct the problem

Most centers use only if surgery is not possible
Speech Therapy
With Structural Anomalies

- Speech therapy CANNOT change abnormal structure
- Speech therapy CANNOT correct VPI
Speech Therapy
With Structural Anomalies

• Speech therapy CAN change abnormal function
  – Compensatory errors secondary to abnormal structure (i.e., malocclusion or VPI)
  – Mislearning (in absence of structural anomalies)
  – Oral-motor dysfunction (apraxia)
Speech Therapy
With Structural Anomalies

• Speech therapy CAN improve the function of the VP structures AFTER surgical correction of the structure

• *Changing structure does not change function*
Speech Therapy

While waiting for surgery to correct VPI:

- Use nose plugging technique
  - Gives the child increased oral pressure to work on articulation
  - Child should wear nose plug at home as much as possible
Speech Therapy

For hypernasality or nasal emission after surgery for VPI:

- Use auditory feedback
- Nasal tube or ONL will provide feedback
Auditory Feedback: Oral & Nasal Listener (ONL) *

* Super Duper Publications- 2007
Speech Therapy for VP Mislearning

- Glottal stops
- Nasalized vowels or ng/l
- Nasalized /r/
- Pharyngeal plosives
- Palatal-dorsal production (lateral lisp)
- Pharyngeal or posterior nasal fricatives
Video: Speech Therapy for phoneme-specific nasal emission due to misarticulation
General Principles

• Do not use blowing or sucking exercises, velar exercises or oral-motor exercises!!!

• Do not “PINCH” the nose to improve VP function

• None of these have any evidence of efficacy and they don’t work!!!
General Principles

• Use general articulation procedures to establish appropriate placement
• Incorporate motor learning principles
Motor Learning

- Necessary for learning to perform all complicated motor movements and sequences without conscious thought
- Dependent on feedback and practice
- Results in brain reorganization due to neural plasticity
Feedback

• Done in speech therapy to shape appropriate production of the speech sound
Practice

• Done first in therapy, and then at home
• Drill work is VERY important
• The number of correct responses elicited (in therapy and at home) is directly related to the rate of progress.
Examples of Motor Learning

• Playing an instrument: piano
• Ballroom dancing: salsa, swing
• Sports: shooting a basketball
• Speech
Motor Learning

• Speech therapy is like piano lessons... if you don’t practice at home, you don’t learn to play the piano!
Goal of Treatment

- Normal speech and resonance
- No evidence of “nasality”
- “Acceptable speech” is not acceptable
Referrals

Check Around...

- This is a specialty area for all disciplines (ENT, surgery and speech path)

- **Refer to a craniofacial team**

- Check with American Cleft Palate-Craniofacial Association (ACPA) for professionals *with experience* in this area ([http://www.acpa-cpf.org/](http://www.acpa-cpf.org/))
Team Approach:
Cincinnati Craniofacial Center
Thanks for your interest!