Speech Assessment of Abnormal Resonance and Velopharyngeal Dysfunction

Ann W. Kummer, PhD
Cincinnati Children’s Hospital Medical Center
Effects of Cleft Palate and VPI on Speech and Resonance

1. Abnormal resonance (sound)
2. Nasal air emission (airflow and air pressure)
3. Dysphonia
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 for speech is affected by the following:

• Length and volume of pharynx
• Size and shape of oral cavity
• Configuration of nasal cavity
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

- Pharyngeal wall
- Velum (soft palate)
- Tongue
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
Normal Velopharyngeal Function

Learning (Articulation)

Anatomy (Structure)  Physiology (Movement)
VELOPHARYNGEAL DYSFUNCTION

Articulation/Speech Learning
(Velopharyngeal Mislearning)

Anatomy
(Velopharyngeal Insufficiency)

Physiology
(Velopharyngeal Incompetence)
VP Insufficiency

- History of cleft
- Submucous cleft palate (overt or occult)
- Short velum or deep pharynx (cranial base anomalies)
- Irregular adenoids
- Enlarged tonsils
VP Insufficiency
Following Surgery or Treatment

- Adenoidectomy
- Maxillary advancement
- Treatment of nasopharyngeal tumors
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
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
Abnormal Resonance

- Hypernasality
- Hyponasality (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 and sounds muffled
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 retrusion
• 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
Nasal Air Emission

- Occurs with or without hypernasality
- *Air* leaks through the valve
- Occurs on high pressure consonants, particularly *voiceless consonants*
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 VPI

Plosives (Stops)
• Pharyngeal plosives
• Glottal stops

Fricatives
• Pharyngeal fricatives
• Posterior nasal fricatives
• Glottal fricative (/h/)
• Nasal sniff
3. 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
PERCEPTUAL EVALUATION
When, What, How, and Why

• **When** the evaluation should be done for the most reliable results and maximum benefit for the patient
• **What** to assess
• **How** to do a perceptual evaluation using simple “low-tech” and “no-tech” procedures
• **Why** the speech evaluation is needed to make appropriate management decisions
When?
Evaluation of VP Function

- Child needs:
  - Connected speech
  - Ability to cooperate for stimulation 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 and speech/language learning
- Consequences of waiting too long
  - Correction will take longer
  - Prognosis is negatively affected
  - Can affect social and emotional development
What?
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 distortions or compensatory errors
Obligatory Distortions

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 plosives
- Pharyngeal fricatives

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 (turbulence) 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
For non-compliant children...
Either/Or Questions

What do you like best?
- Puppy dogs or kitty cats?
- Baby dolls or teddy bears?
- Cup cakes or cookies?
- Baseball or basketball?
- Dancing or singing?
Key to Perceptual Assessment

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

Use same type of speech samples
  » 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: Listening Tube
Prediction of Size of Gap 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

→ Audible nasal emission and possibly mild hypernasality

→ 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

- Dentition and occlusion
- Oral cavity size
- Position of the tongue tip relative to the alveolar ridge
- Presence of a fistula
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
Fistula

Effect depends on location and size
Oronasal Fistula vs. VPI

- Occlude the fistula with gum or fruit roll up
  OR
- Compare the degree of nasal air emission for anterior sounds and posterior sounds
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
Submucous Cleft
Submucous Cleft
Tonsils

• Judge the size and symmetry
• May affect position of the uvula
Uvula

- Should be in midline during rest and phonation
- Look for deviation or pointing to one side
Enlarged Tonsils

- Can extend into pharynx, interfering with LPW and velar movement or preventing a tight VP seal
Nasopharyngoscopy of Tonsil
Velar Paralysis or Paresis

- Affected side of velum droops, causing a lateral VP gap
- Uvula points to unaffected side
INSTRUMENTAL EVALUATION
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
Direct Measures

• Most important for surgical planning
• Allow you to determine location
  – You need to find the hole so you can fill it!
• Can estimate quantity (severity or size), but it’s not very important preoperatively
Indirect Measures

• Indirect measures are important for *objective* quantification of postoperative results
  – Need to do both pre- and postoperatively

• Need objective measures to determine and compare surgical outcomes
Nasometry (KayPentax)

- Analyzes **acoustic energy** from oral and nasal cavities
- Gives an **objective nasalance score**
Basic Equipment

- Headset
- Nasometer box
- Host computer
Headset

- Sound separator plate fits on upper lip
- Uses 2 microphones separated by the plate
  - top mic measures nasal acoustic output
  - bottom mic measures oral acoustic output
Measured Value called “Nasalance”

• Computes a percentage of nasal acoustic energy in speech

Nasal Acoustic Energy

Total \((\text{nasal} + \text{oral})\) Acoustic Energy
Standardized Passages

- Nasalance score can be compared to normative data
- Zoo Passage and Nasal Passage- for adults
- SNAP Test- for kids
**Syllable Repetition/Prolonged Sounds Subtest**

Instructions: Repeat or prolong until the screen is full.

<table>
<thead>
<tr>
<th>Oral + /a/ Syllables</th>
<th>Norms</th>
<th>S.D.</th>
<th>Score (Threshold: ≥15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pa, pa, pa...</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>ta, ta, ta...</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>ka, ka, ka...</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>sa, sa, sa...</td>
<td>7</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>ja, ja, ja...</td>
<td>7</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Oral + /i/ Syllables</th>
<th>Norms</th>
<th>S.D.</th>
<th>Score (Threshold: ≥35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>pi, pi, pi...</td>
<td>17</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>ti, ti, ti...</td>
<td>17</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>ki, ki, ki...</td>
<td>18</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>si, si, si...</td>
<td>17</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>ji, ji, ji...</td>
<td>16</td>
<td>8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nasal + /a/ Syllables</th>
<th>Norms</th>
<th>S.D.</th>
<th>Score (Threshold: ≤40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ma, ma, ma...</td>
<td>53</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>na, na, na...</td>
<td>53</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nasal + /i/ Syllables</th>
<th>Norms</th>
<th>S.D.</th>
<th>Score (Threshold: ≤60)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mi, mi, mi...</td>
<td>72</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>ni, ni, ni...</td>
<td>74</td>
<td>11</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prolonged Sounds</th>
<th>Norms</th>
<th>S.D.</th>
<th>Score (Threshold: +/- 2 SDs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prolonged / a/</td>
<td>6</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Prolonged / i/</td>
<td>19</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Prolonged / s/</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Prolonged / m/</td>
<td>95</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>
SNAP Test: Sibilants Passage
Normal Speech
SNAP Test: Sibilants Passage
Nasal Rustle
SNAP Test: Suzy Passage
Nasal Rustle
SNAP Test: Velars Passage
Nasal Rustle
SNAP Test: Syllable Repetition Nasal Emission
SNAP Test: Zoo Passage
Nasal Emission, Hypernasality, Glottal Stops
SNAP Test: Sibilants Passage
Hypernasality and Nasal Emission
SNAP Test: Nasal Passage
Hyponasality
SNAP Test: Nasal Passage
Cul de Sac/Hyponasality
Nasopharyngoscopy

- Allows direct observation of VP structures and function during speech
- Important for treatment planning
Nasopharyngoscopy

• A rose by any other name…
  – AKA nasendoscopy or video nasendoscopy

• CPT Code 92511 is “nasopharyngoscopy”

“Use CPT code 92511 for a diagnostic nasopharyngoscopy with an endoscope, which views the surface area extending from the posterior edge of the soft palate to the nasopharyngeal wall, including the Eustachian tube openings.”

From: Coding tip: Learn the difference between nasopharyngoscopy and endoscopy procedures, Ambulatory Surgery Reimbursement Update, January 22, 2008.
Nasopharyngoscopy:
To view nasal surface of velum

Can show:
• Evidence of a submucous cleft
  – Absent or dysplastic musculus uvulae
  – Concavity or notch in velum
Nasal Surface of Velum
Submucous Cleft
Nasopharyngoscopy: To view nasal surface of hard palate

Can show:

• Size and effect of a fistula
Nasopharyngoscopy:
To view PPW and pharynx

Can show:
• Adenoids or effect of adenoidectomy
• Passavant’s ridge
• Medialized internal carotids based on pulsations
• Tonsils in pharynx
Passavant’s Ridge
Irregular Adenoids
Protrusion and Indentation
Nasopharyngoscopy of Tonsil
Nasopharyngoscopy:
To view vocal folds

Can show:
- Thickening or edema on cords
- Paralysis or paresis of cords
- Use of ventricular phonation
- Presence of vocal nodules
- Other pathologies
Nasopharyngoscopy: For surgical planning

Can show:

• Probable cause
  – i.e., irregular adenoids versus a velar defect
• Movement and closure during speech
• Size and shape of the gap
• LOCATION, LOCATION, LOCATION
Small Circular Gap in Midline
Medium Size Opening in Midline
Small Lateral Gap
Bowtie Closure
Bowtie Closure
Narrow Coronal Gap
Coronal Gap with Touch Closure in Midline
Nasopharyngoscopy:
Following surgery

Can show:

- Retropharyngeal implant
- Pharyngeal flap and lateral ports
- Sphincter pharyngoplasty
- Effect of adenoidectomy
Pharyngeal Flap and Right Port
Preparation before Appointment

• Patient receives coloring book
  – Explains what to expect in pictures and activities
  – Has practice sentences and sounds

• Parents receive information
Preparation of the Nasal Cavity

- Child blows his nose to eliminate secretions
- Avoids need for nasal suction in many cases
Preparation of the Nasal Cavity

- Nasal spray (neosynephrine and zylocaine)
- Two puffs per nostril
- Patient sniffs
- Child or parent can help
Preparation of the Patient

We ask the child…

• Do you ever pick your nose? We have a little nose picker.
Preparation of the Patient

We are going to be looking for boogers…….
Preparation of Patient

- Explain the “tight spot” (where the scope goes through the choana)
- Demonstrate this with his/her hand
- May make him/her sneeze
Preparation: How many hands?

• For older patients (age 5 and up), one person is fine.
• For some (not all) younger patients (ages 3-5):
  1. Lap holder
  2. Head holder at times
  3. Scope holder/operator - “bad guy”
  4. Behavior/speech elicitor - “good guy”
Position of the Patient

- Put child on parent’s lap
- Parent “hugs” the child around arms and holds his hands
- If necessary, parent puts leg over child’s legs,
Select the Scope

- Consider using a small one (2mm rather than 3 mm)
- “Slime” the end with zylocaine gel
- We call it “donated snot”
Nasopharyngoscopy Procedure

- Put scope in largest nostril (usually non-cleft side)
- Go through the middle meatus
- The scope will go up over turbinate and then down
Nasopharyngoscopy Procedure

- Make sure scope goes down to a vertical position, above port
Easy
Hard
If the child cries...

- One person does the talking
- Need to talk softly and calmly
- Everybody else in the room needs to be quiet
If the child cries...

- Ask the child to open his eyes and look at you.
- Have pictures for the child to see to cue the speech.
- Bargain on what the child has to say to take it out.
If the child cries...

• Worst case scenario: Have the child say something like...
  – “Stop it, stop it, stop it.”
  – “Get this stinking scope out of my nose!”
Nasopharyngoscopy

- It’s not hard for the examiner
- It’s not really very hard for the patient…
Nasopharyngoscopy vs. Videofluoroscopy

- Done without radiation
- Better tolerated by even young patients (barium is noxious!)
- Much better resolution
- Can see entire port in one view
- No false negatives (head rotation)
- Can see even small gaps
Why?
Velopharyngeal Insufficiency (structural abnormality)

- Surgery (speech therapy postoperatively)
- Prosthetics- speech bulb (if surgery is not an option)
- Speech therapy AFTER the structure has been corrected

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
Goal of Treatment

- Normal speech and resonance
- No evidence of “nasality”
- Merely “acceptable speech” is just not acceptable!
Thank you for your attention!