The Role of Pressure Flow and Endoscopic Assessment in Successful Palatal Obturator Revision

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The purpose of this paper is to illustrate the value of combined aerodynamic and endoscopic examination of velopharyngeal function in the revision of prosthetic speech appliances. Use of these combined measures enables the clinician to identify accurately the site(s) of any under- or overobturation. Furthermore, any needed revision is completed accurately and efficiently.

KEY WORDS: endoscopy, nasal airway interference, obturator, pressure-flow, velopharyngeal incompetence.

Prosthodontic management of palatal defects seeks to recreate normal velopharyngeal functioning for speech and for respiration. Defects that are confined to the hard palate can be managed with relative ease, since the hard palate is a static shelf isolating the oral and nasal cavities. However, defects involving the soft palate require more careful consideration. The soft palate or velopharyngeal mechanism is a dynamic valve. Less than careful evaluation of the velopharyngeal dimensions and dynamics can result in unsuccessful obturator construction. Underobturation of the defect may result in residual hyponasal distortion and nasal reflux. Overobturation may result in hyponasal distortion, discomfort, and tissue ulceration.

Pressure-flow assessment of velopharyngeal function has been advocated for some time (Warren and DuBois, 1964) and has been demonstrated to be a reliable measure of velopharyngeal function (Smith and Weinberg, 1980, 1982) and nasal airway patency (Warren, 1984; Warren et al, 1987). The use of an oral endoscope to evaluate velopharyngeal function was described by Taub (1966). Since that time nasopharyngendoscopy, using either a rigid or a flexible endoscope, has been advocated as an excellent method for observing velopharyngeal function (Pigott et al, 1969). Nasopharyngendoscopy does not interfere with the movements of the oral structures. Thus, it allows observation of the velopharyngeal mechanism in connected speech.

Pressure-flow instruments (Reisberg and Smith, 1985), oral endoscopy (Beery et al, 1985), and nasendoscopy (Karnell et al, 1987) have each been used successfully to guide the initial construction of prosthetic speech aids. The combined use of pressure-flow measures and nasendoscopy has not been explored. Further, the focus of these reports has been the fabrication and modification of appliances to provide velopharyngeal competence for speech. Thus far, the modification of obturators that overobturate the nasopharynx has not been addressed.

The purpose of this paper is to describe (1) the use of aerodynamic assessment to determine the degree of overand under obturation and (2) the use of nasal endoscopy in viewing the velopharyngeal port in order to determine the site at which the obturator should be increased or relieved. Two case studies will be reported.

METHODS

Aeromechanical Assessment

Pressure-flow measures for velopharyngeal function during speech and for nasal airway patency during breathing were obtained using Perci-PC (Palatal efficiency rating computed instantaneously). Perci-PC* is a PC-based system that provides for the collection and interactive analysis of pressure-flow data (Riski, 1986). Data can be obtained and analyzed for measures of velopharyngeal orifice area, nasal airway patency, and laryngeal airway resistance.

The Perci-PC (serial #0001-86) used in our lab is based on an IBM PC/XT. The pressure measures were obtained using a Gould-Statham differential pressure transducer, PM5ETC, with a range of ±35 cm H₂O. The flow measures were obtained using a Gould-Statham differential pressure transducer, PM15E, with a range of ±2.5 cm H₂O, and a Fleisch pneumotachograph with a range of 0–1.391 L per second.

Speech Function. The assessment of velopharyngeal port function during speech requires the measurement of the pressure drop across the velopharyngeal port and of the volume-velocity of air through the port. The technique used

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was originally described by Warren and DuBois (1964). The oral catheter consisted of Tygon tubing with an outside diameter of \( \frac{3}{4} \) inch and an inside diameter of \( \frac{1}{8} \) inch. The oral catheter was placed as far posteriorly into the oral cavity as could be tolerated comfortably and was attached to the high side of the differential pressure transducer. The nasal catheter employed the same tubing and was inserted through a cork that was sized to fit the nostril snugly. It was attached to the low side of the differential pressure transducer.

The nasal airflow tubing was Tygon tubing sized to interconnect. The larger end was attached to the Fleisch pneumotachograph. A glass nasal olive was attached to the smaller end and inserted into the more free-breathing nostril.

Because an oral pressure catheter might interfere with lingual function, a speech sample laden with the voiceless, bilabial plosive sound /p/ was utilized (Figs. 1 and 2). The cross-sectional area was calculated with the interactive analysis mode of Perci-PC at peak differential pressures using a modification of the hydraulic equation (Warren and DuBois, 1964).

**Nasal Airway Patency.** The assessment of nasal airway patency was evaluated using the technique described by Warren (1984). The technique measures the transnasal pressure drop and the transnasal air flow volume-velocity during quiet exhalation. The minimal cross-sectional area of the nasal airway during breathing was also calculated with the interactive analysis mode of Perci-PC using the equation for nasal cross-sectional area as described by Warren (1984).

The procedure employed an adult size Vital Signs Inc. anesthesia mask† that covered the nose and mouth. The mask is clear so that lip postures can be monitored, and it has an inflatable cuff that allows a good seal to the face with minimal pressure applied to the mask. Two catheters are inserted through the mask. The oral catheter is inserted into the oral cavity as far back as can be tolerated comfortably. The nasal catheter is inserted through the mask into the free space between the patient and the mask wall.

**Endoscopy**

The Machida ENT US-25 nasal endoscope was used to evaluate velopharyngeal functioning. A Pentax 35-mm camera with a Machida PE-MF76VS endoscopic lens was used to obtain photographic records. The nasal cavities were anesthetized with a topical anesthetic (4-percent lidocaine). The endoscope was inserted slowly, and its movement was guided by the examiner viewing the image through the scope. The end was positioned as far from the structures as possible to allow the best view of the obturators and of the velopharyngeal portal during speech and quiet breathing.

**Perceptual Evaluation**

The perceptual evaluation of speech was performed in a live speaking situation by a speech pathologist (senior author) with training and experience in the evaluation of velopharyngeal function. The speech sample included conversational speech and a reading of a standard paragraph ("My Grandfather"). High quality tape recordings of each patient were also made and rated to verify the judgments made in the live situation. The rating scale proposed by Subtelny et al (1972) was used. The scale includes oronasal resonance, intelligibility, articulation, and nasal air escape.

**CASE STUDY 1**

I.C. is a 60-year-old female who underwent a partial resection of an adenoid cystic carcinoma of the soft palate in 1982. This was followed by a full course of radiation therapy. She suffered a recurrence, had a complete excision of the soft palate, and was fitted with a speech prosthesis in January of 1984. Subsequently, there was no evidence of recurrent tumor. Although she was able to communicate adequately, her speech was markedly hypernasal and she continued to have some regurgitation of food into the na-
sopharynx when wearing the prosthesis. She was referred for evaluation and modification of the appliance from a center in an adjacent state.

Initial Assessment

I.C. ’s conversational speech was judged to be moderately hypernasal. In addition, phrase length was often shortened because of the nasal air loss. Nasal air escape, reduced oral pressure for pressure consonants, and impaired overall speech intelligibility were also present.

Aerodynamic measures were obtained during repeated words and sentences with the original appliance in place (see Fig. 1). Velopharyngeal orifice area was calculated at peak differential pressures using Perci-PC. The peak differential pressure values averaged 3.5 cm H₂O (S.D. = 0.9). The mean nasal airflow rate at peak pressure values was 170 ml per second (S.D. = 0.5), and the mean velopharyngeal orifice area was calculated to be 10.1 mm² (Table 1).

Nasal endoscopic evaluation during speech revealed that the original prosthesis was making contact with the lateral nasopharyngeal wall on the patient’s right side. There was a slight gap at the posterior aspect and a considerable gap on the patient’s left side (see Fig. 2A). The movement of the left pharyngeal wall area was somewhat inconsistent, but demonstrated several millimeters of excursion.

Prosthodontic Procedure

After aerodynamic and endoscopic evaluation, a thermoplastic impression material‡ was applied to the obturator at the site of the observed opening. The patient was then asked to repeat numerous sentences loaded with pressure consonants and to swallow several times to mold the thermoplastic material. After this initial application of material, nasendoscopic examination revealed that a small residual gap remained along the left lateroposterior border. The prosthesis was then removed, examined, and excess material was removed from those sites that showed molding and disruption of the impression material by the pressure of excess contact. Additional material was placed at sites that showed no contact upon inspection of the appliance and endoscopic examination. The prosthesis was then reinserted, and the speech and swallowing tasks were repeated. Endoscopic examination again revealed a small gap along the lateroposterior border. Pressure-flow measures demonstrated some improvement in velopharyngeal function, but revealed that a residual gap remained. The prosthesis was removed again, and additional material was added at the site of the gap. This process was repeated a third time before complete velopharyngeal closure was achieved. Once this was achieved, the thermoplastic material was replaced with autopolymerizing acrylic resin.

Postmanagement Assessment

Oronasal resonance balance with the final appliance in place was judged to be mildly hyponasal. Intelligibility and phrase length were judged to be improved. There was only infrequent nasal air escape, and that may have been related to the short period of time that the patient had worn the revised appliance.

Endoscopic examination during breathing revealed patent ports to the left and the right of the appliance. Mesial move-

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‡ Adaptol, J.F. Jelenko and Co., Armenli, NY.

| TABLE 1 Average Differential Oronasal Peak Pressure, Nasal Airflow Volume Velocity, and Calculated Velopharyngeal Orifice Area for Patient I.C., Using Original and Modified Appliances* |
|---------------------------------|----------------|----------------|
| **Appliance**                   | **Differential Pressure (cm H₂O)** | **Nasal Airflow (ml/sec)** | **Velopharyngeal Orifice Area (cm²)** |
| Original                        | 3.5            | 170            | 0.10            |
| Revised                         | 5.2            | 0.0            | 0.00            |

* The measurements were obtained from the speech wave forms illustrated in Figures 1A and 1B.
ment of the lateral pharyngeal walls closed the ports completely during speech and sustained phonation (see Fig. 2B).

The aerodynamic measures were retaken during repeated words and sentences with the final modified obturator in place. The peak differential pressure value averaged 5.2 cm H$_2$O (S.D. = 1.8). Mean nasal airflow at pressure was 0.0 ml per second, indicating complete velopharyngeal closure around the obturator (see Table 1).

**CASE STUDY 2**

R.M. is a 30-year-old male born with a complete bilateral cleft of the lip and palate. Several attempts to close the palatal cleft were unsuccessful. A large palatal defect was subsequently managed with a palatal obturator. The patient’s chief complaint was impaired nasal breathing with the appliance in place. In contrast, he reported adequate nasal breathing without the obturator.

**Initial Assessment**

R.M.’s speech was characterized by normal articulatory placement. There was a mild degree of hyponasality, apparently because of overobturation of the nasopharynx by the appliance.

The patency of the nasal airway was evaluated during quiet exhalation. Measurements were obtained from the pressure and flow waveforms at points of steady airflow. The error in the calculation of orifice area is reported to be minimized by taking the measures at points of steady state airflow (Smith and Weinberg, 1983).

Pressure-flow values were initially obtained with and without the original obturator (Fig. 3 and Table 2). Nasal cross-sectional area was reduced by a factor of three with the obturator in place. The patient reported that the obturator made it much more difficult to breathe nasally and that he could breathe comfortably with his lips closed for only short periods of time. Without the obturator, the cross-sectional area of the nasal passage fell within the range expected for normal patency (Warren et al, 1987).

The Machida ENT US-25 nasal endoscope was used to evaluate velopharyngeal functioning during breathing and speech. Examination during speech revealed active mesial movement of the lateral pharyngeal walls closing against the appliance (Fig. 4A). During quite breathing there were small, constricted portals lateral to the appliance. Velopharyngeal movement without the obturator was very active (Fig. 4B). The evaluation suggested that the lateral margins of the obturator could be reduced to increase nasal airway patency without compromising velopharyngeal competence.

**Prosthodontic Procedures**

The lateral borders of the obturator tailpiece were relieved several millimeters at a time. After each relief procedure, velopharyngeal function during speech was evaluated clinically, and velopharyngeal port function was viewed endoscopically to assure that velopharyngeal competence was retained and to assess the movement of the lateral pharyngeal walls. Several millimeters were relieved from the appliance during the initial visit. The patient was discharged and returned several months later, at which time the procedure was repeated. A relief of several millimeters was accomplished during the second visit also.
TABLE 2  Average Transnasal Pressure Drop, Nasal Airflow Volume Velocity, and Calculated Nasal Cross-sectional Area for Patient R.C.*

<table>
<thead>
<tr>
<th>Appliance</th>
<th>Differential Pressure (cm H₂O)</th>
<th>Nasal Airflow (ml/sec)</th>
<th>Nasal Cross-Sectional Area (cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>2.4 (S.D. = 0.6)</td>
<td>251 (S.D. = 11.0)</td>
<td>0.18 (S.D. = 2.7)</td>
</tr>
<tr>
<td>None</td>
<td>1.5 (S.D. = 0.1)</td>
<td>704 (S.D. = 8.4)</td>
<td>0.64 (S.D. = 2.2)</td>
</tr>
<tr>
<td>Revised</td>
<td>1.0 (S.D. = 0.8)</td>
<td>531 (S.D. = 12.4)</td>
<td>0.58 (S.D. = 1.1)</td>
</tr>
</tbody>
</table>

* The measurements were taken from the nasal exhalation wave forms in Figures 3A, B, and C.

Postmodification Assessment

R.M. demonstrated a marked improvement in oronasal resonance during speech. In addition, the patient reported that nasal breathing was comparable with and without the appliance.

Nasal airway cross-sectional area was increased to 57.8 mm² with the modified appliance in place. This compared
favorably with measurements taken without the appliance, which indicated the cross-sectional area of the nasal passages to be 64.3 mm² (see Table 2). Further, this cross-sectional area corresponds favorably to the nasal cross-sectional area of normal, nonleft individuals (Warren, 1984; Warren et al, 1987). Nasal endoscopy revealed larger portals bilaterally during quiet breathing and an increase in the mesial movement of the lateral pharyngeal walls during speech. The appliance was noticeably smaller along the lateroposterior margins (Fig. 4C).

**DISCUSSION**

The goal when managing a palatal defect is to (re)create normal velopharyngeal function. This goal is not realized when inappropriate coupling of the oral and nasal cavities and hypernasality remains. Neither is this goal realized when the velopharyngeal port fails to couple the cavities for the nasal speech sounds and for breathing.

Dysfunction of the velopharyngeal mechanism can result from cleft palate, neurologic insult, or ablative surgery in the treatment of cancer. Failure to provide velopharyngeal competence during speech results in hypernasal resonance and impairment of those consonant sounds that require oral air pressure. Frequently, speech intelligibility is compromised. Often this creates excessive demands on the respiratory system, which must compensate for the loss of air through the nose (Warren and Wood, 1969; Wood and Warren, 1971; Minsley et al, 1987). The speaker’s phrase length is shortened, and speaking becomes effortful and fatiguing. Further, there may be nasal reflux during eating, which is uncomfortable and often socially embarrassing.

There are numerous surgical procedures that have been reported. Palatal defects are sometimes closed surgically with forehead flaps (Biller et al, 1973), split thickness skin grafts and tongue flaps (Conley et al, 1957), palatal island flaps (Gullane and Arena, 1977), or delayed deltopectoral flaps (Park et al, 1974). Shapiro et al (1986) advocated the primary reconstruction of these palatal defects. They found this surgical technique to be simple and effective, and that patients had more normal speech and no nasal reflux during the recovery period. Another advantage to a primary surgical technique is that speech and swallowing can be normalized throughout a period of additional radiation or chemotherapy, during which time prosthetic obturation may not be possible.

Prosthetic management becomes the treatment of choice when surgical intervention is contraindicated, when initial surgical attempts have failed, or when a patient refuses further surgery. Since many patients in this population are edentulous and require dentures, the palatal obturator can be incorporated into the construction of their dentures. Patients in this population are also subject to tongue lesions, which necessitate partial or total glossectomy. In this population the palate can be contoured to compensate for the loss of tongue tissue and function that can affect both deglutition and speech.

A primary disadvantage of surgical management is that the flaps may overobturate or underobturate the velopharyngeal port. Thus, the patient may be left with hyponasality and poor nasal breathing on the one hand or hypernasality and distorted, unintelligible speech on the other.

Prosthetic management has a major advantage in that the appliance can be carefully planned, evaluated, and modified as necessary. Careful planning requires that velopharyngeal port function be visualized carefully with endoscopy. This type of evaluation and more precise modification of the appliance decrease the number and the length of the sessions required to complete the process (Beery et al, 1985). In the first patient cited in this report only one afternoon was required to achieve the results described.

**CONCLUSIONS**

Pressure-flow assessment and endoscopic examination each have their advantages in obturator design and revision. However, an approach in which both instruments are utilized offers greater advantages. Pressure-flow instrumentation allows exact determination of the amount of under- or overobturation and evaluation of small interim changes in velopharyngeal port size during revision (Reisberg and Smith, 1985). Endoscopic examination then allows detailed observation of the velopharyngeal port relative to the appliance. Areas of under- or overobturation can be identified and revised.

**REFERENCES**


