Effect of Restorative Procedures on the Nasopharyngeal Airway in Cleft Palate

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In a recent communication, Warren, Duany and Fischer reported that nasal airway resistance is higher in the cleft population (*4*). This was attributed to nasal deformities and maxillary growth deficits, both of which tend to reduce the size of the nasal airspace (*1*). High nasal airway resistance has important implications in breathing and speech since airflow may become turbulent and, in the presence of velopharyngeal incompetency, produce undesirable noises during sound productions. In addition, high airway resistance may lead to mouth breathing and possibly dental malocclusion.

Secondary restorative procedures for residual palatal incompetency, such as the posterior pharyngeal flap and the prosthetic speech appliance, significantly reduce the nasopharyngeal airspace. The purpose of both procedures is to provide a mass of tissue or plastic against which the lateral and posterior pharyngeal walls can close during the production of sounds requiring oro-nasal separation. The question considered in the present investigation is whether the change in nasopharyngeal airspace dimensions resulting from these procedures produces a significant increase in airway resistance or work during breathing.

Method

The sample population for this study consisted of sixty-two cleft palate and twenty-nine normal control subjects. The cleft palate group comprised fifteen subjects who had been treated with prosthetic speech appliances, twenty who had received posterior pharyngeal flaps and twenty-seven with repaired palates but no secondary procedures. Nasal airway resistance was calculated from the parameters of pressure and airflow during breathing

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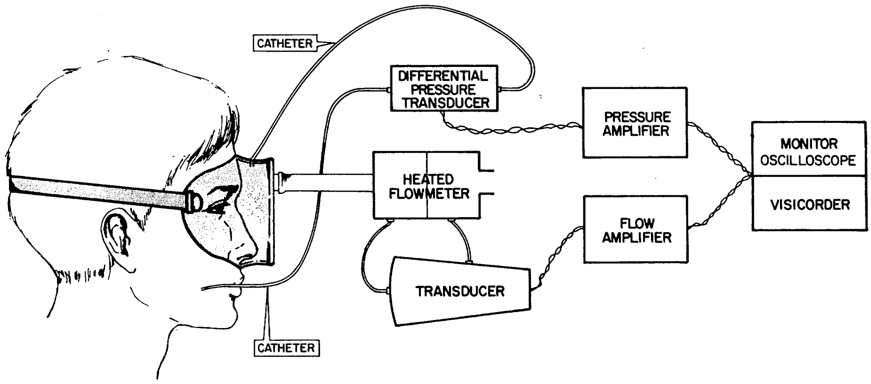

FIGURE 1. Diagrammatic representation of the equipment used.

utilizing the modified Ohm equation (*4, 6*). In this equation, nasal resistance is defined as the ratio of the pressure drop across the nose (ΔP, cm H_2O) to the volume rate of nasal air emission ($\mathring{V}$, L/sec) or $R = \Delta P/\mathring{V}$. Figure 1 illustrates the apparatus used. The nasal pressure drop was measured with a differential pressure transducer connected to two catheters. The first catheter was positioned in the subject's oropharynx as far posteriorly as could be tolerated and the second catheter was placed within the nasal mask in front of the nose. In this way the pressure component produced by resistances across the mask, tubing and pneumotachograph were cancelled out. Both catheters were occluded at the tip but had side holes for measurement of static pressures. The subjects were cautioned not to occlude or bite the oropharyngeal catheter although such activity was easily recognized on the monitor oscilloscope.

Nasal airflow was measured with a heated pneumotachograph connected to the well-adapted nasal mask. Particular attention was given to positioning the mask so that it did not contact the nostrils. After sitting in a controlled environment of stable temperature and humidity for thirty minutes, each subject was asked to inhale as normally as possible through his mouth, to close his lips, and then to exhale through his nose. The resulting pressure and airflow patterns were recorded simultaneously on photosensitive paper by a direct writing recorder. Pressure was then calibrated against the water manometer and airflow was calibrated against a rotameter. The measurements of resistance were calculated at flow rates of .5L/sec and .25L/sec. These rates were selected because they are consistent with normal respiratory breathing patterns and provide a basis for comparison of results with other studies. In addition, calculation of nasal resistance at given rates of airflow is necessary because the relationship between pressure and airflow is influenced by turbulence. That is, when airflow is laminar there is a linear relationship between the two parameters and when there is turbulence the relationship becomes quadratic. Therefore, to compare data among subjects, the resistance values must be calculated at specific rates of airflow.

Results

Speech Appliances. Table 1 compares data for each subject with and without the prosthetic speech appliance. In every instance but one resistance is increased by insertion of the appliance, with a mean difference of 1.4cm H_2O/L/sec. Statistical analysis of these data demonstrates that the difference is statistically significant (paired comparison test) at the .05 level. There are two possible explanations for the one instance of slightly reduced airway resistance with insertion of the appliance. The plumping effect of the appliance may have altered the alar dimensions or on the other hand it may reflect measurement error.

The group was further differentiated into those who achieved adequate velopharyngeal closure with their appliances and those who did not. Palatopharyngeal orifice size was measured during production of consonant sounds by an analog computer system so that subjects who achieved adequate closure could be compared with those who did not. The instrumentation and techniques have been described in detail previously (*3*). Orifice size is calculated from the respiratory parameters of orifice differential pressure and nasal airflow. An orifice size greater than 20mm^2 during plosive consonant production was considered inadequate, and an opening less than 20mm^2 was considered adequate. Justification for employing this dimension for differentiating competency is based upon respiratory studies

TABLE 1. Nasal resistance with and without appliances (cm H_2O/L/sec at .5L/sec).

*subject**	*with*	*without*
1	3.5	3.4
2	6.8	2.5
3	7.4	6.6
4	3.6	3.3
5	4.1	3.2
6	3.3	0.8
7	4.6	3.5
8	6.4	2.5
9	1.4	1.4
10	2.6	1.7
11	6.7	3.5
12	5.6	4.9
13	4.9	2.8
14	2.1	1.4
15	1.1	1.4
mean	4.27	2.86
S.D.	2.01	1.51

* All subjects over 12 years of age.

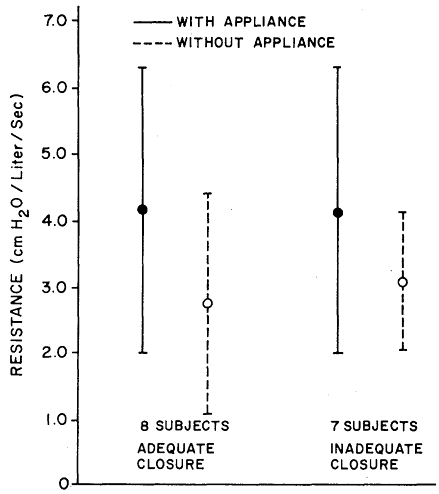

FIGURE 2. Comparison of airway resistances in the prosthetically treated groups.

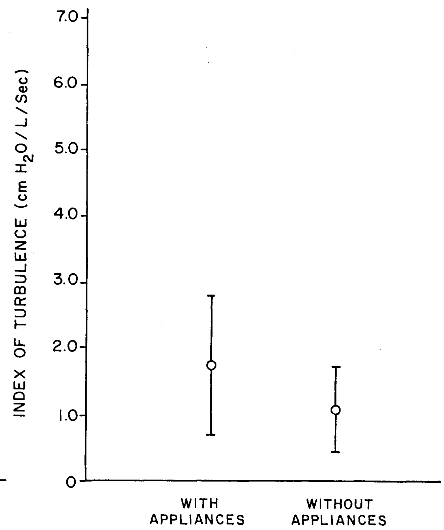

FIGURE 3. Comparison of turbulence index with and without appliances.

of normal and cleft palate speech. Briefly, these studies demonstrated that, whenever the palatopharyngeal opening is greater than 20mm^2, intraoral pressure and nasal emission of air are influenced more strongly by nasal airway resistance than by the specific degree of palatopharyngeal opening. Eight subjects achieved adequate closure and seven subjects did not. Figure 2 is a graphic comparison of resistance for both groups at a flow rate of .5L/sec. Statistical analysis of these data revealed a significant difference in resistance with and without appliances for the adequate group and no statistically significant difference in the inadequate closure group. This indicates that the ratio of speech bulb volume to nasopharyngeal volume is larger in those subjects who achieved adequate palatopharyngeal closure.

In order to determine the effect of appliances on airway turbulence an index of turbulence was calculated. The index was derived from the difference in resistance at flow rates of .5L/sec and .25L/sec and is related to the amount of turbulence in the airway. Figure 3 illustrates mean differences and standard deviations with and without appliances. A paired comparison test revealed a significant increase ($p < .02$) in turbulence with the speech aid in position.

Pharyngeal Flaps. The data for subjects with posterior pharyngeal flaps are presented in Table 2. Because of changes in physical size which occur with age the results are grouped according to age, that is, 7–11, 12–14, and 15 and older. Figure 4 compares mean resistances of the surgically treated groups with the normal control group. It is interesting to note that posterior pharyngeal flaps increase airway resistance in the younger subjects but have almost no effect on adults. The cleft group with no secondary proce-

TABLE 2. Nasal resistance of subjects with posterior pharyngeal flaps (cm $H_2O/L/sec$).

	ages 7–11	ages 12–14	ages 15 and over
	8.3	13.2	1.8
	3.3	6.2	2.3
	7.2	1.8	2.6
	5.0	2.7	2.8
	6.9	4.7	3.9
	3.6	11.6	5.0
	6.9		6.5
mean	5.89	6.70	3.56
S.D.	1.93	4.70	1.68

dures shows a statistically significant higher resistance than the normal group ($p < .05$).

Figure 5 compares all groups, that is, subjects with flaps, unoperated palates, surgically closed palates, appliances and normals. All data are from subjects over 15 years of age. Those with speech appliances exhibit the largest increase in nasopharyngeal resistance.

Discussion

The data obtained in this study indicate that restorative procedures associated with the treatment of cleft palate usually increase nasal airway resistance but the probable effects on breathing and speech appear to be minimal. The only exception appears to be young patients with posterior pharyngeal flaps. Previous studies in our laboratory have indicated that airway resistance below 4.5 cm $H_2O/L/sec$ has little effect on the breathing

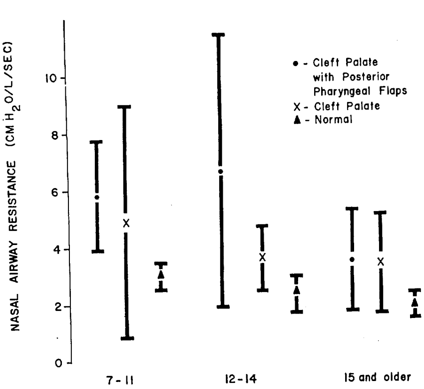

FIGURE 4. Comparison of airway resistances among surgically treated and normal control groups at different age levels.

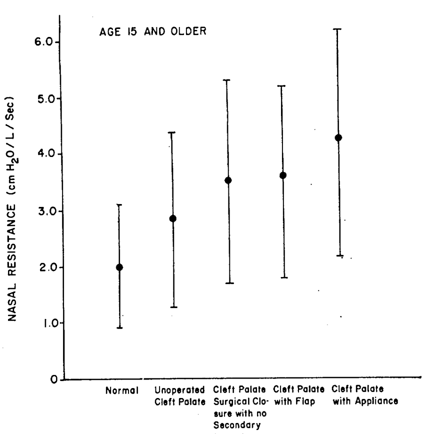

FIGURE 5. Comparison of resistances among all groups age 15 and over.

process (*6*). On the other hand, nasal resistances greater than 4.5cm H_2O/L/sec resulted in mouth breathing in 77% of all subjects studied. This is in contrast to a 26% incidence of mouth breathing for resistances below that value. Although mouth breathing in some instances is the result of habit rather than airway resistance it seems clear that at a certain point the work of breathing through the nose is great enough to produce a change to the oral route.

Nasal airway resistance in young posterior pharyngeal flap patients was above what might be considered normal, although this was not true for older flap patients. Apparently, when growth has been completed and the tonsils and adenoids have atrophied, the flap occupies a physiologically insignificant volume compared to total resting nasopharyngeal volume. In the younger patients, the larger flap to nasopharyngeal volume may result in a higher incidence of mouth breathing. Slightly more than 50% of the subjects with flaps had resistances higher than 4.5cm H_2O/L/sec compared to 33% of the cleft subjects without flaps and 3% of the normal subjects. However, the data do suggest that if mouth breathing does occur in the younger patient after a flap procedure, it should be eliminated with nasopharyngeal growth unless habit patterns become established.

The greatest intra-group variability in resistance occurred in the young posterior pharyngeal flap subjects with a range of 11.4cm H_2O/L/sec. This compares with 6.3cm H_2O/L/sec for those with appliances, 5.8cm H_2O/L/sec for subjects without appliances, 4.7cm H_2O/L/sec for adults with posterior pharyngeal flaps and 4.1cm H_2O/L/sec for normal subjects. This large degree of intra-group variability in the young subjects with flaps may be attributed to the presence of a large amount of adenoid tissue which was incorporated into the flap of the two subjects who demonstrated the highest resistances.

It is interesting to note that nasopharyngeal resistance was similar in subjects with appliances, regardless of whether closure was achieved or not. This means that the difference between groups can be attributed to the greater lateral and posterior pharyngeal wall activity in those subjects who achieved closure.

The finding that speech appliances increase nasopharyngeal resistance to an extent may be significant in terms of speech performance, especially in patients with inadequate closure. These individuals would have greater airway turbulence around the pharyngeal section of the appliance and thus be more susceptible to pharyngeal sound distortions. This would certainly be the case if tongue carriage is high and respiratory effort is increased, conditions which often result from palatal incompetency (*2, 5*).

Summary

The effect of secondary palatal procedures on the nasopharyngeal airspace was studied in sixty-two cleft palate and twenty-nine normal control subjects. The cleft group consisted of fifteen subjects who had been treated

with prosthetic speech appliances, twenty who had received posterior pharyngeal flaps and twenty-seven with repaired palates and no secondary procedures. Nasopharyngeal airspace was evaluated in terms of airway resistance to breathing utilizing the modified Ohm equation.

The results indicate that restorative procedures do increase nasal airway resistance to some extent. In some young pharyngeal flap patients the increase appears to be great enough to produce mouth breathing. However, resistance appears to decrease with growth and adults with flaps demonstrated only slight differences from non-flap patients. Subjects with speech appliances exhibited the largest change in airway resistance but this increase does not appear to be large enough to alter breathing patterns. However, the data did indicate that patients with appliances which did not provide physiologically adequate palatopharyngeal closure may be more susceptible to pharyngeal sound distortions because of the increase in turbulent airflow around the pharyngeal section.

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