Nasal Pathway Resistance in Normal and Cleft Lip and Palate Subjects

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Clefts of the lip and palate often produce deformities within the nasal cavity (*1*, *3*). These defects may include deviated septums, vomerine spurs, atresia of the nostrils, thickening of the nasal mucosa and injected turbinates.

In a recent study using a mechanical analog of the upper speech mechanism, Warren and Ryon (*6*) reported that the nasal cavity has a significant influence upon the respiratory parameters of simulated speech production in the presence of velopharyngeal incompetency. That is, both intraoral pressure and nasal emission of air appear to be affected by conditions within the nasal pathway. In light of this, it is important to determine, in humans, how structural deformities alter speech patterns. In this way the complex phenomenon of "cleft palate speech" should become better understood.

The present study was designed as a preliminary step toward achieving this goal. Specifically, the purpose of this initial study was to determine whether there is a difference in nasal resistance to airflow between a representative cleft lip and/or palate group and a normal sample.

Materials and Methods

The normal group consisted of 29 individuals, 10 males and 19 females, ages 10 to 39. The cleft palate sample was composed of 12 males and 15 females with an age range of 9 to 44. Included in this heterogeneous group were 8 subjects with postoperative unilateral cleft lip and palate, 4 subjects with postoperative bilateral cleft lip and palate, 4 subjects with postoperative cleft lip and unoperated palate, 5 subjects with postoperative cleft palate, 3 subjects with unoperated cleft palate, 2 subjects with postoperative submucous cleft palate, and 1 subject with an unoperated submucous cleft palate. Individuals having pharyngeal flaps

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were not included in the cleft palate sample because of the possibility that flaps increase airway resistance during breathing.

Nasal pathway resistance was calculated from the parameters of pressure and airflow during breathing utilizing the modified Ohm equation (*2*). 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 ($\dot{V}$, L/sec), or $R = \Delta P/\dot{V}$. Specifically, the technique measures nasal resistance + velopharyngeal orifice resistance during breathing. However, velopharyngeal orifice resistance is negligible (*5*) as long as the adenoids are unremarkable and this was verified by the otolaryngologist's examination.

Figure 1 illustrates the apparatus used. The nasal pressure drop was measured with a differential pressure transducer (Statham PM 283 TC) 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 a nasal mask in front of the nose. In this way the pressure component produced by resistances across the mask, tubing and pnemotachograph were cancelled out. Both catheters were occluded at their tips 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 30 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 (Figure 2) were recorded simultaneously on photosensitive paper by a direct writing recorder (Honey-

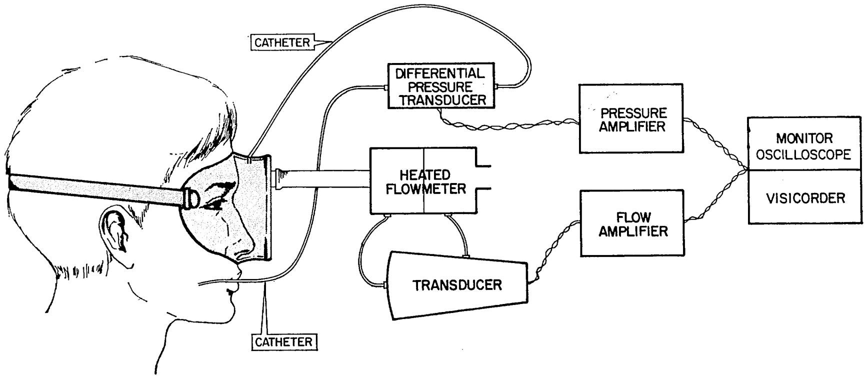

FIGURE 1. Technique and equipment used to measure nasal airway resistance. The subject was asked to inhale through his mouth, close his lips and exhale through his nose.

FIGURE 2. Pressure and airflow patterns from which nasal resistance was calculated. Pressure was measured at .5L/sec airflow.

well 1508 Visicorder). Pressure was then calibrated against a water manometer and airflow was calibrated against a rotameter. The measurements of resistance were calculated at a flow rate of .5L/sec. This rate was selected because it is consistent with normal respiratory breathing patterns and provides a basis for comparison of results with other studies. In addition, calculation of nasal resistance at a given rate 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 a specific flow rate.

An otolaryngologist independently evaluated the subjects upon completion of the measurements in order to obtain a general impression of conditions within the nasal cavity and oropharynx. All clinically evident irregularities were noted.

Results

The data for normals are presented in Table 1. The data for males and females are pooled since a t test revealed no significant difference in resistances. Because of changes in physical size which occur with age, the results were grouped into three age categories; 9–11 years, 12–13 years and 15 and older. The mean resistances for these groups are 3.0, 2.4 and 2.0 cm H_2O/L/sec respectively. This indicates a trend of lower resistance with increased age up to about 15 years. Apparently at 15 years the nose reaches its maximum internal cross-sectional area and age no longer influences the results.

The data for the cleft palate sample are presented in Table 2; the trend of lower resistances with older ages is also apparent. The mean resistances are higher than those observed in the normal sample with a

TABLE 1. Nasal resistance in normals.

subject	*sex*	*age*	*resistance (cm $H_2O/L/sec$)*
15 years and older			
B. B.	F	39	1.0
D. E.	F	23	2.2
J. F.	M	30	1.0
N. F.	F	20	2.0
J. G.	M	18	1.7
S. J.	F	20	2.9
J. K.	M	22	0.7
C. L.	F	22	0.8
S. M.	M	23	1.6
S. McA.	F	23	1.5
C. McR.	F	22	2.7
M. P.	F	19	1.6
F. T.	F	22	0.8
J. T.	F	20	3.9
S. W.	F	16	4.8
D. W.	M	22	1.4
D. W.	M	31	3.3
P. H.	F	15	1.3
			mean 2.0
			SD 1.1
12–13 years			
G. H.	F	13	2.6
D. H.	F	13	1.4
D. M.	F	13	2.3
E. B.	M	12	3.2
D. M.	M	12	2.4
			mean 2.4
			SD .6
9–11 years			
K. W.	F	11	3.2
D. V.	F	10	3.1
B. S.	M	11	2.5
J. B.	F	10	2.5
S. H.	F	11	3.0
D. M.	M	11	3.4
			mean 3.0
			SD .4

mean of 4.9, 3.6 and 3.5 cm $H_2O/L/sec$ for the 9–11, 12–13, and 15 and older groups respectively. Statistical comparison of the normative and cleft palate data reveal significant differences at the 5% level for the 9–11 and 15 and older groups. Borderline significance (7% level) is noted between the 12–13 groups. However, the fact that the level of significance is not as great in this group is probably due to the smaller sample size.

TABLE 2. Nasal resistance in cleft lip and/or palate subjects.

subject	*sex*	*age*	*resistance (cm $H_2O/L/sec$)*
15 years and older			
B. C.	F	23	4.9
G. C.	M	17	2.6
V. E.	M	21	4.9
P. F.	M	35	3.2
D. J.	M	18	3.3
E. P.	F	16	1.4
A. O'D.	F	30	1.7
P. P.	M	16	5.0
L. S.	F	37	8.0
G. C.	M	29	2.9
S. H.	M	18	3.4
O. G.	F	30	1.8
A. S.	F	18	1.7
E. B.	M	39	3.7
			mean 3.5
			SD 1.8
12–13 years			
J. C.	M	12	2.6
M. J.	F	13	5.2
G. R.	M	12	3.4
J. B.	F	13	3.2
			mean 3.6
			SD 1.1
9–11 years			
K. B.	F	11	5.7
D. C.	F	11	7.0
B. K.	F	9	5.0
L. L.	F	11	2.6
K. M.	F	11	3.6
D. S.	F	9	3.4
D. W.	M	10	9.2
B. M.	F	9	3.1
K. B.	M	10	4.2
			mean 4.9
			SD 2.1

Otolaryngological examinations were performed on 25 of 29 normals and 25 of 27 cleft palate subjects. In the normal group, 14 of the 25 subjects presented clinical evidence of septal defects, vomerine spurs, or turbinate hypertrophy in spite of the fact that their breathing space was judged to be normal. 17 of the 25 cleft palate subjects also presented similar nasal defects which were usually more severe, however.

It is interesting to note that among those individuals whose clefts involved only their palates, 7 out of 10 were judged by the otolaryngologist to be free of nasal defects. On the other hand, only 1 out of 15 subjects whose lips as well as palates were involved was classified as free of nasal defects.

Discussion

The results of the study indicate that nasal pathway resistance is generally higher in the cleft palate population. This trend was observed in all the age groups investigated.

Undoubtedly, the difference in resistance results from nasal deformities and maxillary growth deficits both of which tend to reduce the size of the nasal passages. Indeed, there is ample evidence to support this contention. Numerous studies have shown that retarded maxillary growth frequently occurs in individuals with clefts (*1, 4*). Similarly, Drettner (*3*) has demonstrated that septal deformities, atresia of the nostrils, and turbinate hypertrophy diminish airway size. In his study he noted that 45% of the cleft palate subjects presented narrower nasal airways than the normal controls. Drettner also reported that airway narrowing was greatest when the lip as well as the palate were involved and this is confirmed by the present study.

The finding of higher nasal resistance in cleft individuals has important implications in the area of speech. Most speech clinicians agree that speech performance among patients with palatal incompetency varies greatly. Recent studies in our laboratory suggest a reason for this. It appears that the level of intelligibility attained by such speakers is determined to a great extent by the manner in which the various articulatory structures of the vocal tract react to the incompetency rather than the specific degree of incompetency present (*6, 7, 8*).

In addition, the present data, although representing only an initial part of a continuing study, raise some interesting questions concerning the possibility that structural deformities of the resonating chambers also influence the speech result.

For example, it is known that high nasal resistance compensates to some degree for palatal inadequacy since higher intraoral pressures can be achieved (*6*). If, however, the volume rate of airflow into the nose is large enough, do undesirable noises resulting from airflow turbulence occur, and if so, do they distort consonant sound production? On the other hand, an individual with normal nasal resistance might have more nasal emission of air but less turbulent airflow. In this case, air entering the nasal cavity presumably passes through with less noise. Does this result in more intelligible speech? These questions, among others, are presently being considered in our laboratory.

Summary

Nasal pathway resistance was studied in 29 normal and 27 cleft lip and/or palate individuals. The results indicate that resistance is higher in the cleft population and this is presumed to be due to nasal deformi-

ties and maxillary growth deficits, both of which tend to reduce the size of the nasal passages. The data also indicate that the frequency of nasal deformities is much greater when the lip as well as the palate are involved. These findings raise the possibility that structural deformities of the resonating chambers may influence the speech performance of cleft palate individuals.

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References

1. Aduss, H., and S. Pruzansky, The nasal cavity in complete unilateral cleft lip and palate. *Arch. Otolaryng.*, *85*, 75–84, 1967.
2. Butler, J., The work of breathing through the nose. *Clin. Science*, *19*, 55–62, 1960.
3. Drettner, B., The nasal airway and hearing in patients with cleft palate. *Acta Otolaryng.*, *52*, 131–142, 1960.
4. Foster, T. D., Maxillary deformities in repaired clefts of the lip and palate. *Brit. J. plastic Surg.*, *15*, 182–190, 1962.
5. Warren, D. W., and A. B. DuBois, A pressure-flow technique for measuring velopharyngeal orifice area during continuous speech. *Cleft Palate J.*, *1*, 52–71, 1964.
6. Warren, D. W., and W. E. Ryon, Oral port constriction, nasal resistance, and respiratory aspects of cleft palate speech: an analog study. *Cleft Palate J.*, *4*, 38–46, 1967.
7. Warren, D. W., Nasal emission of air and velopharyngeal function. *Cleft Palate J.*, *4*, 148–156, 1967.
8. Warren, D. W., and S. B. Mackler, Duration of oral port constriction in normal and cleft palate speech. *J. speech hear. Res.*, *11*, 391–401, 1968.