Oral and Nasal Sound Pressure Level as Related to Presence or Absence of Velopharyngeal Closure

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Judgments of hypernasality influence recommendations for speech therapy and surgical procedures as well as prosthodontic treatment. Bradford and associates (*1*) have demonstrated that individual assessments of nasality lack reliability. They caution that discretion should be used in making decisions concerning speech therapy or physical management of the problem based on subjective perceptions of hypernasality. Several studies (*3, 4*) have attempted to correlate oral and nasal sound pressure levels (SPL) with nasality scores assigned by judges. Shelton and associates (*4*) studied 31 cleft palate patients and concluded that "the relationship between nasality judgments and SPL measures is not sufficiently great to warrant use of the recording apparatus in the diagnosis of nasality in individual clients". They also reported that "experimentation of this type appears to have utility in testing the validity of various indices to adequacy of palato-pharyngeal closure".

In the present investigation, sound pressure level measurements of subjects with no velopharyngeal gap and cleft palate speakers, both with a gap and with no gap, as determined by cinefluorographic analysis, were studied. Cinefluorography films have been produced showing the presence or absence of velopharyngeal closure during the sustained phonation of the vowel /i/.

Since a perusal of the literature revealed little information regarding differences between the sound pressure level for right and left nostril, this factor was investigated in the present study. Mean sound pressure levels were determined by averaging the decibel value for each phonation that was traced by a Bruel & Kjaer level recorder (*2*).

Procedure

Sixty-one persons served as subjects for the main part of this study. Twenty-nine of the subjects had repaired cleft palates, and 16 of these

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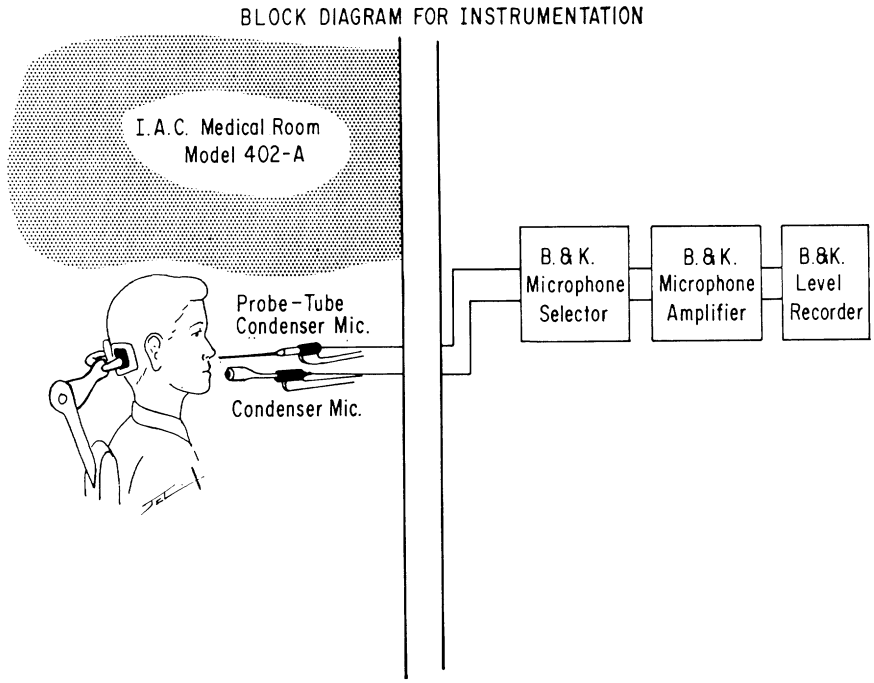

FIGURE 1. Schematic diagram showing placement of microphones and the instrumentation used to study oral and nasal SPL.

had velopharyngeal gaps according to the cinefluorographic analysis. The two cleft palate subgroups (16 Ss without closure, 13 Ss with closure) consisted of teenagers enrolled at Duke University Summer Speech Camp. The remainder of the subjects had no visible oral or nasal anomalies, and their speech was judged to be within normal limits. This normal subgroup was made up of persons seen at Duke Medical Center for disorders unrelated to speech.

Figure 1 shows the instrumentation employed in this study. Bruel and Kjaer (B & K) instrumentation was used exclusively for the tests. The subjects were seated in a sound treated room (IAC Medical Room Model 402A). The room's acoustical characteristics were checked with a Bruel & Kjaer precision sound level meter and found to be within published specifications. A sound level meter was used inside the room to insure that each subject could monitor his overall acoustic radiation level. A specially designed chair for this project provided a headrest to maintain a steady head position and to allow for proper positioning of microphones. Once the subject's head had been positioned in a vertical plane, a B & K one-half inch microphone was placed approximately one-fourth inch from the subject's lips, and the housing of the microphone was positioned perpendicularly to the body of the subject. A second one-

half inch microphone with a probe attached was placed at the entrance to the nasal cavity, again positioned perpendicularly to the body of the subject. Our preliminary experimental data have indicated that the positioning of the receivers with respect to the plane of the subject's body has very little effect on the sound level recorded, but as anticipated the distance between the sources and the receivers produced a significant variation in the data recorded.

Two B & K one-half inch condensor microphones (type 4134) recorded the radiation sound pressure levels. A B & K two channel microphone selector (type 4408) was employed, with one channel being used for the nasal probe and one for the oral probe. After the nasal SPL measurements were recorded, the selector was switched to channel two for the oral SPL measurements.

Physical separation of the oral and nasal probes was attempted on a trial basis by means of a contoured bridge that fit across the subject's upper lip. Bridges of fiberglass and foam rubber, held in place by orthodontic head gear, were tested on five normal subjects. No differences in oral and nasal sound pressures were found for measurements with or without the bridges; therefore, the bridges were not used for purposes of this study.

In order to record the nasal radiation, a 4 mm diameter probe-tube was attached to one of the half-inch condensor microphones. The length of the probe-tube was 240 mm. The combined probe-tube condensor microphone was calibrated in accordance with the procedure outlined in the Bruel and Kjaer manual (*2*), and the resulting frequency response characteristics of the microphone with the probe attached were varied in order to duplicate the response curve for the "correct damping" as specified in the Bruel and Kjaer Manual. The response characteristic of the system was flat within ± 2.5 dB from 20 Hz to 9 K Hz and was considered suitable for the present study.

The signal from the oral microphone and the probe-tube microphone (nasal radiation) went into a B & K microphone selector (type 4408). The signal from the oral microphone and the probe-tube microphone (nasal radiation) was amplified by a B & K microphone amplifier (type 2603). A B & K graphic level recorder (type 2305) recorded the output signals from the amplifier. The one-half inch condensor microphone used to measure the oral sound pressure level was calibrated utilizing a B & K pistophone (type 4220). Then, using the pistophone, the nasal probe-tube condensor microphone was also calibrated.

The speech sample for each subject consisted of several sustained phonations of the vowel /i/. The subject was instructed to sustain the vowel /i/ for five seconds while his speaking level was monitored on a sound level meter. The test included five sustained vocalizations of /i/ for each nostril and five for the mouth.

TABLE 1. The mean and standard deviation of differences between oral and right and left nasal sound pressure levels for N (normals), X (cleft group—no gap), and O (cleft group—with gap).

	normal	*cleft*	
		no gap	*gap*
right			
mean	1.72813	8.11250	4.100
SD	1.38872	3.74164	3.13043
left			
mean	1.87344	8.33125	4.45154
SD	1.72785	3.55485	2.44555
total	32	16	13

Results

Table 1 presents the mean and standard deviation of differences between oral and right and left nasal sound pressure levels for the normal group (N-group), the cleft group with gaps (O-group), and the cleft group without gaps (X-group). Using the raw data, the left and right oral-nasal differences within the three categories were found to be not significantly different by t tests. F tests for homogeneity of variance demonstrated the appropriateness of the t tests.

The variances of the three groups were found to be nonhomogeneous; therefore, between-group t tests using raw data were deemed inappropriate. The larger variances were associated with the larger mean values indicating that a logarithmic transformation might yield homogeneous variances (*5*). Since some scores were zero, the $\log_e (x + 1)$ transformation was used. Table 2 presents the transformed means, standard deviations and significance levels of t tests of the indicated comparisons. All three categories differ significantly with the X- and O-group comparison showing the most significance. We conclude that the measures taken (oral-nasal SPL differences) are markedly different for normals and cleft palate subjects with or without velopharyngeal closure.

Discussion

The physiology of the surgically repaired cleft palate has often been compared with the movement of the normal palate. In the present study, even when the cleft palate subjects did obtain velopharyngeal closure, the degree of difference between their oral and nasal SPL measures was quite different from the degree of difference for the oral and nasal SPL measures for the normal subjects. The exact reason for this finding is not known since the same type of cinefluorographic analysis and SPL measurements were used for each group. As has often been pointed out, once structural anomalies of the oral and nasal cavities occur, even

TABLE 2. The transformed means $\log_e (x + 1)$, standard deviations, and significance levels of t tests of the comparisons of the groups' scores.

	right	*left*
N-group		
mean	3.55953	3.68850
SD	.87799	.85841
X-group		
mean	3.97248	4.12017
SD	.86408	.81290
	$.01 < p < .0125$	$.025 < p < .05$
N-group		
mean	3.55953	3.68850
SD	.87799	.85841
O-group		
mean	3.24696	3.33328
SD	.97353	.88268
	$.05 < p < .1$	$.05 < p < .1$
X-group		
mean	3.97248	4.12107
SD	.86408	.81290
O-group		
mean	3.24696	3.33328
SD	.97353	.88268
	$.005 < p < .0125$	$.0025 < p < .005$

with adequate reconstructive surgery, certain deviations may be noted. The significant difference found between the SPL measurements for the normal subjects and for those with a velopharyngeal gap would have been expected if the instrumentation and experimental procedures were correct. The utilization of this type of instrumentation would appear to be fruitful for future research.

Since a review of the literature failed to disclose any research dealing with the relationship between SPL measures for right and left nostril, and because a deviated septum, an asymmetrical movement of the palate during phonation, excess scarring tissue, or any of a number of other reasons might cause more pressure to be coming from one nostril than from the other, this factor was investigated. The results indicated no significant differences between SPL measurements for the left and right nostril for all three groups of subjects.

Summary

This study was designed to investigate the relationship between oral and nasal sound pressure level (SPL) as related to presence or absence of velopharyngeal closure. SPL measurements were made of normal sub-

jects with no velopharyngeal gap, of cleft palate speakers with a velopharyngeal gap, and of cleft palate subjects with no velopharyngeal gap. Statistically significant differences were found between the normal group and the cleft palate group with velopharyngeal gap, and between the normals and the cleft palate group with no gap. No significant differences were noted between the SPL levels for the right and left nostril for all the subjects.

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