Nasal Emission of Air and Velopharyngeal Function

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Nasal emission of air during speech production is a defect usually associated with cleft palate (*1–4*, *10*). Because of the clinical importance of assessing velopharyngeal competency, certain techniques have been developed which utilize measures of nasal leakage as an index of velopharyngeal function (*3*, *4*, *10*). Instrumentation such as the warm wire flowmeter or nasal anemometer has been described as being capable of serving 'the vital need of standardizing the clinical evaluation of patients' (*4*). The underlying assumption upon which the validity of these techniques rests has never been tested however. That is, in order to infer that nasal emission is, in fact, a measure of palatopharyngeal competency, one must show that nasal leakage is related to size of the velopharyngeal orifice. The present study was designed to test this assumption.

Method

An analog computer system, utilizing the pressure-flow technique (*5–7*) for estimating velopharyngeal orifice size, was used in this study (Figure 1). Briefly, this technique is based upon the assumption that velopharyngeal orifice size can be calculated from simultaneous measurements of the pressure drop across the orifice and airflow passing through. The pressure drop across the orifice (oropharyngeal pressure minus nasopharyngeal pressure) is measured by placing one catheter in the left nostril and another in the oropharynx (Figure 2). The nasal catheter is secured by a cork which blocks the nostril, creating a stagnant column of air. Both catheters are designed to measure static air pressures and transmit these pressures to a differential pressure transducer. Nasal airflow is measured by a heated pneumotachograph connected by plastic tubing to the subject's right nostril. The parameters of pressure and airflow are converted to electrical voltages, amplified and recorded on photo-sensitive paper. A microphone placed within one foot of the subject's chin records the speech sample.

Velopharyngeal orifice size is calculated from the parameters of pres-

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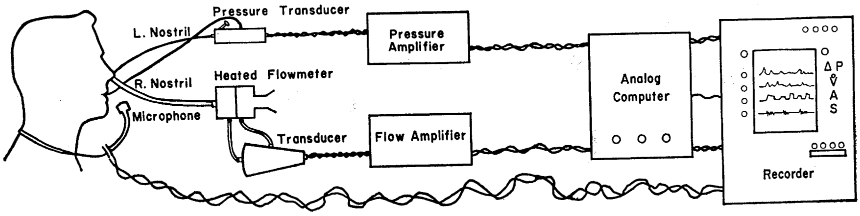

FIGURE 1. Diagrammatic representation of the analog computer system.

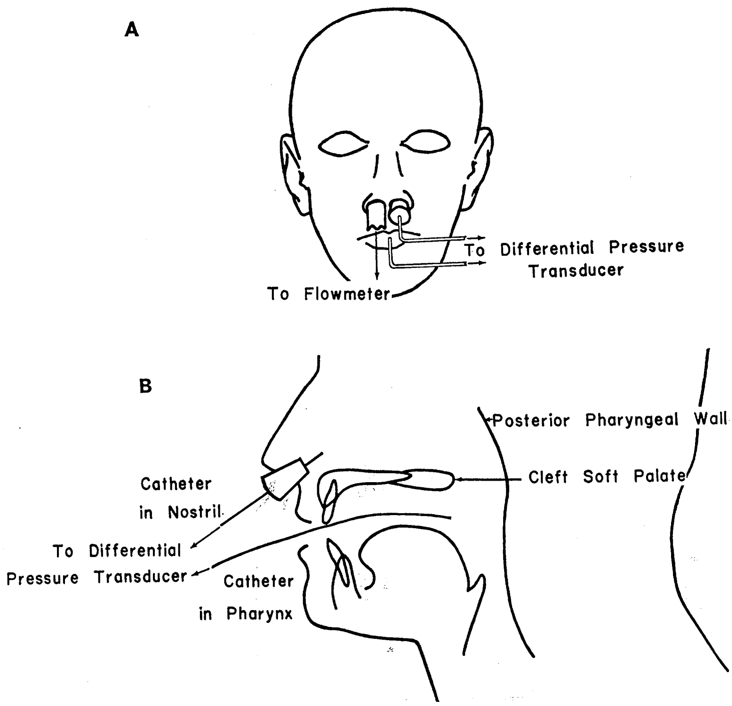

FIGURE 2. The pressure drop across the velopharyngeal orifice is measured by catheters placed in the oropharynx and nasal cavity and attached to a differential pressure transducer. Nasal airflow is measured by a heated pneumotachograph attached to the right nostril.

sure and airflow by the computer which instantaneously solves the hydraulic equation shown in Appendix 1.

Procedure

Twenty-eight cleft palate subjects ranging in age from 8 to 47 were used in this study. The sample included subjects with surgically-closed as well as prosthetically-treated clefts. Each subject was instructed to phonate a series of test words and sentences. The initial plosive consonant /p/ in *papa* was the sound selected for analysis (Figure 3).

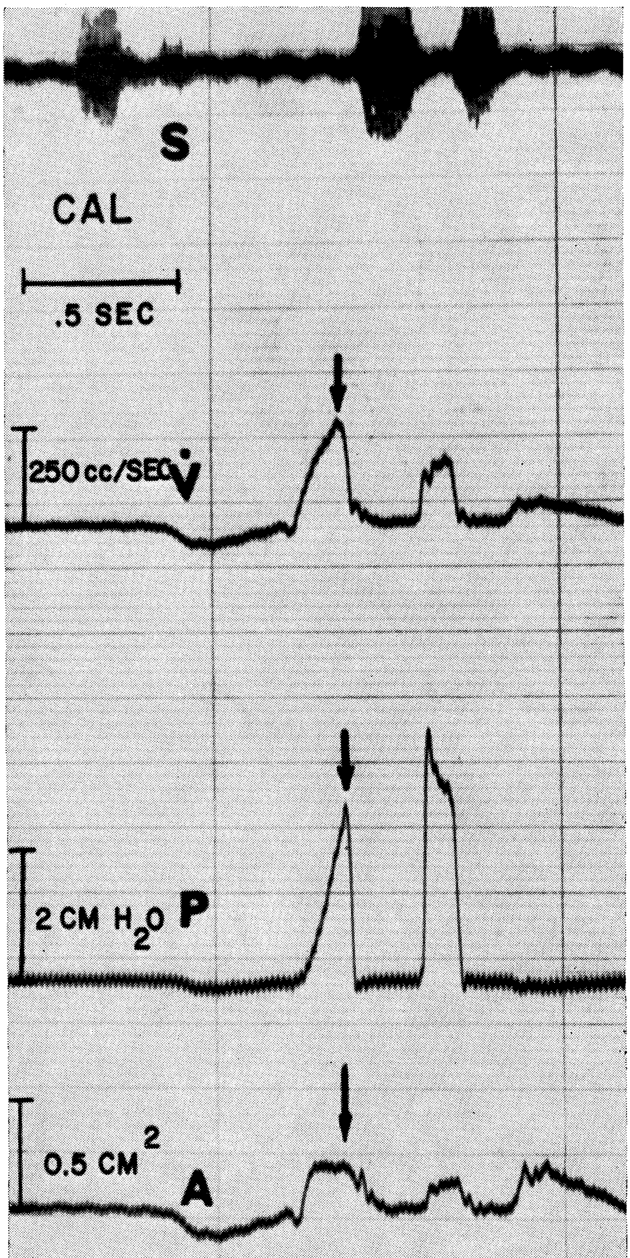

FIGURE 3. An oscillographic record of the word *papa* produced by a cleft palate subject. S is the sound record, $\dot{V}$ nasal emission of air, P orifice differential pressure and A area of the velopharyngeal orifice. Arrows point to where the measurements were made on the initial consonant p. It should be noted that the computer calculates orifice size for consonants when velopharyngeal orifice size is 1.0 cm^2 or less. Since pressure and airflow are quite low for vowels the computer does not calculate orifice size during vowel production.

Sounds requiring an open oral port, such as fricatives and vowels, were not utilized because, in the presence of velopharyngeal incompetency, the effects of oral port opening can mask the effects of velopharyngeal function.

Results

General Results. Figure 4 illustrates graphically the relationship between nasal emission of air during the production of the plosive /p/ and velopharyngeal orifice size. It should be noted that the range of orifice sizes includes sizes which can be considered to represent adequate closure (0–0.2 cm^2), slight inadequacy (0.21–0.4 cm^2), and moderate inadequacy (0.41–1.0 cm^2). The arbitrary groupings differentiating the degrees of adequacy is based upon personal interpretation of pressure-flow data in our laboratory. Gross inadequacy (above 1.0 cm^2) cannot be accurately measured with the present equipment because of the extremelv low differential pressures involved.

Statistical analysis of the data presented in Figure 4 reveals a correlation of .77 between nasal emission and orifice size, significant at the 1% level. A linear regression test yielded results which were also significant at the 1% level. This can be interpreted to mean that, for these pooled data (including values representing adequate, slightly inadequate and moderately inadequate closure), nasal emission is linearly related to orifice size. However, the observation (Figure 4) that this relationship becomes more variable as orifice size increases suggests the possibility that these data should not be pooled. To determine whether they should

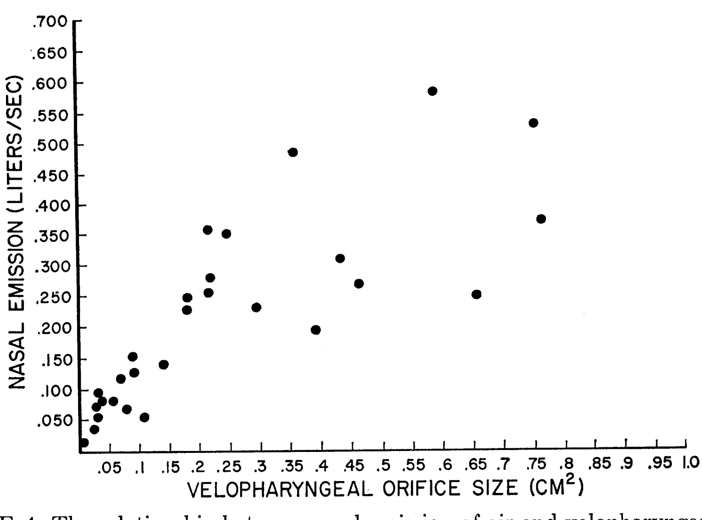

FIGURE 4. The relationship between nasal emission of air and velopharyngeal orifice size decreases in intensity as orifice size increases. This indicates that data from subjects with adequate closure should not be pooled with those from subjects with velopharyngeal incompetency.

not be, data were then grouped into two categories: adequate closure (0–0.2 cm^2) and inadequate closure (above 0.2 cm^2), and further analyzed.

Data from the 15 subjects who exhibited adequate velopharyngeal closure are illustrated in Figure 5. Linear regression reveals a significant linear relationship between nasal emission and orifice size. The strength of the relationship is further demonstrated by a correlation coefficient of .93.

The 13 subjects exhibiting velopharyngeal inadequacy (openings larger than 0.2 cm^2) provide quite different results. Figure 6 indicates wide scatter and the obtained correlation is .43.

GROSS INADEQUACY. As noted previously gross inadequacy cannot be accurately measured on the instrumentation used because of the low pressure drop across the velopharyngeal orifice. At these low pressures, the voltage output from the pressure amplifier is too low compared to the voltage output from the flow amplifier and the accuracy of the computer cannot be considered reliable. However, because it is of interest to know how gross inadequacy affects nasal emission, a method was devised for estimating orifice size within this range. When orifice pressure approximated zero, an arbitrary value equal to the lowest pressure which could be measured reliably at the highest amplifier sensitivity was used for the differential pressure value. The hydraulic equation was then solved manually from the arbitrary pressure and measured airflow values. Since the actual pressure was less than this amount, the calculated area of the velopharyngeal orifice was less than the actual area. Thus if

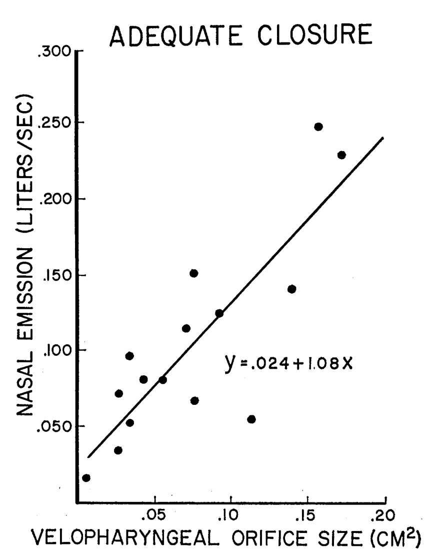

FIGURE 5. Linear regression of nasal emission of air on velopharyngeal orifice size in the range of adequate closure. A correlation of .93 indicates a strong relationship between the two parameters.

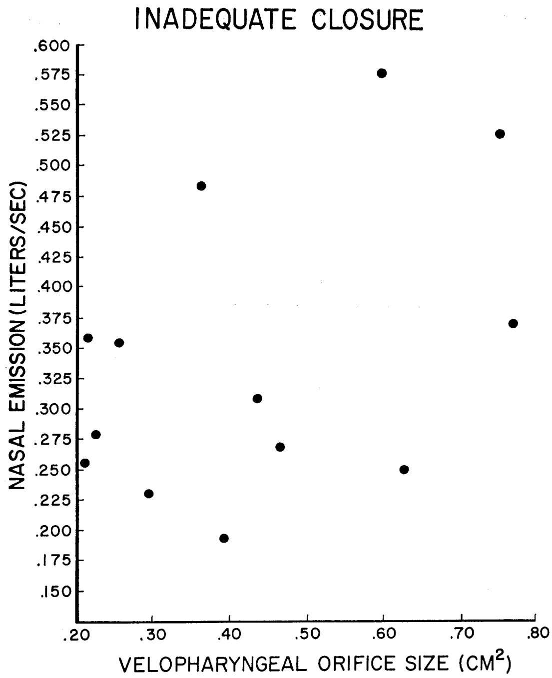

FIGURE 6. In the range of velopharyngeal incompetency nasal emission of air is not related to size of the velopharyngeal orifice.

the calculated area measured 4 cm^2, then it was recorded as being greater than 4 cm^2.

Two patients with wide clefts requiring speech appliances were used for this portion of the study. Orifice size prior to speech appliance construction measured greater than 4.0 cm^2 in one subject (Figure 7) and greater than 5.0 cm^2 in the other (Figure 8). Insertion of a preliminary appliance reduced the velopharyngeal opening in the first subject to an amount less than 0.7 cm^2 but greater than 0.2 cm^2. It can be easily observed that nasal leakage of air is not appreciably altered even though the sphincter is much less incompetent. It is only when velopharyngeal closure becomes competent (less than 0.2 cm^2) that nasal emission is significantly diminished (Figure 8).

Nasal Emission Rates. It is of interest to note that all subjects classified as having velopharyngeal insufficiency exhibited peak nasal emission rates greater than 175 cc/sec for the consonant /p/. On the other hand, all but two of the subjects classified as having adequate closure produced an acceptable /p/ with less than 155 cc/sec peak flows. The remaining two subjects had flow rates of 249 and 230 cc/sec at orifice sizes of 0.16 and 0.18 cm^2, respectively, and these openings are fairly close to the slight inadequacy range.

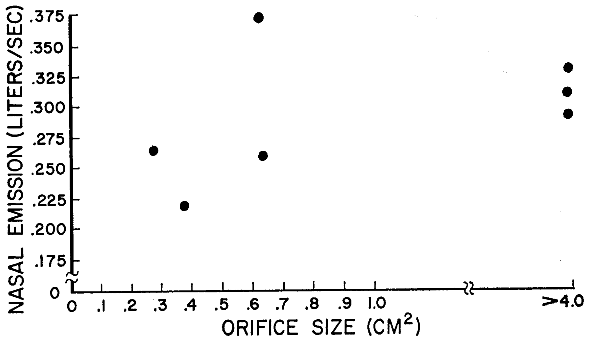

FIGURE 7. Patient I. Before construction of a prosthetic speech appliance orifice size was greater than 4.0 cm². After insertion of the appliance, orifice size is substantially reduced but because closure is still not adequate there is only a slight change in nasal emission of air. This indicates that the speech aid should be enlarged.

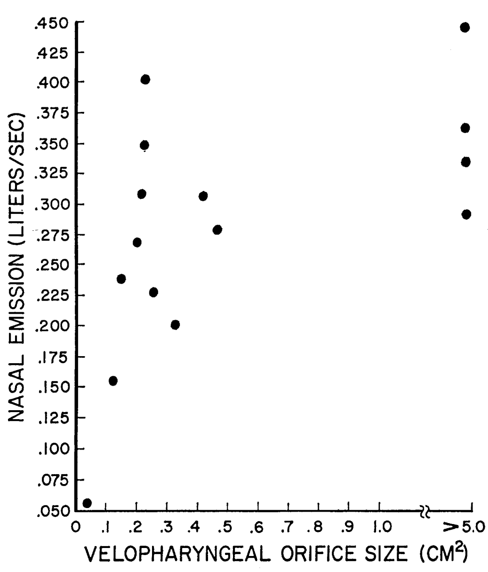

FIGURE 8. Patient II. Before construction of the appliance orifice size was greater than 5.0 cm². As previously noted a speech appliance apparently has little effect on nasal emission of air until competent velopharyngeal closure is obtained.

Discussion

Contrary to reports of other investigators (*3, 4, 10*), the present study indicates that all ranges of velopharyngeal incompetency cannot be reliably estimated from measurements of nasal emission of air. The correlation between the two parameters decreases in strength as sphincter inadequacy increases in magnitude. This may be attributed to the fact that the velopharyngeal mechanism seems to have a dichotomous effect on the respiratory aspects of speech. For example, previous studies in our laboratory (*8, 9*) have indicated that for plosive sounds made with an incompetent velopharyngeal sphincter, pressure and airflow characteristics are determined primarily by nasal resistance and respiratory effort and not by orifice size. This accounts for the high and linear relationship between nasal emission and orifice size in the range of adequate closure and for the low and apparently nonlinear relationship in the range of inadequacy.

Stated in other terms, respiratory effort and nasal resistance probably account for the variability in nasal emission rates observed among individuals with the same degree of velopharyngeal incompetency. For example, an individual with high nasal resistance to airflow can obtain a given intraoral pressure for plosives with less air release from the lungs than could an individual with the same degree of sphincter dysfunction but who has lower nasal resistance. Less air release from the lungs or less respiratory effort results in less nasal emission of air.

It appears, then, that the nasal flowmeter or anemometer has questionable value as a tool to assess the bases for speech problems of cleft palate speakers. At best, its use should be limited to gross judgments of velopharyngeal incompetency. That is, it is fairly safe to consider peak nasal flow rates of above 250 cc/sec during plosive sound production to be indicative of inadequate closure. However, the converse may not always be true. Flow rates of less than 250 cc/sec may occur in spite of sphincter incompetency if there is nasal blockage or decreased respiratory effort.

It is interesting to note that a speech appliance must provide adequate velopharyngeal closure before nasal emission of air is significantly reduced. It probably also follows that unless surgical reconstruction produces velopharyngeal competency very little reduction in nasal leakage of air should be expected.

Summary

A pressure-flow technique was utilized to determine whether nasal emission of air is a useful determinant of velopharyngeal competency. Results of this study reveal that although nasal emission of air is linearly and significantly related to orifice size in the range of competent closure (0 to 0.2 cm^2), there is no linear or significant relationship in the range of incompetency (greater than 0.2 cm^2). It can be concluded, therefore, that the usefulness of the nasal anemometer or flowmeter as a tool for assessing velopharyngeal function through the entire range of incompetency is questionable.

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Appendix 1

$$\text{orifice area} = \frac{\text{volume rate of nasal airflow}}{k\sqrt{2\left(\dfrac{\text{orifice differential pressure}}{\text{density of air}}\right)}}$$