Measuring Palatopharyngeal Competence with the Nasal Anemometer

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This report describes an instrument which measures nasal leakage (and, inferentially, palatopharyngeal competence) in normal and cleft palate patients under standardized and what are considered to be virtually normal conditions of speech. This device is referred to as a nasal anemometer, or a warm wire flowmeter, or a 'quantitative meter'. It was designed to fill a number of needs in the clinical evaluation of cleft palate and other functional abnormalities of the organs or speech (*1, 6, 9*).

The instrument serves the vital need of standardizing the clinical evaluation of patients in different centers, especially where new methods of surgery are being assessed or where effects of speech therapy are being investigated. Measurements of air flow under these conditions are greatly preferable to the subjective opinions of even the best clinicians (*2, 3, 8, 11, 12, 13*).

The warm wire flowmeter can measure with great sensitivity even minute alterations in the velocity and volume of air flow. It is easily suitable for the measurement of the different syllabic stresses in polysyllabic words. Since the instrument has essentially no back pressure, even changes in air flow within a single phoneme can be recorded if the paper-writer moves at sufficiently high speeds. Another advantage is that it is capable of measuring valving competence in essentially normal speech.

The meter is designed to measure air flow from the nose, mouth, or both. Recording is possible in cubic feet per minute or cubic centimeters per second of air at one atmosphere.

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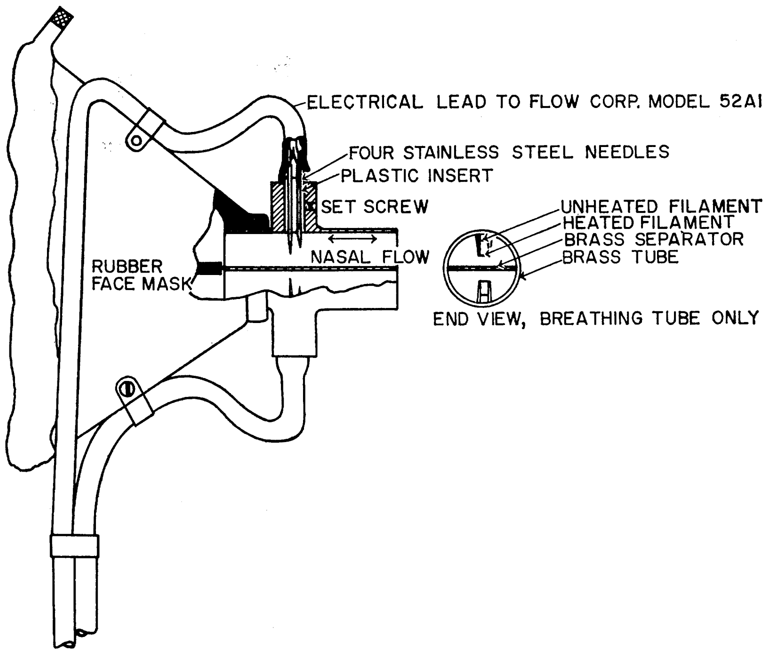

FIGURE 1. Schematic diagram to illustrate an anesthetist's adult face mask with partition separating nasal and oral chambers.

Description of Equipment

A previously published report (7) described the principle of the basic instrument for measuring simultaneous recordings of nasal and oral air flow. In the first nasal and oral anemometer, sensing elements were contained in a special fitting which was attached to a face mask. A rubber partition was placed to separate oral and nasal chambers with the small sensing element in each compartment (Figures 1, 2, and 3).

The purpose of this paper is to describe a change in technique for leakage only. Air flow changes may be measured by the cooling effect on a thin electrically heated wire filament referred to as the sensing element. This sensing element is contained in a special T-shaped probe (Figure 4). This probe is constructed so that it is interchangeable in a nasal, oral, or face mask (Figure 5). One of the nasal ports is blocked and the other, which carries the sensing probe, is used for nasal recording. The same mask can be adapted for oral recordings. The face mask is the conventional anesthetist's face mask for an adult with a covering to permit easy observation of the seal. The authors found it helpful to permit a parent to assist in handling the face mask to gain the confidence of young children, but the nasal and oral mask is strapped in the conventional manner (Figure 6). After assurance that the patient would not receive an anesthetic, cooperation is always obtained. One marked ad-

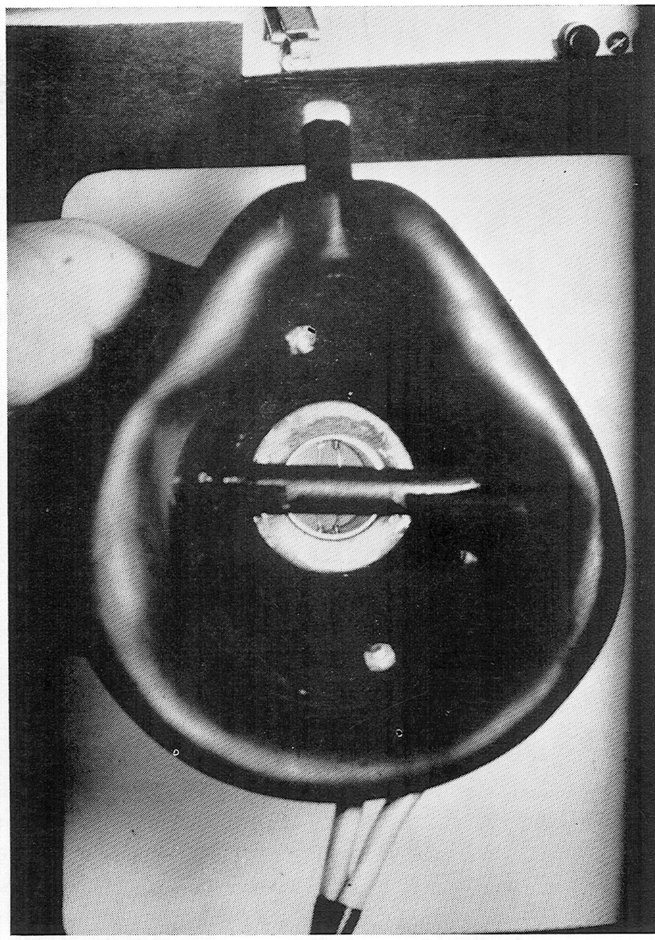

FIGURE 2. Anesthetist's adult face mask with two sensing elements for simultaneous recording of nasal and oral air flow.

vantage of this technique as compared to other pressure techniques of measuring velopharyngeal incompetency is its comfort and simplicity. Here, the young patient does not need to consciously control his oral musculature. Even children of three or four years of age may be tested. Figure 6 depicts a five year old youngster.

The small size of the sensing element (approximately .04 inches in length and .005 inches in diameter) results in negligible flow interference. The sensing element is connected to a flowmeter which measures linear velocity and is calibrated in feet per minute. The meter operates on a rechargeable, sealed, nickel cadmium battery. Fully charged batteries may be recharged overnight from standard 115 volt AC outlets. Battery life is approximately 10 years.

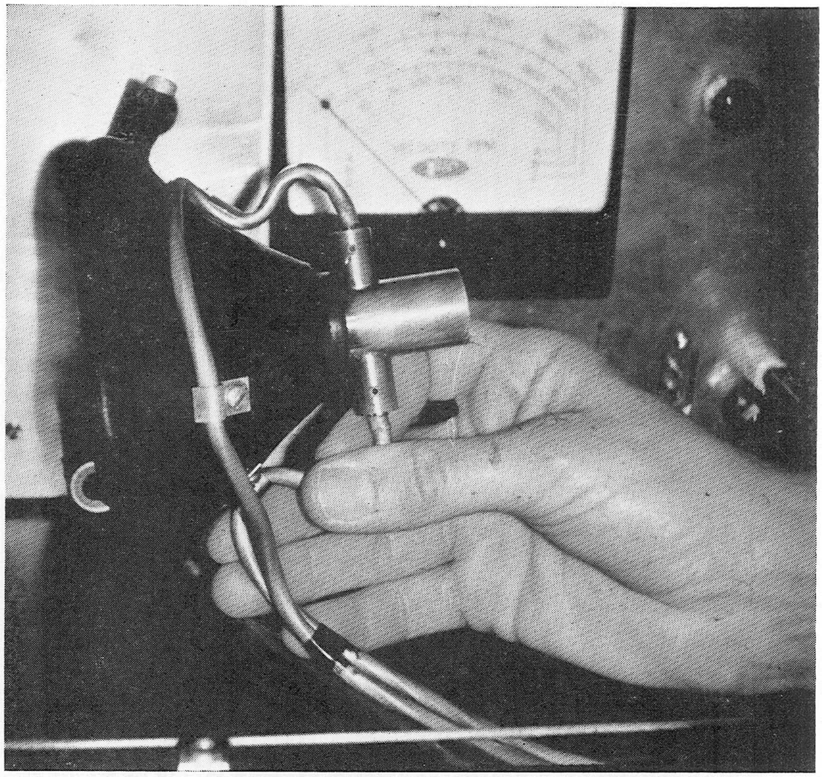

FIGURE 3. Side view of anesthetist's conventional face mask with two probes; one instrument with self-contained rechargeable batteries is in the background.

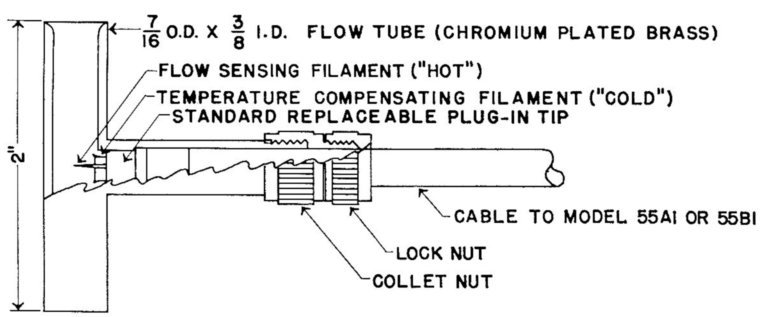

FIGURE 4. Schematic drawing of special T probe used to house interchangeable sensing element for nasal, oral, or face mask.

The special circuit automatically supplies just enough electrical current to the heated filament to maintain its absolute temperature above that of the unheated filament at a fixed ratio of six to five. Higher velocities of air flow have a greater cooling effect on the heated filament and automatically require more current to the heated filament to maintain

FIGURE 5. Warm wire anemometer with special T attachment for nasal, oral, or face mask.

the fixed temperature ratio. It is this current that is read on the meter panel and a proportional voltage is fed to the output terminals if a chart reading is desired.

In this study, readings were taken directly from the meter. Preliminary testing revealed close correlation between the recordings by a Sanborn recorder and the readings directly from the meter. A damping switch which decreases the fluctuations of the needle and provides a more stable reading was inserted in the meter. This proved to be of considerable help, especially in the cases where the flow of air was relatively turbulent. This single precaution led to very reproducible direct readings.

In this equipment the temperature of the room or of the air passing over the sensing probe (inhaled air as contrasted to exhaled air) does not affect the reading. If the airstream temperature changes, the temperature of the two wire filaments changes by the same amount, producing no change in the meter reading. Thus, the instrument responds only to velocity, correcting automatically for airstream temperature changes. Since the cross sectional area of the sensing element is known, the rate of flow can be calibrated in units such as cubic feet per minute. The probe

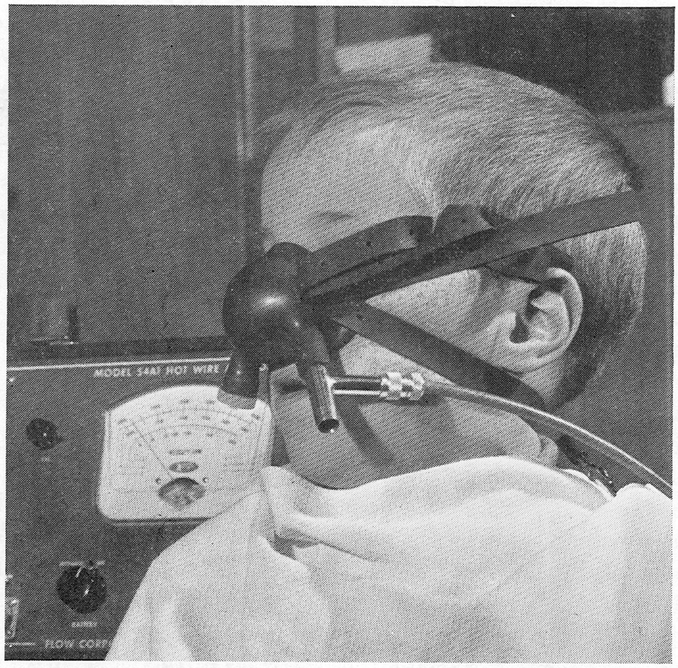

FIGURE 6. Nasal anemometer on five year old patient with adjustable head and neck band. (Instrument in the background.)

is the same for each mask (nasal, oral, or face) so that the readings at all these sites can be directly compared.

Experimental Methods

Development of the Nasal Anemometer. Preliminary experiments revealed that a specially designed nasal anesthetist's mask provided an excellent seal to permit all nasal air to pass out one exit where it could be measured. It was important to avoid any back pressure or turbulence in the nasal passages which would reduce or disturb the flow of air and give a false reading. The mask and small probe which were chosen met all these criteria.

The pressure of the nasal mask can be altered by changing the adjustable neck and head bands (Figure 6). The pressure may be placed mainly on the nasal bone to prevent occlusion of the nostrils. The seal is uniform and presses gently around the remaining part of the mask and provides one exit where we have placed the sensing element. One of the first masks contained two probes, one at each nostril. For those interested in very sensitive measurements of each nasal port, our original device may be approximated.

By blocking one port, we require all air to pass out the remaining exit. Previous testing with only one opening revealed no difference in reading, whether the port was centrally located, or located to one side as is presently employed. The present version of the mask has two openings since it is easier to manufacture in this form. Easy interchangeability of the probe is important. The nasal mask provides a close fit for the probe, but it may be removed to other masks with ease.

As previously noted, one of the marked advantages is the measurement of the nasal leakage under normal speaking conditions. Once placed in position, the mask requires no adjustments for the children or adults tested. This simplicity is in marked contrast to the conventional pressure techniques where even the adult patient is not always completely familiar with the muscle activity required for blowing or sucking.

Use of the Nasal, Oral, and Facial Anemometer. A pilot study was designed to evaluate the reliability of the warm wire flowmeter. Thirty-five cleft palate patients and 13 normal patients were tested. Each patient was administered the following: a) measurements of the air flow by the nasal, oral, and facial anemometer, b) speech tests, c) orthodontic examination, and d) pressure measurements. This paper will deal only with the first set of measurements, those involving the warm wire flowmeter. Future work will reveal the comparison of this device to other conventional means for evaluating palatopharyngeal competence. The following assessments were made: a) the speech tests consisted of a word intelligibility test and ratings, vowel nasality, and nasality in connected discourse judged by both trained teachers of speech and by untrained office personnel; b) the orthodontic examination included cephalometric x-ray films taken during rest position, maximum opening, and closure of the soft palate as well as during phonation of /p, b, and k/; c) pressure measurements were taken with the nasal anemometer and the Hunter[1] and Chase[2] oral manometer, nostrils opened and closed.

Under standardized conditions, each patient was requested to emit a prolonged vowel sound /i, u, and a/. They were instructed to give other sounds: ma-ma, me-me, puppy, sixty-six, kitty, and coca-cola. The patient was instructed to give the vowel sound at a comfortable speaking range. This was observed on a vu. meter. Five recordings were taken and the means and ranges in feet per minute for the normal and cleft palate patients were recorded (Tables 1, 2, and 3).

When the nasal anemometer is worn and the patient is instructed to exert positive pressure on the Hunter oral manometer, we observe a pressure of 14 and 16 ounces per square inch for the cleft palate and normal patients respectively; the flowmeter gives almost 500 feet per minute nasal leakage for the cleft palate patient to one foot per minute leakage for the normal patient. This is but one example to illustrate the sensitivity of the instrument.

[1] Hunter Manufacturing Company, Inc., Iowa City, Iowa.
[2] Emerson Manufacturing Company, Inc., Cambridge, Massachusetts.

TABLE 1. Nasal flow rates from nasal anemometer (feet per minute) for thirty-five cleft palate and thirteen normal children for four conditions.

Condition	Cleft Palate		Normal	
	Mean	*Range*	*Mean*	*Range*
/i/	122.4	0–405	15.0	0–92
/u/	139.4	0–405	2.0	0–10
/a/	36.4	0–125	39.2	0–160
ma-ma	155.6	30–420	228.9	85–330

TABLE 2. Nasal flow rates (feet per minute) and pressure measurements (ounces per square inch) with Hunter Manometer for two conditions.

Condition	Cleft Palate				Normal			
	Hunter Manometer		Nasal Flowmeter		Hunter Manometer		Nasal Flowmeter	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Expiration........	15.5	2–144	494.8	0–2700	16.6	11.21	0.7	0.4
Inspiration.......	10.0	2–84	424.0	0–1840	14.8	7.20	1.6	0.7

TABLE 3. Nasal flow rate (feet per minute) and pressure measurements (units of pressure) with Chase Manometer for two conditions.

Condition	Cleft Palate				Normal			
	Chase Manometer		Nasal Flowmeter		Chase Manometer		Nasal Flowmeter	
	Mean	*Range*	*Mean*	*Range*	*Mean*	*Range*	*Mean*	*Range*
Expiration.........	30.5	9–75	557.2	0–1680	50.3	46–54	1.3	0–5
Inspiration........	28.8	2–71	507.5	0–400	59.3	53–65	0.8	0–3

Discussion

The usefulness of this equipment to the field of speech has already been cited. The technique may have general applicability to other specialities of science (*4, 5, 10*). An instrument which can precisely measure air flow through nasal and oral cavities may have other applications in respiratory physiology. Tidal air volume for example may be measured more simply and practically by this instrument. Another possible application may be the comparative patency of the left and right nasal airways. A practical application of this equipment has been suggested in that it may be used to compare the efficiency of decongestant agents on the left and right airways of the same individual.

Summary

The measurements in this study are those obtained by the cooling effect of air passing over the warm wire sensing unit. The sensing unit consists of a heated wire filament and an unheated wire filament, both exposed to the air stream. The special circuit automatically supplies just enough electrical current to the heated filament to maintain its absolute temperature above that of the unheated filament at a fixed ratio (about 1.2:1.0). Higher velocities of air flow have a greater cooling effect on the heated filament and call automatically for more current to the heated filament to maintain the fixed temperature ratio. It is this current that is read on the panel meter. With this principle, the authors utilize a nasal anemometer to determine the flow rate in feet per minute when normal and cleft palate patients gave sounds under standardized conditions. We note that when the sound/u/ is given for the cleft palate patients, we get an average of 139 feet per minute while the normal patients give only two feet per minute; however, when a sustained /a/ is given, we obtain 36 and 39 respectively. This conclusively illustrates /i/ and /u/ would be a better sound to test nasal leakage rather than /a/.

Nasopharyngeal competence is the ultimate measure of success of any cleft palate surgical reconstruction. Previous techniques to measure nasal competency enlisted mechanical means which utilized sucking or blowing devices where the nasal passageway was first patent then blocked. The nasal anemometer has the advantage of recording nasal leakage during essentially normal speech under standardized conditions. Most important, however, is the aspect of giving a quantitative repeatable figure to measure nasal leakage. Thus, we remove much of the personal bias of any operator, as well as the willingness or ability of the patient to cooperate.

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