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Rhinomanometric recording in children

Beni Solow and Ellen Greve, Copenhagen, Denmark

SUMMARY

The present paper describes the development of a method for rhinomanometric assessment of nasal respiratory resistance in children, based on a commercially available equipment, the Mercury Nasal Resistance Meter, NR 1.

The instrument was modified to improve performance, and a special technique was developed for individual lining of the nose mask. The posterior rhinomanometric technique was further modified by fitting the oral tubing with a collar, and by the use of a bio-feedback procedure based on oscilloscope display of the flow-pressure diagram. It could then be used in all subjects, a considerable improvement over previous methods.

The error of the method was analysed in a sample of 17 children aged 8–12 examined at two occasions. There was no systematic error. For the posterior method the method error within a session was about 0.2 cm H_2O/l/sec at a flow rate of 0.2 l/sec.

INTRODUCTION

Assessment of the nasal respiratory resistance can provide valuable information in the clinical handling of afflictions of the nasopharyngeal region. Since Zwaardemaker (1891) described how a cold mirror held under the nose could be used to examine nasal respiration, and Courtade (1903) described his Pneumodographe based on the same principle, more than thirty methods for recording and measuring the nasal resistance have been published. Among these may be mentioned those of Stoksted (1951, 1959), Aschan, Drettner and Ronge (1958), Masing (1965), Ingelstedt, Jonson and Rundcrantz (1969), Fischer (1970), Kern (1973), Bachmann (1973), Masing and Frimberger (1974). Due to the complicated nature of the nasal regulation of airflow, and the rapid technological and electronic developments in instrumentation, no single method has so far gained general acceptance. It is the purpose of the present paper to describe a rhinomanometric method which has been developed for the measurement of nasal respiratory resistance in children by means of a relatively new commercially available equipment.

METHODS

Equipment

Nasal respiratory resistance is usually defined as pressure drop over the nose divided by airflow through the nose, $NRR = \Delta p/\dot{V}$.

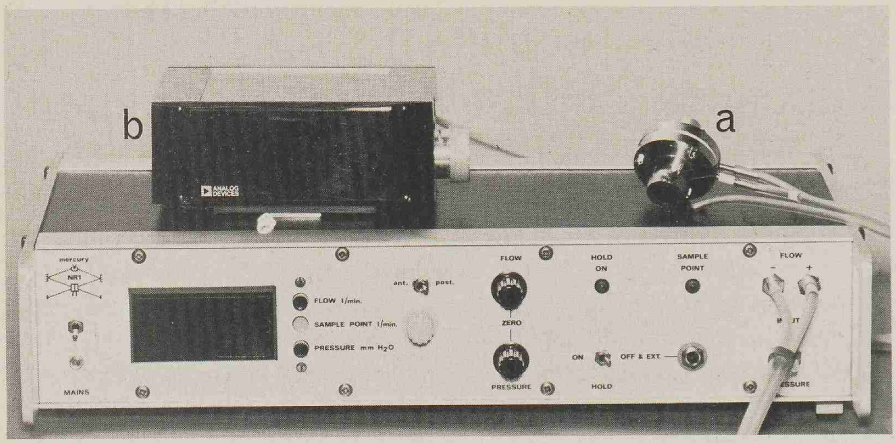

Figure 1. NR1 Nasal resistance meter. a. Flowhead. b. Extra digital display.

In the present study, pressure drop and flow were recorded by a Nasal Resistance Meter, NR1[1], (Figure 1), which is based on two membrane-type differential pressure transducers. A threshold feature enables the apparatus to retain on display the pressure value corresponding to a preselected flow threshold.

To provide better resolution, the original digital display of the NR1 had to be replaced by one with an additional decimal digit. Moreover, the equipment was modified to accept plug-in of an extra display with a higher refresh rate (6/sec) which permitted readout in the natural respiratory rythm.

The NR1 was further modified by the installation of a switch-controlled time delay in the flow circuit to compensate for the delay in the timing of the pressure pulse caused by the use of an extra length of catheter in the anterior recording procedure.

The equipment was supplemented by a storage screen oscilloscope to permit monitoring of the recordings by continuous display of the pressure-flow diagram (Figure 2).

Due to temperature sensitivity, the instrument had to be switched on for about 1 hour before stable zero-adjustments could be performed. Weekly calibration of pressure recording[2] and flow recording[3] were found to be necessary to ensure long-term stability of the recordings (Figure 3).

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[1] NR1 Nasal Resistance Meter, Mercury Electronics, Glasgow, Scotland.

[2] Durablock® inclined manometer type M 102-AV, Dwyer Instruments, Inc., Michigan City, IN 46360, USA.

[3] Rotamesser® flowmeter type LIVF-01, Rota Apparate- und Maschinenbau, Baden, W, Germany.

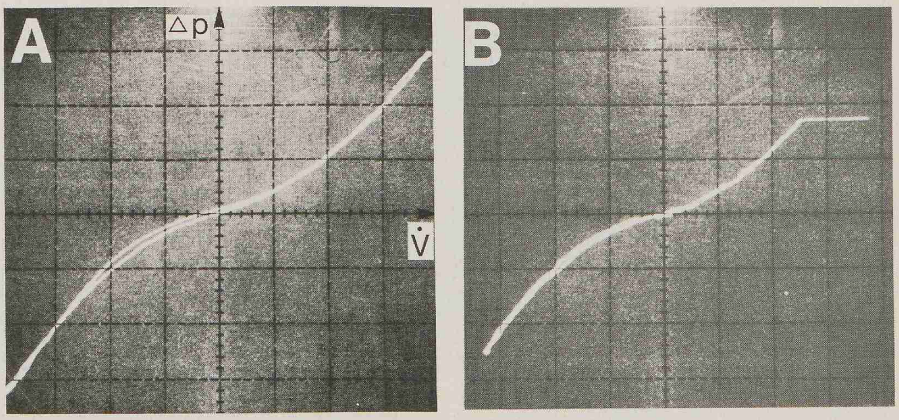

Fig 2.
A. Oscilloscope display of flow ($\dot{V}$) and pressure drop (Δp) during a respiratory cycle.
B. Effect of threshold feature on curve shape: Threshold set at 0.2 l/sec. Level of horizontal segment indicates pressure drop at threshold.

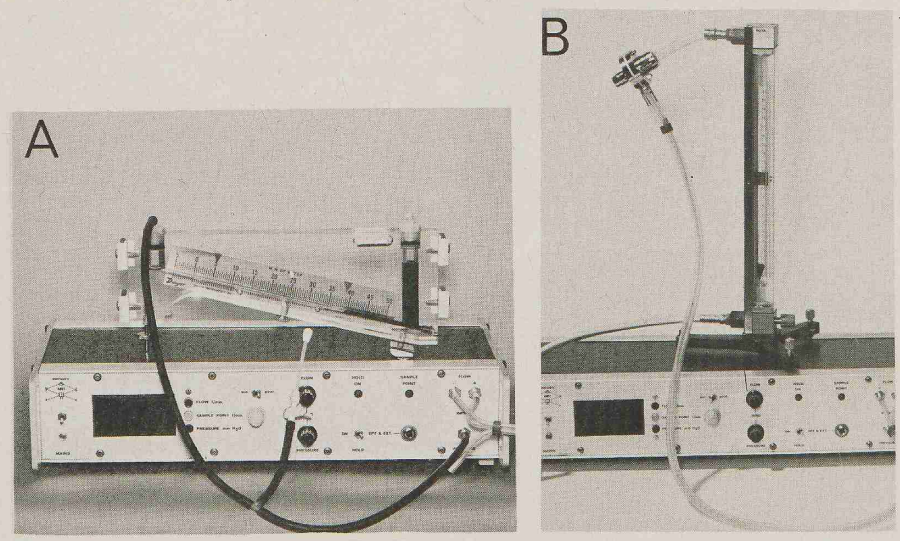

Figure 3.
A. Calibration of pressure recording. Dwyer manometer attached in parallel to pressure inlet.
B. Calibration of flow recording. Rota Laboratory flowmeter attached to flowhead.

PROCEDURES

Recording of pressure drop

In *posterior* rhinometry, the resistance of the total nasal passage is measured. The retronasal pressure is recorded by means of a short length of tubing inserted in the oral cavity.

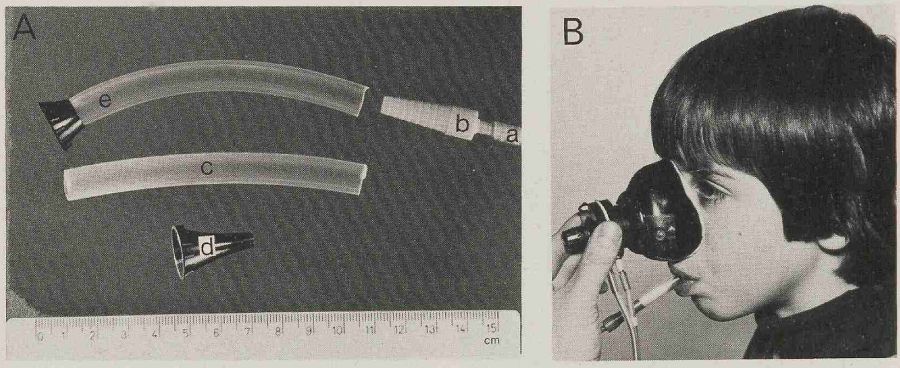

Figure 4.
Posterior rhinomanometric recording.
A. Oral tubing. a. Pressure inlet tube of NR1. b. Fitting. c. 9 mm plastic tubing. d. Disposable tip for otoscope. e. Part of otoscope tip used as collar on plastic tubing.
B. Recording procedure.

A 10 cm length of disposable tubing connected to the tube of the recording equipment by a fitting was found to be suitable. The 4 mm tubing supplied by the manufacturer could be used successfully only in few subjects due to occlusion by saliva or contact with the oral mucosa. Instead, a length of 9 mm tubing fitted with an 18 mm collar, produced from the disposable tip[4] for an otoscope by cutting off about 1 cm, was found efficient in preventing contact between tongue and soft palate (Figure 4). During recording, the child holds the oral tubing and is instructed to insert it as far back in the mouth as possible. By the use of this technique in combination with the oscilloscope bio-feedback technique described below, the Posterior rhinomanometry could be carried out in all subjects.

In *anterior* rhinometry, the resistance for each nasal half is obtained by sealing the pressure recording tube into the opposite nostril, the measured pressure thus being identical to that behind choanae. In the present study, a procedure developed at the Department of Otolaryngology, Malmö, (University of Lund, Sweden) was used (Figures 5–6). A piece of adhesive tape[5] is cut into a 2 by 3 cm size and is pierced from the non-adhesive side by a length of 1.2 mm polyethylene tubing. The end of the tubing is flared out by briefly exposing it to a flame, and the tube is retracted until the flared-out collar engages the adhesive surface of the tape. The joint is tightened on the non-adhesive side by a tightening mass[6]. An

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[4] 4 mm disposable tips for fiber optic otoscope, Welch Allyn International, Scaneteles Falls, NY 13153, USA.
[5] Leukoflex® tape, Beiersdorf AG, Hamburg, W. Germany.
[6] Bostic® Karosserikit 900, Bostic AB, Helsingborg, Sweden.

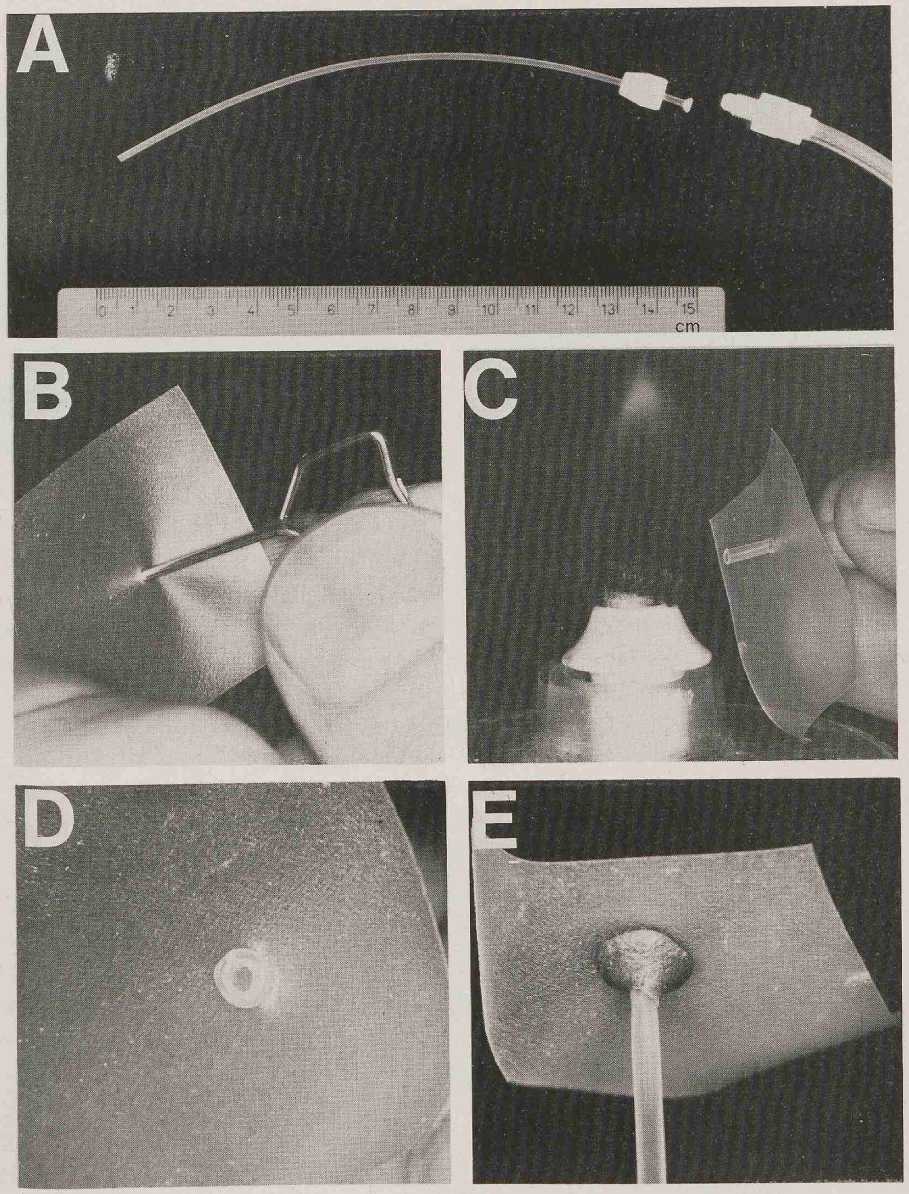

Figure 5. Preparation of catheter for anterior rhinomanometric recording.
A. Prefabricated catheter with fitting for pressure inlet tube.
B. Adhesive tape is perforated.
C. Pierced by the catheter which is flared out by flame.
D. Retracted to engage tape.
E. Sealed on non-adhesive side. Procedure developed by Department of Otolaryngology, Malmö (University of Lund, Sweden).

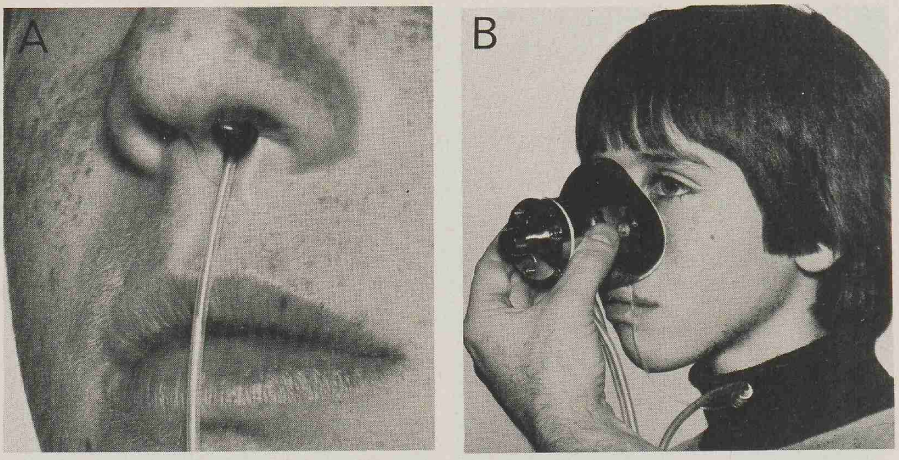

Figure 6. Anterior rhinomanometric recording.
A. Attachment to nostril.
B. Recording procedure.

airtight non-deforming attachment to the nose is then produced by simply sticking the adhesive tape onto the rim of the nostril. In order to connect the polyethylene tubing to the tubing of the present equipment, a stock of 15 cm lengths of polyethylene tubing with fittings for a 4 mm tubing at one end were produced[7] (Figure 5A). The method could be applied in alle subjects with no substantial problems.

Recording of flow

Nasal airflow was recorded by a pneumotachygraph placed in a mask. The NR1 equipment included an adult size inflated-rim mask covering nose and mouth. A mask covering only the nose (Aschan, Drettner and Ronge, 1958; Linder-Aronson, 1970) was found to be preferable, permitting a better control of the insertion of the oral tubing. However, all masks tested produced unstable results due to poor fit or deformation of the soft tissues. A procedure was therefore developed for individually lining the rim of the mask for each subject (Figure 7). The "Everseal" mask[8] was found to be most suitable for this purpose. To secure adhesion of the lining material, the inverted edge of the mask was painted with an adhesive liquid[9] and allowed to dry for a few minutes. For lining, "Xantopren® function"[10], a material normally used for taking impressions in the preparation of

[7] Catheter type 6715AO pol 6. Surgimed A/S, Ølstykke, Denmark.
[8] Everseal mask size 0, Medical & Industrial Equipment, Ltd., London, England.
[9] HOLD adhesive, Hill Bros, Ltd., Hull, England.
[10] Xantopren® function, Bayer AG, Leverkusen, W. Germany.

certain types of dentures, was used. The material is doughlike in consistency and sets to an elastic consistency a few minutes after the admixture of two hardening liquids. The setting time is sufficient for placing of the material on the rim of the mask, and the impression taking by gently placing the lined mask in position over the nose.
After the adoption of the procedure of lining the nose mask individually for each subject, the variability in the recordings due to poor fit of the nose mask was practically eliminated.

Monitoring of the recording
Due to the many possible sources of error during the recording session, and the sensitive physiologic processes involved in the control of nasal airflow, it is necessary to monitor the continuous changes in flow and pressure drop during the entire recording session. The optimal equipment for monitoring is a storage-screen oscilloscope in the *X–Y* mode (Figures 8–9).
During the recording, the child is seated facing the storage screen. When difficulties are encoutered due to blocking of the oro-pharyngeal passage during the posterior recording, a *bio-feedback technique* is used for conditioning the child's muscular control. By pointing out to the child when the correct flow-pressure curve appears on the screen among the random traces seen during the blocking of the oro-pharyngeal passage, even four-year old children could be taught to control their oral soft-tissues sufficiently to permit the posterior recording.

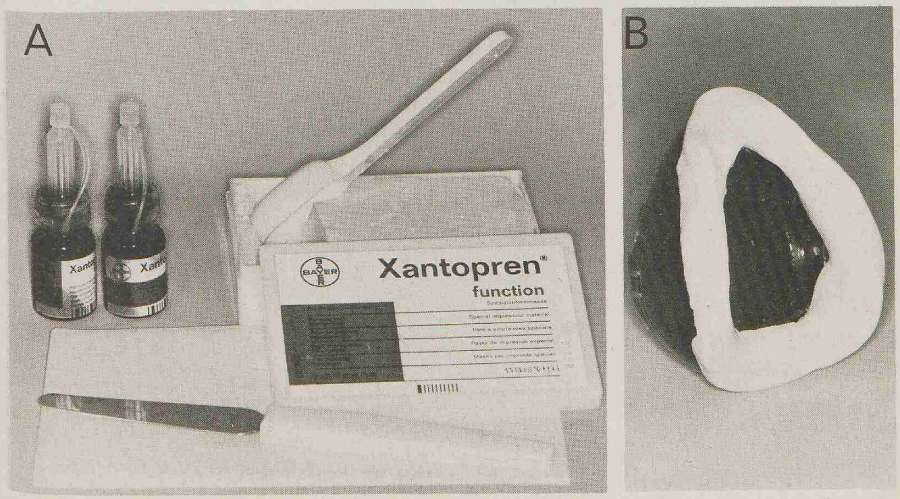

Figure 7. Lining of mask.
A. Lining material.
B. Everseal mask with fitted lining.

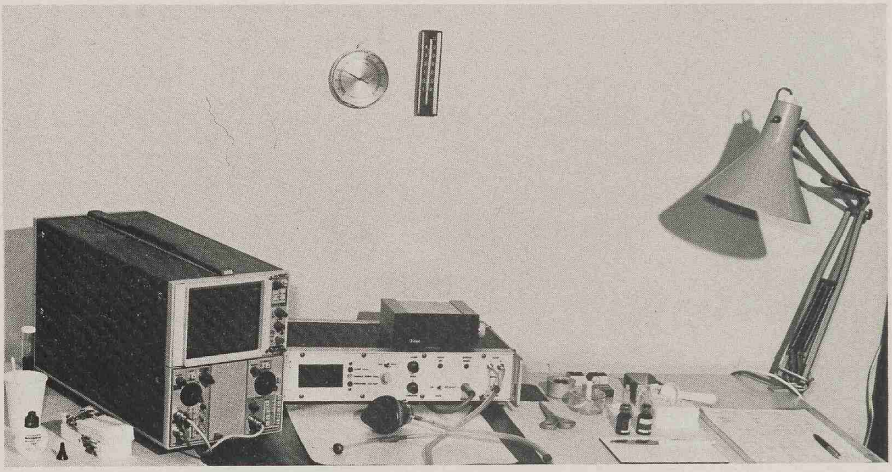

Figure 8. Set-up for rhinomanometric recording.

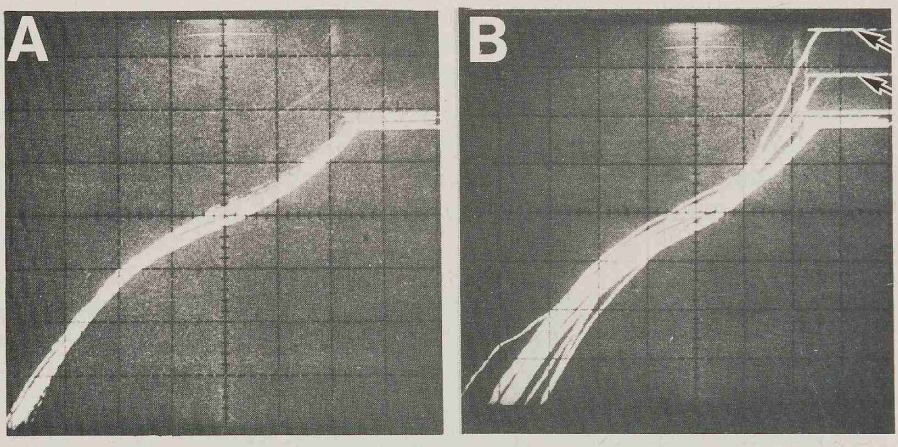

Figure 9. Monitoring of recording session.
A. Horizontal segments closely spaced, indicating stable recordings.
B. Closely spaced segments accepted, two outliers (arrows) rejected.

ERROR OF THE METHOD

In order to assess the error of the method for the rhinomanometric recordings, a sample of children in orthodontic treatment at the Institute of Orthodontics, the Royal Dental College, Copenhagen, were recorded at two occasions, two weeks apart.

The sample comprised 6 boys and 11 girls in the age range 8 to 14 years. Before the recording, each child was administered 2–3 drops of 0.5% Neosynephrine® in each nostril. For posterior rhinomanometry a flow threshold of 0.2 l/sec was used, for the anterior recordings a threshold of 0.1 l/sec was used. Each type of recording

was repeated in four series, each comprising four respirations.

The results obtained at the two occasions, the mean differences and the method errors are given in table 1. A comparison of the different series of recordings obtained at the first session is given in table 2.

Neither the between-session nor the within-session comparison showed any systematic differences significant at the 5% level.

The comparison of the recordings obtained at the two occasions showed method errors of about 0.5 cm H_2O/l/sec for the posterior method and about 4.5 cm H_2O/l/sec for the anterior method. Comparison of the first and second series and of the first and fourth series of recordings at the first recording session showed method errors of about 0.2 cm H_2O/l/sec for the posterior method and about 0.8 cm H_2O/l/sec for the anterior method.

Table 1. Nasal respiratory resistance in children (cmH_2O/l/sec). Comparison of measurements two weeks apart.

Method	Flow threshold l/sec	Sample size *N*	1. recording		2. recording		Difference		
			Mean	SE	Mean	SE	Mean	SE	*s(i)*
Posterior	0.2	17	1.62	0.14	1.77	0.14	0.15	0.17	0.50
Ant. right	0.1	16	5.29	1.45	4.34	0.56	-1.09	1.54	4.29
left	0.1	16	3.81	0.27	6.86	1.51	2.96	1.52	4.65

Each measurement was calculated as the mean of sixteen recordings. The method error, $s(i) = \sqrt{\Sigma d^2/2N}$, where N is the sample size, and d the difference between two measurements.

Table 2. Method error for nasal respiratory resistance (cm H_2O/l/sec). Comparison between measurements obtained at the same session.

Method	Flow threshold l/sec	Measurement No. compared	Sample size *N*	Differences				
				Min.	Max.	Mean	SE	*s(i)*
Posterior	0.2	2-1	17	−0.3	0.9	0.12	0.09	0.26
	0.2	4-1	17	−0.4	0.4	−0.05	0.06	0.17
Ant. right	0.1	2-1	17	−1.1	3.2	0.19	0.27	0.78
	0.1	4-1	17	−1.7	1.9	−0.16	0.21	0.61
left	0.1	2-1	17	−2.5	2.8	−0.09	0.27	0.76
	0.1	4-1	17	−3.3	2.0	−0.20	0.26	0.75

Each measurement was calculated as the mean of four sequential recordings. The method error, $s(i) = \sqrt{\Sigma d^2/2N}$, where N is the sample size, and d the difference between two measurements.

DISCUSSION

The multitude of methods developed for recording of Nasal Respiratory Resistance reflect the problems of obtaining representative, reproducible and valid measurement of this physiological parameter.

Due to the turbulence created at higher airflow rates the relationship between pressure drop and flow is not constant during the respiratory cycle, and the pressure-flow diagram has a typical reverse sigmoid shape. The ratio between pressure drop and airflow at a single point of the curve therefore cannot be used to characterize all aspects of the nasal respiratory resistance in a given physiologic situation. A number of authors have argued that for various values of x, the ratio $\Delta p/\dot{V}^x$ would remain constant over the entire respiratory cycle (Aschan et al., 1958; Spoor, 1963; Masing, 1965; Drettner, 1969; Fischer, 1970; Kern, 1973). It has been shown, however, that these ratios were actually still not constant for all flow rates (Solomon and Stohrer, 1965; Bachmann, 1973).

In the present study the approach was chosen to measure the pressure drop only at a single, relatively low airflow value under standardized conditions. The recorded values therefore can be used only for intra- and inter-individual comparisons under the same standardized experimental conditions.

The most commonly used rhinomanometric method has been the one in which pressure drop is recorded by the posterior method. This method obviously does not work when the oral cavity is sealed posteriorly by contact between velum and tongue. However, voluntary control of the position of the velum is difficult for adults, and even more so for children.

Two procedures developed in the present study served to eliminate this source of failure of the posterior recording. The use of an oral tubing fitted with a collar induced the subject to elevate the velum by reflex to avoid unpleasant contact with the collar. The use of the bio-feedback technique, in which the oscilloscope display provided an immediate visual reward for correct behaviour, further supported this conditioning of velar positional control.

Some authors report that the posterior method cannot be used in 25% to 50% of the subjects examined (Kortekangas, 1972; Kern, 1973). The finding that posterior rhinomanometric recordings could be carried out in all subjects in the present study thus constitutes a considerable improvement over previous methods.

In anterior rhinomanometry, the main technical problem is the attachment and sealing of the pressure recording tube to one nostril. Some of the sealing procedures reported in the literature have been found to produce significant deformation of the flow limiting segment (Bridger, 1970) of the opposite nasal half, thus affecting the resistance which is being recorded (Masing, 1965). It has been shown, moreover, that when one nostril is blocked, tonus in the opposite alar musculature increases, with a possible effect on the nasal resistance (Van Dishoeck, 1937).

The method adopted in the present study of using adhesive tape to seal the nostril and to suspend a pressure recording catheter seemed to eliminate the problem of physical deformation of the nostril. On the other hand, the increased tonus in the opposite, free nostril would seem to be inherent in the method. The recordings obtained by the anterior method have therefore been treated as separate entities, instead of being used as a basis for calculation of the total nasal respiratory resistance.

The analysis of the error of the method showed that the rhinomanometric method for assessment of nasal respiratory resistance described above produces results which are reproducible within the individual recording session with a very small method error.

Comparison of the results obtained at two recording sessions two weeks apart showed considerably larger method errors. This may have been due to the frequent occurence of rhinitis in the period of study and probably reflects true fluctuations in the nasal resistance which could not always be eliminated by the use of nose drops.

ZUSAMMENFASSUNG

Der vorliegende Beitrag beschreibt die Entwicklung einer Methode zur rhinomanometrischen Beurteilung nasalen Atmungswiderstands bei Kindern. Die der Method zugrundeliegende Ausrüstung war das Messgerät "Mercury Nasal Resistance Meter, NR1".

Das Gerät wurde abgeändert, um die Leistung zu verbessern, und eine besondere Technik wurde im Hinblick auf individuelle Anpassung der Nasenmaske entwickelt. Die posteriore rhinomanometrische Technik wurde ferner abgeändert, und zwar durch die Ausstattung des Mundstücks mit einem Kragen sowie durch die Anwendung eines auf einem oscillographischen Strömungs-Druck-diagramm basierten Bio-Rückkopplungsverfahrens. Die Abmessung konnte hiernach bei allen Untersuchungspersonen durchgeführt werden, was gegenüber früheren Methoden eine erhebliche Verbesserung bedeutete.

Der Verfahrensfehler wurde aufgrund einer Untersuchungsgruppe von 17 Kindern im Alter von 8 bis 12 Jahren analysiert. Die Kinder wurden zweimal untersucht. Es lag kein systematischer Fehler vor. In der einzelnen Versuchsreihe war der Verfahrensfehler der posterioren Methode ungefähr 0.2 cm H_2O/L/Sek bei einer Ströhmung von 0.2 L/Sek.

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B. Solow, dr. odont.
E. Greve, D.D.S.
Institute of Orthodontics
Royal Dental College
Jagtvej 160
DK-2100 Copenhagen Ø, Denmark