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Rhinomanometric method error in the assessment of nasal respiratory resistance

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SUMMARY

Reproducibility of nasal resistance recording is important if meaningful clinical and investigative data are to be assembled.

The present study investigated by duplicate determination, reproducibility of anterior (unilateral) and posterior (bilateral) recordings of nasal respiratory resistance (NRR) for 12 subjects.

Improved accuracy was achieved with frequent use of a calibration device and visual feedback for the patient.

The results show that the recordings are reproducible with a small method error of between 13.6 Pascals/cc/sec x 10^3 and 41.5 Pascals/cc/sec x 10^3.

INTRODUCTION

Rhinomanometry is the term given to the measurement of nasal resistance to airflow. The regulating mechanisms that control this airflow are complex and the accurate recording of nasal respiratory resistance (NRR) is important if the diagnostic value of the technique is to become well established. Many methods have been published for recording and measurement (Aschan et al., 1958; Rasmus and Jacobs, 1969; Maran et al., 1971; Kern, 1973; Mackay, 1979; Masing, 1979; Broms et al., 1979; Mygind, 1980; Solow and Greve, 1980; Gurley and Vig, 1982), but until recently no standards have been set, although suggestions concerning standards had previously been made by Kern (1973, 1977, 1981) and Broms et al. (1982). In 1983 the first International Meeting on Standardisation of Rhinomanometry was held in Brussels, Belgium and recommendations were made concerning terminology, methods of measurement, calibration and expression of results (Clement, 1984).

The present study was designed to test the reproducibility of nasal respiratory resistance (NRR) measurements determined by a Mercury NR3 computerised rhinomanometer*, to establish that accurate recordings could be made.

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SUBJECTS AND METHODS

A. Equipment development

A pilot study was carried out with a commercially available rhinomanometer NR1 (Mercury Electronics). This equipment had a liquid crystal display and measurements or airflow at a fixed pressure, or pressure at a fixed flow could be read from the meter. The liquid crystal display had a slow refresh rate and its response to the varying analogue input was inadequate. No visual feedback for the patient was available as suggested by Solow and Greve (1980) and the fit of the face mask provided was poor. No calibration device was available with the machine to test the accuracy of the measurement.

After initially proposing to increase the refresh rate of the liquid crystal display so a more rapid response occurred, it was decided to use the sigmoid curve produced on an X/Y plotter by the rhinomanometer (NR1) during a respiratory cycle. This

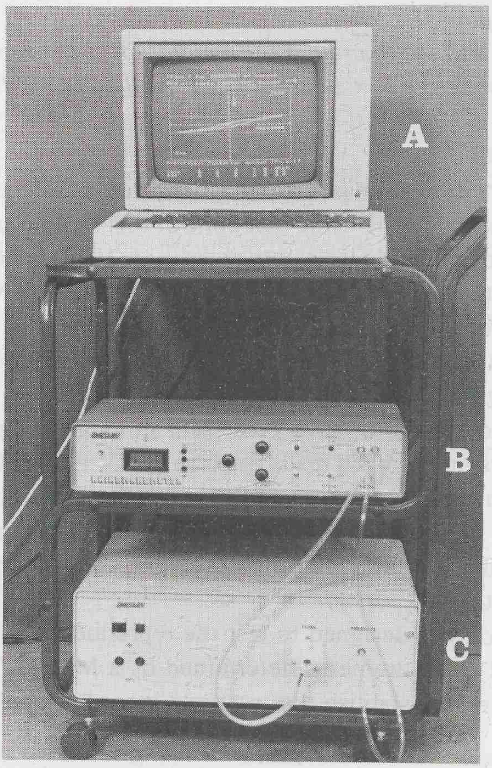

Figure 1. Computerised Rhinomanometer
a. BBC microcomputer and VDU
b. NR3 Rhinomanometer
c. Calibrator

could be used for calculation of nasal respiratory resistance for one cycle of inspiration and expiration.

Recordings on a number of children were attempted but co-operation problems became apparent when numerous repeat measurements were required to obtain a mean value of nasal respiratory resistance for four respiratory cycles.

Further developments by Mercury Electronics led to the availability of a computerised rhinomanometer (NR3).

The programme was designed to calculate values for the nasal respiratory resistance (NRR) at a present pressure or preset flow threshold. The values for inspiration and expiration were displayed on a VDU monitor for each respiratory cycle and the mean values for four such measurements were calculated and shown on the screen. A visual feedback was provided for the patient on the VDU screen which displayed the pressure/flow curve from which the nasal respiratory resistance was calculated.

This system of recording immediately overcame the difficulties experienced previously, but the problem of calibration of the recording device still remained to be solved. The initial calibration was carried out with a static pressure and flow signal to the pressure and flow channels of the rhinomanometer, the pressure being applied by the use of a calibrated water column manometer connected to a clinical syringe to apply a controlled pressure. The flow calibration was initially carried out by the Anaesthetic Department of the Edinburgh Royal Infirmary. These methods, although initially adequate, proved difficult for routine and frequent calibration of the equipment.

The need for a simple dynamic calibration device which could be installed adjacent to the rhinomanometer at the same room tempeture was required.

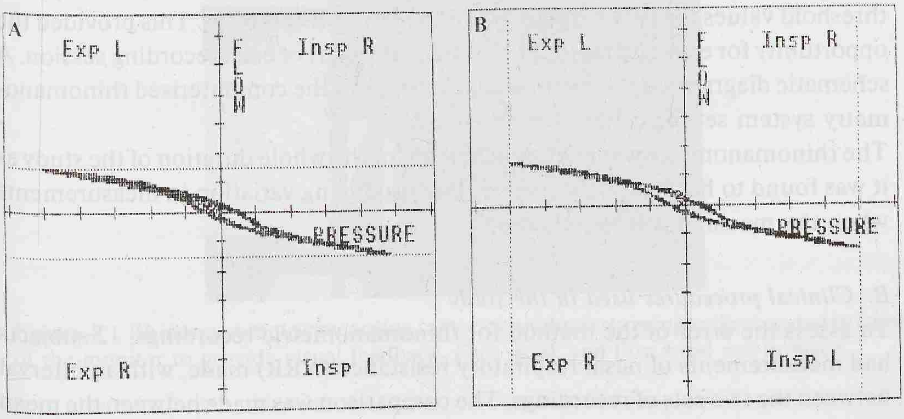

Figure 2. Sigmoid curve produced on VDU for a respiratory cycle.
a. Preset flow 150 cc/sec: Sigmoid curve adjusted to peak to defined limits.
b. Preset pressure 500 Pascals: Sigmoid curve adjusted to peak to defined limits.

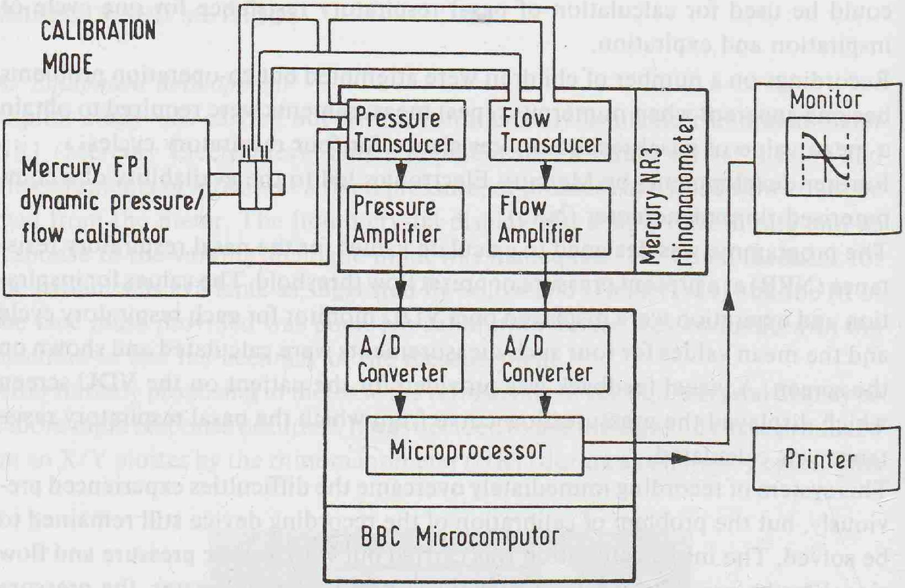

Figure 3. Schematic diagram of the computerised rhinomanometry system set for calibration.

Mercury Electronics constructed a dynamic pressure and flow calibration unit at the request of the author producing a flow that peaked at 150 cc/sec and a pressure that peaked at 500 Pascals. This dynamic signal resembled the normal respiratory cycle and this produced a sigmoid curve on the VDU (Figure 2) which could be adjusted at calibration points on the rhinomanometer to peak to preset threshold values for flow (Figure 2a) and pressure (Figure 2b). This provided the opportunity for easy and rapid calibration at the start of each recording session. A schematic diagram shows the interrelationships of the computerised rhinomanometry system set for calibration (Figure 3).
The rhinomanometer was kept switched on for the whole duration of the study as it was found to have a long warm-up time producing variation in measurements when the machine was switched on.

B. Clinical procedures used in the study

To assess the error of the method for rhinomanometric recordings, 12 subjects had measurements of nasal respiratory resistance (NRR) made, with an interval between the two sets of recordings. The comparison was made between the mean four respiratory cycles for the first measurements with the mean of four respiratory cycles for the second measurement, using a computerised rhinomanometer (Mercury NR3) to record values of nasal respiration (Figure 1).

Each patient from the sample was administered, on arrival, xylometazoline hydrochloride (Otrivine®) as a nasal spray to each nostril. The subject was asked to sit quietly without blowing the nose for five minutes.

Rhinomanometric recordings followed with the patient seated in front of the monitor of the rhinomanometer which displayed the sigmoid curve trace of the respiratory cycle (Figure 4), providing visual feedback and enhanced accuracy. All recordings of nasal respiratory resistance (NRR) took place at least half an hour after the administration of the nasal spray. Unilateral (anterior) measurements of nasal respiratory resistance were carried out initially, (Figure 4) followed by bilateral (posterior) measurements, mean value for four respiratory cycles being recorded.

Systematic differences between the two sets of values were assessed by "t" tests for paired samples; the error variation was assessed by the Hald statistic (Hald, 1960).

Figure 4. Rhinomanometric recording (anterior method) showing subject seated in front of the monitor to provide visual feedback. Face mask and flow head not in place.

RESULTS

Rhinomanometric measurements for posterior values for inspiration and expiration for first and second recordings are shown in Tables 1 and 2. The values for

Table 1. Duplicate determination of rhinomanometric recordings for posterior values of nasal resistance during inspiration (Pascals/cc/sec x 10^3)

	subject	first recorded value	second recorded value	difference
JK	1	340.4	408.9	−68.5
MD	2	322.0	338.8	−16.8
LS	3	135.8	133.5	2.3
RM	4	192.7	181.2	11.5
JW	5	206.6	195.7	10.9
RN	6	296.8	282.7	14.1
GP	7	205.0	181.6	23.4
AW	8	185.3	141.1	43.9
EG	9	144.7	144.1	0.6
LT	10	150.8	146.8	4.1
LM	11	343.4	322.6	20.6
DL	12	166.1	151.5	14.6

N = 12 Each measurement was calculated as the mean of four recordings.

Table 2. Duplicate determination of rhinomanometric recordings for posterior values of nasal resistance during expiration (Pascals/cc/sec x 10^3)

	subject	first recorded value	second recorded value	difference
JK	1	275.3	312.8	−37.5
MD	2	289.2	279.0	10.2
LS	3	128.1	125.9	2.3
RM	4	160.6	163.8	− 3.2
JW	5	170.6	185.3	−14.7
RN	6	255.4	234.4	21.0
GP	7	163.7	161.2	2.5
AW	8	165.9	124.5	41.4
EG	9	145.0	127.0	18.0
LT	10	148.6	157.3	− 8.7
LM	11	325.4	313.4	12.0
DL	12	160.5	163.3	− 2.0

N = 12 Each measurement was calculated as the mean of four recordings.

left side nasal resistance during inspiration and expiration are shown in Tables 3 and 4 for right side nasal resistance during inspiration and expiration in Tables 5 and 6.

The summary table (Table 7) shows the analysis of the data for the first and second recordings and the differences between the two sets of measurements. The statistical analysis (Table 7) showed that the recordings could be repeated with no systematic differences. The method errors ranged from 13.6 to 41.5 Pascals/cc/sec x 10^3. This constituted 1.4% to 5.2% of the total variances in the control sample.

Table 3. Duplicate determination of rhinomanometric recordings for anterior values of left side nasal resistance during inspiration (Pascals/cc/sec x 10^3)

subject		first recorded value	second recorded value	difference
JK	1	767.5	712.7	54.8
MD	2	547.4	408.0	139.4
LS	3	305.8	292.4	13.4
RM	4	320.6	313.6	7.0
JW	5	396.3	398.7	– 2.4
RN	6	441.2	468.6	– 27.4
GP	7	423.0	406.1	16.9
AW	8	301.6	309.8	– 8.2
EG	9	346.2	336.4	9.8
LT	10	538.8	491.3	47.5
LM	11	557.4	554.6	2.8
DL	12	321.2	341.7	– 20.5

N = 12 Each measurement was calculated as the mean of four recordings.

Table 4. Duplicate determination of rhinomanometric recordings for anterior values of left side nasal resistance during expiration (Pascals/cc/sec x 10^3)

subject		first recorded value	second recorded value	difference
JK	1	722.8	699.5	23.3
MD	2	609.1	609.2	– 0.1
LS	3	293.0	266.5	26.5
RM	4	323.3	318.4	4.9
JW	5	428.7	454.6	–25.9
RN	6	490.5	419.3	71.2
GP	7	368.3	370.8	– 2.5
AW	8	309.5	308.0	1.5
EG	9	325.8	325.5	0.3
LT	10	580.2	516.3	63.9
LM	11	528.5	548.9	–19.7
DL	12	275.7	327.4	–22.6

N = 12 Each measurement was calculated as the mean of four recordings.

DISCUSSION

The present study was commenced prior to established standards for rhinomanometry although Kern (1977, 1981) commented on the need for conformity amongst researchers for terminology, recording method and calculation of results. In 1970 the American Academy of Ophthalmology and Otolaryngology had considered these areas and published a "Report of a Committee on Standardisation of Definitions, Terms, and Symbols in Rhinomanometry". This text was, however, more of a glossary of terms, symbols and gas laws than a clear cut international recommendation.

Table 5. Duplicate determination of rhinomanometric recordings for anterior values of right side nasal resistance during inspiration (Pascals/cc/sec x 10^3)

	subject	first recorded value	second recorded value	difference
JK	1	622.6	665.4	– 42.8
MD	2	512.3	338.0	174.3
LS	3	337.9	325.2	12.7
RM	4	298.5	275.1	23.4
JW	5	471.5	457.0	14.5
RN	6	462.5	433.7	28.8
GP	7	362.1	379.7	– 17.6
AW	8	327.5	350.2	– 22.7
EG	9	322.3	352.2	– 29.9
LT	10	444.2	441.2	3.0
LM	11	721.2	665.2	56.0
DL	12	379.1	328.5	50.6

N = 12 Each measurement was calculated as the mean of four recordings.

Table 6. Duplicate determination of rhinomanometric recordings for anterior values of right side nasal resistance during expiration (Pascals/cc/sec x 10^3)

	subject	first recorded value	second recorded value	difference
JK	1	503.6	523.7	– 20.6
MD	2	494.9	378.6	116.3
LS	3	326.7	342.7	– 16.0
RM	4	258.4	249.2	9.2
JW	5	497.6	463.6	34.0
RN	6	403.6	393.0	10.6
GP	7	332.4	352.6	– 20.2
AW	8	317.5	337.5	– 20.0
EG	9	297.9	348.4	– 50.5
LT	10	430.8	400.7	30.1
LM	11	618.2	544.4	73.8
DL	12	319.1	298.0	21.1

N = 12 Each measurement was calculated as the mean of four recordings.

This study has followed the latest recommendations of the Committee Report on Standardisation of Rhinomanometry (Clement, 1984) although accuracy of measurement was increased by the use of a scuba type diving mask (Hansen et al., 1984), dynamic calibration with a unit developed for the study, and visual feedback for the patient by the use of computerised recording which produced results of nasal respiratory resistance (NRR) derived from the mean of four respiratory cycles.

The recommendations included the adoption of SI units and all recordings for nasal respiratory resistance (NRR) are shown in Pascals/cc/sec which in the present study were raised to the power 3 for clarity of expression.

Table 7. Duplicate determination of nasal respiratory (NRR) for posterior and anterior measurements (Pascals/cc/sec x 10^3)

method	pressure threshold (Pascals)	sample size N		1 recording			2 recording			difference				
				mean	S.D.	S.E.	mean	S.D.	S.E.	mean	S.D.	S.E.	S(i)	t
posterior	150	12	insp.	224.1	79.0	22.8	219.0	94.1	27.2	5.1	27.4	7.9	18.9	0.642 n.s.
			exp.	199.0	67.2	19.4	195.7	71.0	20.5	3.8	19.7	5.7	13.6	0.675 n.s.
ant. left	150	12	insp.	438.9	141.1	40.7	419.5	122.4	35.3	19.4	44.8	12.9	33.3	1.503 n.s.
			exp.	437.95	146.5	42.3	430.4	136.9	39.5	7.6	35.0	10.11	24.3	0.750 n.s.
ant. right	150	12	insp.	438.5	130.0	37.53	417.6	127.4	36.8	20.8	57.3	16.6	41.5	1.260 n.s.
			exp.	400.0	109.3	31.6	386.0	87.2	25.2	14.0	46.1	13.3	32.7	1.051 n.s.

Method error $s(i) = \sqrt{\frac{\Sigma d^2}{2N}}$ (Hald 1960).

For practical clinical purposes, the Committee Report on Standardisation of Rhinomanometry (Clement, 1984) recommended the use of the resistance value calculated at a point on the curve corresponding to a pressure difference of 150 Pascals. This recommendation was followed throughout the study, although the method of calculation of nasal respiratory resistance is less accurate when flow through the nasal compartments becomes turbulent. The data are therefore not representative of vigorous flow and pressure but the large differences seen between right and left side of the nasal compartments during quiet respiration are certainly valid indicators of the underlying anatomical deformity.

Other methods of evaluating the curve have been described (Broms et al., 1979; Broms et al., 1982) and the mathematical model expressing resistance at radius 200 in a polar co-ordinate system on the curve was considered by the Committee on Standardisation equally as good as a pressure of 150 Pascals in the recommended co-ordinate system. With newer technology it may become possible to record both the laminar and turbulent flow components to calculate more accurately the values for nasal respiratory resistance.

The flow pattern of inspiratory and expiratory air is however different. On inspiration, air enters the nose and traverses the nasal valve, which is the main resistor in the nasal airway (Warren et al., 1984), creating turbulence. The flow is directed through the middle meatus to the choanae but a few eddies are formed in the olfactory cleft and a small amount of air passes along the floor of the nose. At the site of the nasal valve, in addition to the variable alar component, resistance is regulated by septal and turbinate erectile tissue. The erectile tissue around the middle and inferior turbinates further in the nasal compartments have little or no effect on resistance to airflow in the normal nose. On expiration, however, a diffuse tide of warm moist air sweeps through all parts of the nasal cavity.

The patency of the nasal airway is affected unequally by the nasal cycle and also by many different stimuli such as thermal, tactile, medication, posture, exercise, allergens, irritants and emotion. Invasive instrumentation causes a marked departure from normal function. During measurements of unilateral nasal respiratory resistance, a small diameter pressure recording tube was attached by adhesive tape to the nasal aperture (Figure 3) thus avoiding any distortion likely to be caused by insertion of the recording tube into the anterior nares.

CONCLUSION

The study demonstrates that nasal respiratory resistance (NRR) can be measured with a small method error using a Mercury rhinomanometer. Improvements in accuracy involved the use of a calibration device, scuba face mask, adhesive attachment to nasal aperture for anterior measurements, and visual feedback for the patient from the sigmoid trace on a monitor.

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ZUSAMMENFASSUNG

Reproduzierbarkeit der Aufzeichningen des nasalen Widerstands ist wichtig wenn aussagekräftige klinische und wissenschaftliche Daten zusammengestellt werden sollen.

Die vorliegende Studie untersuchte durch zweifache Bestimmung die Reproduzierbarkeit fruherer (unilateraler) und späterer (bilateraler) Aufzeichnungen des nasalen Atmungswiderstands (NRR) von 12 Versuchspersonen.

Verbesserte Genauigkeit wurde durch häufigen Gebrauch einer Eichungsvorrichtung und durch visuelles Feedback für den Patienten erreicht.

Die Ergebnisse zeigen, daß die Aufzeichnungen reproduzierbar sind, mit einem kleinen methodischen Fehler zwischen 13.6 Pascals/cc/sec x 10^3 und 41.5 Pascals/cc/sec x 10^3.

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