ORIGINAL CONTRIBUTION

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Can we always trust rhinomanometry?*

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SUMMARY

Objectives: *Rhinomanometry before and after decongestion distinguishes a nasal airway organic stenosis from congestion of nasal mucosa in patients with nasal stuffiness. Together with rhinoscopy and patient history, it is used to decide if nasal surgery would benefit the patient. Rhinomanometry measurements should thus be reliable and reproducible.*
Materials and methods: *We performed repetitive active anterior rhinomanometry in 9 persons during 5 months to test reproducibility of nasal airway resistance (NAR) over time. We also did test-retest measurements in several participants. Xylometazoline hydrochloride was applied in each nasal cavity to minimize effects of mucosal variation and the nasal cavity was examined with rhinoscopy. The participants evaluated subjective nasal stuffiness on a visual analogue scale (VAS).*
Results: *The long term mean coefficient of variation (CV) of NAR over time was 27% for the whole group while the short term CV was 7 - 17% for test-retest within an hour. Mean NAR reduction after decongestion was 33%, but 13% of NAR values were not reduced after decongestion. Participants had difficulties estimating stuffiness on a VAS in 15% of the assessments, but there was no correlation between the VAS estimates and NAR.*
Conclusion: *We found a high NAR variation over a period of five months. This implies low long-term rhinomanometry reproducibility and we suggest future research on standardised decongestion to increase the reproducibility.*

Key words: rhinomanometry, nasal airway obstruction, xylometazoline, reproducibility of results, standardization

INTRODUCTION

The reproducibility of any clinical measurement depends on equipment reliability, the skill of the person performing the test, patient cooperation, and finally real variation in the measured parameter. Zwaardemaker (1889) was the first to record an objective assessment of nasal flow, obtaining breathing spots on a cold mirror [1]. Today, we have more sophisticated techniques available to the rhinologist for assessment of nasal obstruction, yet an ideal objective method does not exist. However, anterior active rhinomanometry is the most frequently used method in clinical practice according to the International Standardization Committee of Rhinomanometry, ICSR [2,3]. The reproducibility of rhinomanometric measurements, both anterior and posterior, over a short period for groups of participants or patients is well studied. The short-time reproducibility after decongestion of the nasal mucosa with exercise or nasal spray treatment is good both in patients with and without skeletal stenosis [4-6]. Broms found a better reproducibility for the total nose than for the single nasal cavity after exercise using anterior active rhinomanometry [4]. Sipilä et al. found a better reproducibility using Broms v_2 than using the nasal resistance at 150 pascal [5]. A comparison between two methods to decongest the nasal mucosa, the traditional nasal spray and a bellow devise, showed no difference. However, in that study there was a higher mean value in some measurements during late autumn than during spring [6]. This was explained by a presumed higher frequency of infectious rhinitis with nasal mucosal oedema during autumn. Silkoff et al. tested 6 persons without nasal problems during a 2 month period using posterior rhinomanometry according to the previously described Toronto methodologies [7]. Each person was tested 5 times with intervals of 1-2 weeks. They found acceptable reproducibility with variation coefficients between 7 and 15%, thus within the range of other widely accepted clinical measurements. Reproducibility of measurements of the total nose before decongestion repeated after 24 hours was good according to Jones et al. [8]. Even anterior active rhinomanometry for the single cavity before decongestion could in the hands of experienced performers give coefficients of variation between 8 and 15% [9]. In normal clinical settings, only one rhinomanometric measurement with and without nasal decongestion with topical applications of xylo-or oxymetazoline hydrochloride is done for each patient. The practical consequence of a false pathologically high NAR for the single nasal cavity

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could at worst result in surgical intervention. On the contrary, a false normal NAR would not indicate surgery although surgery might improve the nasal airflow.

The primary aim of this study was to investigate if NAR values for any single participant (with or without septal deviation) after proper decongestion of the nose would remain the same during autumn, winter and spring months. We would investigate if NAR was important by itself without being compared to an actual rhinoscopy and the patient´s history. A secondary aim was to investigate if nasal stuffiness is always easy to determine for the participant. Finally, we wanted to see how subjective nasal stuffiness, self-assessed on a visual analogue scale (VAS), correlates to NAR, especially after decongestion.

MATERIALS AND METHODS

Participants

We recruited nine healthy adult participants, staff at our ENT-department, three men and six women, mean age 45 years (32-59), in this prospective study. Four participants reported nose problems such as stuffiness.

Participant examination

Before the first rhinomanometric measurement, we examined the nasal cavity of all participants and they underwent a standard skin prick test for allergy (alder, hazel, birch, timothy, mugwort, house dust mites, moulds and pets). None of the participants had any allergic symptoms. One (nr 3) had a positive reaction to grass (timothy) in the skin prick test without having any symptoms during the season. Three participants had a deviated nasal septum, and six had a rather straight septum according to the authors' ocular assessment. Unfortunately, no widely accepted objective classification of septal deviation has been developed for routine use [10,11]. All participants underwent 10-15 active anterior rhinomanometries with 2-3 week intervals from late autumn to early spring. They were all without nose drops seven days prior to the measurement. We asked about subjective symptoms of infections/ rhinitis before each measurement, and if a participant experienced any symptoms of rhinitis, no rhinomanometry was done that day.

Test-retest

Five participants underwent 10 measurements each within an hour after the nose was decongested as a short term test-retest. We performed the measurements according to the ICSR [2,3]. The rhinomanometries were done at the same time of the day for each individual. Before the rhinomanometry, all participants were acclimatized in the examination room at 21° C and 50% relative humidity for at least 15 minutes. We calibrated the rhinomanometer (Rhino Comp®, Sweden) once a day before the first measurement. The pneumotachograph was checked by connecting a metal artificial nose to the built-in calibration pump. Calibration was continued until measurements gave values determined by the manufacturer. The equipment was regularly tested by our medical technical department. The anterior active rhinomanometry was performed before and after decongestion of the nasal mucosa with administration of two puffs (0.28 ml) of Xylometazoline hydrochloride 1 mg/ml into each nasal cavity followed by one extra puff (0.14 ml) in each nasal cavity 7-8 minutes later [12]. After the participant gently had blowed/cleared his/her nose, the rhinomanometry was repeated 15 minutes after the first nose spray dose. A transparent full face mask was used and one nostril was sealed with adhesive tape for the pressure recording and the flow was measured on the other side with the pneumotachograph. NAR values for the right and left nasal cavities were obtained at each occasion and values for the total nose were calculated from the individual cavities. NAR was represented in v_2 values as previously outlined by Broms [4]. The relevant nasal airway resistance R_2 is tan v_2 (R_2 = 10 x tan v_2 for one cavity and R_2 = 5 x tan v_2 for the total nose).

Statistic evaluation was based on v_2, an angle calculated from points on the whole curve where it intersects a circle with the radius of 200 Pa on the abscissa and of 200 cm3/sec on the ordinate [13]. Resistance at 150 Pa, R150, can be calculated from R_2. NAR can be given as a resistance R at 150 Pa or as v_2 according to ICSR [3] and the consensus report on acoustic rhinometry and rhinomanometry [2]. The v_2 varies between 0 and 90 degrees with the normal mean values for the decongested mucosa being 13.1 ± 6.8 degrees [12]. The upper 95% confidence limits are taken as a maximum normal value according to Broms [14].

Four experienced nurses performed the rhinomanometries. They had all done these measurements for many years and do each at least 100 measurements per year.

Each participant was both asked to assess his/her degree of nasal stuffiness at each rhinomanometry on a 100 mm VAS scale and also if it was easy to assess nasal stuffiness with the options yes or no. When VAS was 0 mm this would imply a completely free nose, whereas 100 mm implied a completely blocked nose.

This study was conducted in accordance with the Declaration of Helsinki. No ethical review board application was considered necessary by the local ethics committee.

Statistics

The results were analysed using the SPSS 14.0 software for Windows. The Spearman's rank order correlation coefficient and the coefficient of variation (CV) were used to test the reproducibility.

RESULTS

The results are summarized in Table 1, Table 2, and Figure 1. It should be emphasized that in this study we tested single individuals over months and not a group of persons at one given occasion. We did not find any correlation between difficulties to decongest the nasal mucosa and any particular season or time of year, although we noticed a trend to a higher NAR during spring for most of our participants. None of the participants showed any sign of being habituated to rhinomanometry during the investigations. Thus, NAR values did not decrease

Table 1. v_2 before and after decongestion, CV = coefficient of variation. **Mean ± SD. We use the terms "narrow and wide side" even for straight septum, because there is most often a slight side difference.

Participant No.	V_2 Normal Broms [14]	Septum shape	V_2 narrow before**	V_2 narrow after**	V_2 wide before**	V_2 wide after**	V_2 Total before**	V_2 Total after**	CV narrow after	CV wide after	CV total after
1	24	straight	40 ± 13	32 ± 12	41 ± 12	7 ± 8	40 ± 12	29 ± 8	37.5	29.6	27.6
2	28	straight	35 ± 12	23 ± 12	33 ± 8	22 ± 8	33 ± 6	23 ± 9	52.5	36.4	39.1
3	28	straight	27 ± 7	20 ± 4	23 ± 5	16 ± 2	27 ± 7	18 ± 2	20.0	12.5	11.1
4	29	straight	38 ± 13	13 ± 5	25 ± 12	8 ± 2	29 ± 13	9 ± 2	38.5	25.0	22.2
5	28	straight	34 ± 21	20 ± 8	22 ± 13	16 ± 8	24 ± 8	18 ± 7	40.0	50.0	38.9
6	20	straight	19 ± 6	14 ± 4	16 ± 6	11 ± 2	16 ± 4	12 ± 2	28.6	18.1	16.7
7	19	deviation	85 ± 4	76 ± 6	73 ± 10	56 ± 14	79 ± 6	66 ± 10	7.9	25.0	5.2
8	23	deviation	69 ± 13	52 ± 11	16 ± 6	10 ± 2	30 ± 9	18 ± 4	21.2	20.0	22
9	30	deviation	63 ± 11	41 ± 8	36 ± 9	22 ± 9	47 ± 10	30 ± 7	19.5	40.9	23.3

Table 2. VAS before and after decongestion. **Mean ± SD. VAS 0 reflects a completely free nose whereas VAS 10 reflects a completely blocked nose.

Participant no	Septum shape	VAS Narrow before **	VAS Narrow after**	VAS Wide before**	VAS Wide after**	VAS Total before**	VAS Total after**
1	straight	0+0	0	0	0	0	0
2	straight	3.0 ± 2.0	1.8 ±1.5	1.6 ± 1.4	1.0 ± 0.8	2.9 ± 1.7	1.6 ± 1.3
3	straight	3.0 ± 0.9	2.1 ± 0.7	2.8 ± 0.8	1.5 ± 0.7	1.1 ± 0.3	0.3 ± 0.7
4	straight	3.4 ± 2.3	1.0 ± 1.0	1.3 ± 1.0	0.3 ± 0.6	1.9 ± 1.2	0.2 ± 0.4
5	straight	6.0 ± 1.8	4.2 ± 1.8	3.3 ± 1.4	3.0 ± 1.4	3.8 ± 1.1	3.3 ± 1.3
6	straight	2.7 ± 1.0	1.5 ± 0.9	2.5 ± 1.4	1.5 ± 0.9	0.1 ± 0.4	0 ± 0.3
7	deviation	8.0 ± 0.7	7.7 ± 0.7	6.7 ± 1.6	6.0 ± 1.3	6.6 ± 1.1	5.6 ± 1.3
8	deviation	6.0 ± 0.9	3.9 ± 0.9	1.1 ± 0.7	0.1 ± 0.3	3.5 ± 1.2	1.9 ± 0.7
9	deviation	6.3 ± 0.8	4.1 ± 1.2	2.2 ± 1.2	1.1 ± 1.2	4.1 ± 1.2	2.5 ± 0.8

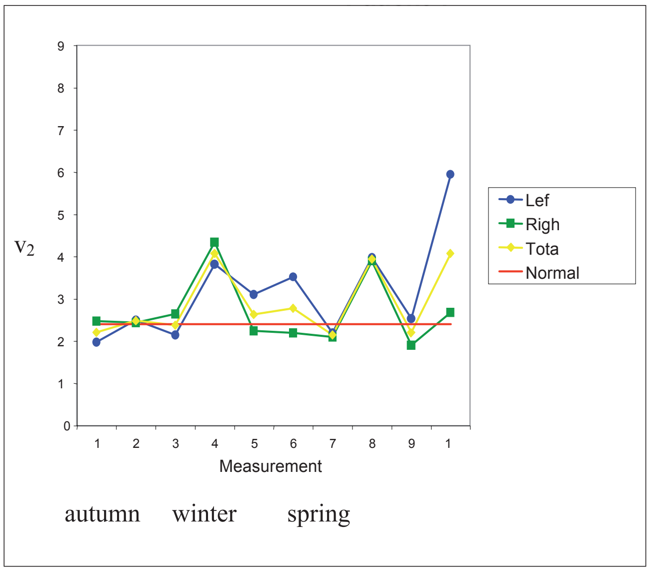
after repeated rhinomanometries as a sign of habituation during the investigation period. While none of the participants reported any subjective allergies, one person had a positive skin prick test reaction to grass.

The 5 participants who did the 10 test-retest the same day had a mean decongestion of 29%. The CV for these test-retests was 8-17%.

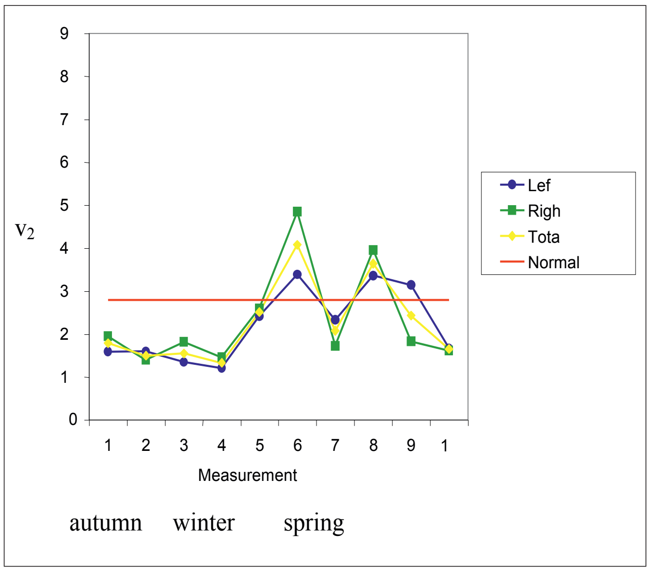
On average during the five month period, v_2 was reduced by 33% for each side and for the total nose after decongestion; in 29 out of 216 measurements (13%) no reduction in v_2 was seen after decongestion. This occurred 1-7 times per participant. Of the 6 participants with rhinoscopic normal nasal cavities and no stuffiness, 4 had 1-5 measurements with high NAR indicating an organic stenosis. One participant with a right side septal deviation had 1 measurement without signs of organic stenosis, and 2 measurements with signs of bilateral stenosis. In the whole group of 9 healthy participants, the CV for the repeated measurements varied between 8 and 53% for a single side and for the total nose. The CV was 11-53% for the 3 participants with septal deviation and 8-41% for the 6 participants with a straight septum. The 3 participants with septal deviations had a narrow side pathological NAR in all rhinomanometries except for 1 (97%). In the 6 participants with a straight septum, the NAR was pathological in 19 out of 148 measurements (13%). Two participants with a straight septum had no pathological rhinomanometric measurements at all. The remaining 4 participants with a straight septum had 1-10 pathological measurements (1/30, 3/28, 5/20, 10/20), i.e. in 3-50% of the measurements.

The participant (nr 7) with the lowest CV of 7.9% had a pronounced septal deviation with stuffiness on both sides with an acceptable NAR CV on the narrower side. The other 2 participants (nr 8 and 9) with septal deviations and high v_2 values, continued to have high values since they had an organic stenosis. However, their CV was 21.2% and 19.5% on the narrow side. The range of their v_2 varied between 30-62 and 24-54. For 3 participants (nr 3, 4 and 6), NAR was consistently low after decongestion. These 3 participants had low mean v_2 values of 20 or below and they continued to have low values after decongestion during the test period. Also some of their measurements did not give a reduction after decongestion, probably since they were maximally decongested already.

We used the Spearman's Rank Correlation Coefficient to measure the bivariate correlation between the variables v_2 and VAS. We found no significant correlation for any of the 10 participants after decongestion for wide side v_2 and VAS subjective nasal stuffiness. Two participants with a straight septum



Patient 1



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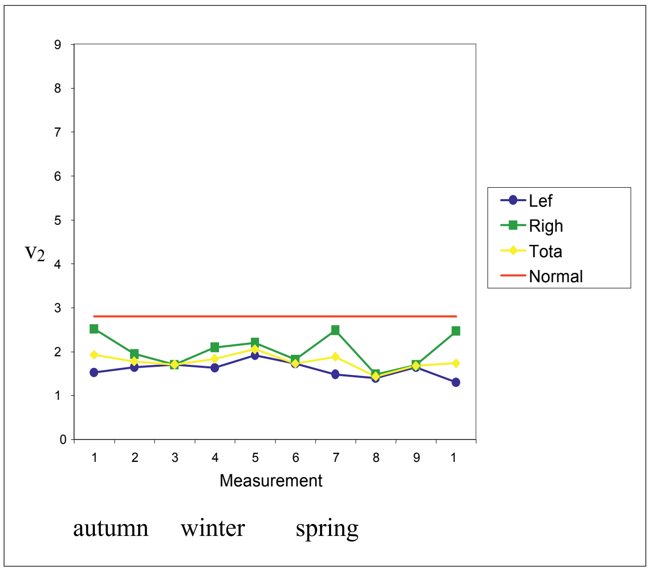

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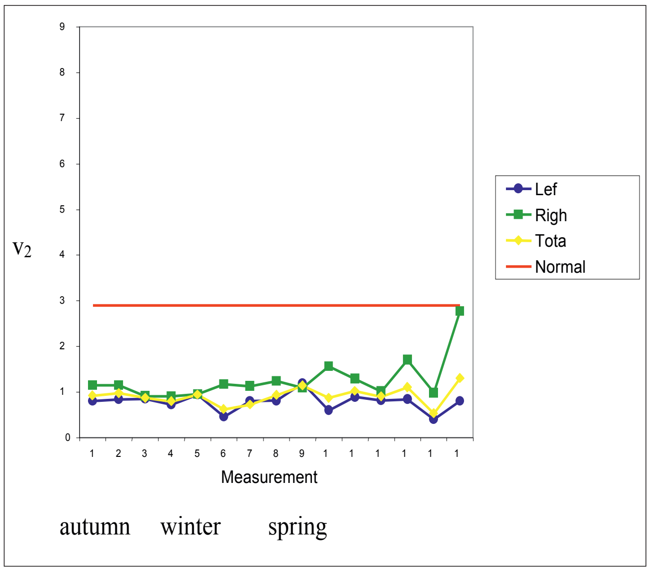

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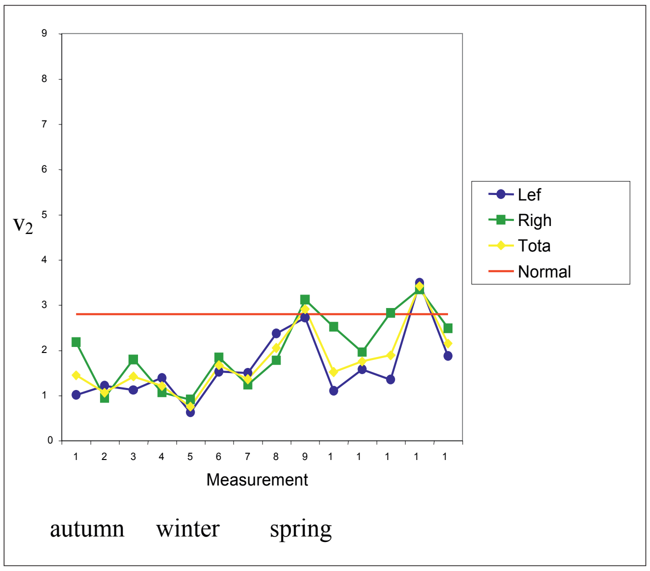

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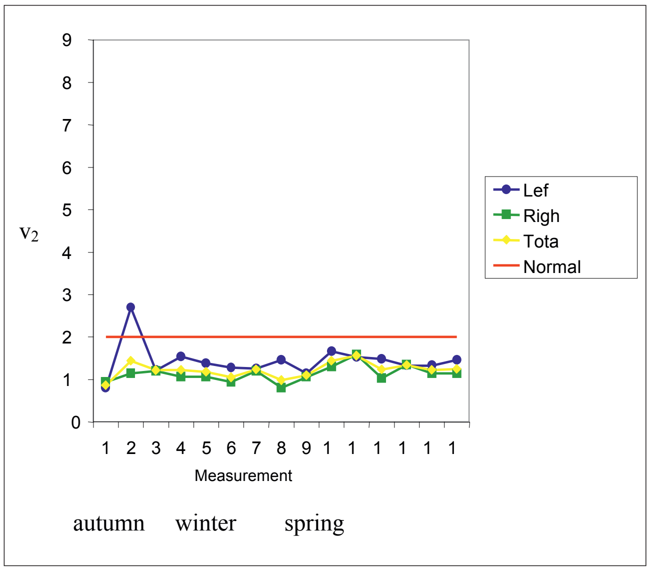

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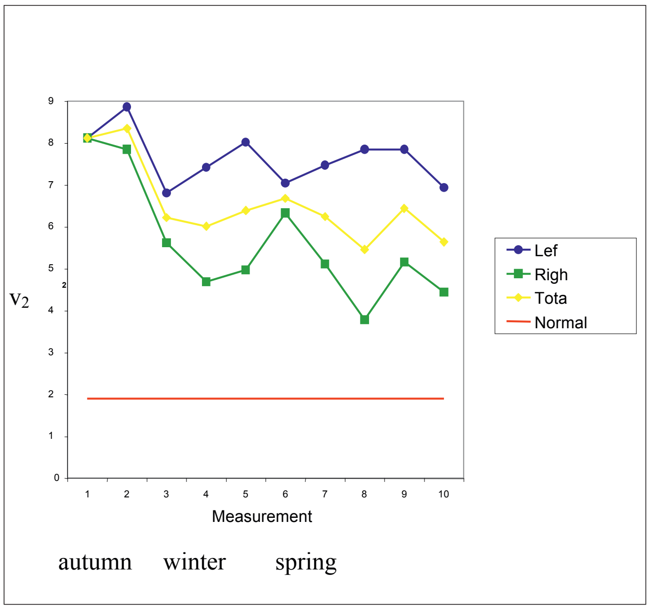
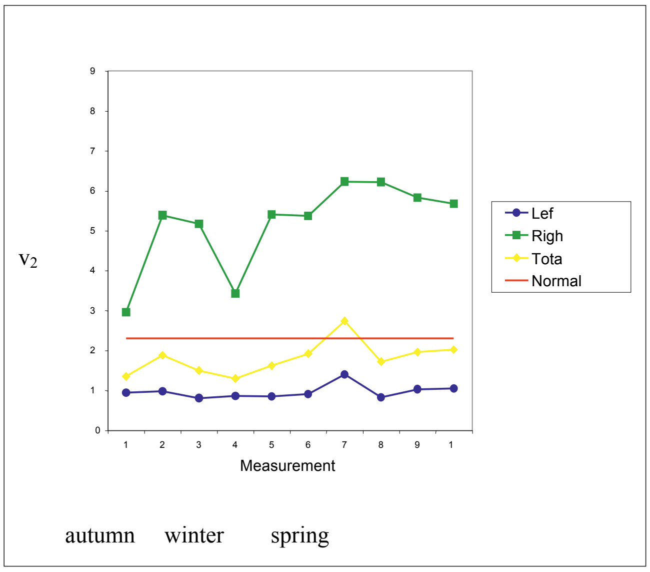
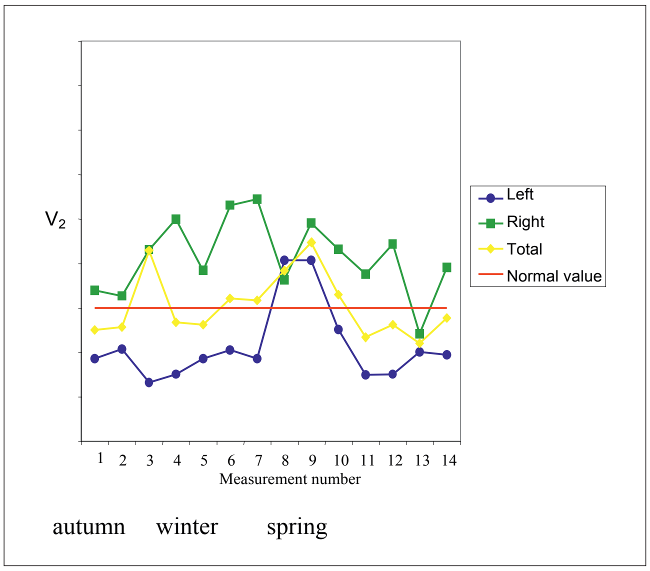


Patient 7



Patient 8



Patient 9

Figure1. The decongested NAR from all the rhinomanometries in the ten participants. The horizontal line is the limit for normal value according to Broms [14].

(nr 3 and 8) had correlation coefficients of 0.78** and 0.64* respectively, when the variables were VAS subjective nasal stuffiness and narrow side v_2 after decongestion. Participants had difficulties estimating nasal stuffiness by using VAS in 32 of all 216 assessments (15%).

DISCUSSION

In this clinical study of nasal airway resistance in healthy subjects, the average variation (CV) for rhinomanometry measurements over a five month period was 27% (range 8-53%). Only 2 out of 9 participants had a CV under 15%, widely considered an adequate reproducibility [9], but only for one side of the nose. This indicates a rather poor long-term reproducibility. The results showed no significant seasonal variation. Neither did we find any habituation to the rhinomanometric procedure.

The CV for the 10 test-retests the same day was 7-17%, thus an acceptable variation. This tells us that rhinomanometry as a method has good short term reproducibility. The 10 measurements took about an hour and the congestion of the nasal mucosa was nearly constant during this time. But when compared with the 10 measurements done every second week during five months, the reproducibility decreased. Even when we subdivided the participants into a septal deviation group (CV range 8-41%) and a straight septum group (CV range 11-53%), the CV was still high. The main difference between the measurements was the daily status of the nasal mucosa and the pharmacological decongestion on the day of the rhinomanometry. There may be several causes, as we discuss below, why we could not decongest to the same level at each rhinomanometric measurement every second week.

It is important to know that rhinomanometry is a method for measuring the patency of a channel through which airflow is conducted. The channel consists of the nasal cavity of bone and cartilage lined with mucosa. There are several factors influencing this channel. The mucosa lining the channel is sensitive to temperature, humidity, smell, pain, emotional stress, body position and the nasal cycle. In 21-39% of the population there seems to be a periodicity of nasal airflow, called the nasal cycle, and this cyclic change of the congestion of the mucosa alternates every 2-6 hours between the right and left side [15,16]. However, few people with normal nasal physiology actually sense these changes.

Six of the 9 participants were women. Two were premenopausal and not pregnant, and 4 were postmenopausal. We did not ask about their menstrual cycle, the use of contraceptive pills or menopausal hormone therapy since earlier studies have not shown significant correlation between differences in airflow and hormonal levels or the menstrual cycle [18,19].

Rhinomanometry is primarily used to make a distinction between skeletal stenosis and mucosal swelling. Thus, we select patients who may benefit from surgical treatment of their nasal stuffiness, but the final decision is based on patient history, rhinoscopy and rhinomanometry together. Another use of rhinomanometry is to monitor results of surgical procedures by assessing NAR. Therefore, it is essential to get reproducible NAR values after proper decongestion of the nasal mucosa. In half of the participants, the decongestion varied. The average decongestion in our study was 33% compared to 37% in earlier studies by Caene et al. [17]. Broms suggested a limit level value where there is a 50% chance for a patient with a NAR value above this level to get better after a nose operation [14]. It is therefore important that NAR values are as realistic as possible. However, limit values in biological materials are no absolute cut-off levels. Hence, there is a clinical problem in patients whose NAR value is relatively close to the limit value. For participants in our study with v_2 between 20 and 50, some measurements would contain a value both below and over the limit value outlined by Broms [4]. Broms also found that NAR reproducibility was good after deconcongestion with nose drops after an interval of at least a week [4]. Sipilä et al. found similar retest-results [5]. In both studies, the reproducibility was good in most patients with low NAR but worse in patients with higher NAR. However, in these studies with results similar to ours, neither standard deviation nor CV was reported.

One logical explanation to the long term variability of the measurements in our study is the lack of sufficient decongestion as the measurements were done under standardized conditions according to the ICSR [2,3] by experienced nurses, who immediately noticed if a measurement was technically incorrect. If the nurses were in doubt about a measurement (e.g. mask problems), they always repeated the measurement or consulted the physician. Although they did not subjectively suffer from rhinitis, the decongestion of our participants could be inadequate or caused by an inflammation of the nasal mucosa with interstitial oedema, which may be difficult to decongest. Another suggested explanation could be that the nasal cavities may not have been sufficiently cleaned. Yet the participants were asked to blow/clear their noses gently before each measurement to remove mucus and crusts. We examined the nasal cavities of all the participants only once before the first rhinomanometry in this study and not before each of the measurements. In our clinical practice, we do rhinomanometry as a consulting assignment from ENT-physicians from other ENT-departments without prior nasal examination the same day. Furthermore, we wanted to perform the study as similar to clinical practice as possible.

It seems obvious that our standard procedure is not sufficient for all persons at all times [2]. Thus, we suggest that a more formalized procedure is necessary for decongestion, perhaps with a supplement of an anti-inflammatory nasal spray. In the report from ISCR [2,3], there are however no recommendations on how to decongest the nasal mucosa. It lies solely in the hands of the rhinomanometrist.

In the work by Carney et al., they found a CV between 19-60% for the undecongested nose [9]. After performing rhinomanometry with a more time consuming procedure, the CV decreased to 7-15% but still for the undecongested nose. In fact, we have always used their ”Nottingham Protocol” but modified so that we use only one set of data instead of the more time consuming 12 points of data. The practical consequence of this variation is to do another rhinomanometry if the rhinomanometric results do not seem reasonable compared to the rhinoscopic findings and the patient history, or to reconsider the diagnosis. With this poor long term reproducibility of rhinomanometry, it should not be used alone to decide for or against an operation or to monitor the results of nasal operations.

The correlation between NAR and subjective nasal stuffiness assessed by VAS was weak in our study. This said with respect to that it is a relatively small material and that 44% had nasal obstruction subjectively. Four out of 9 participants (44%) experienced that it was sometimes difficult to estimate their nasal stuffiness both before and after decongestion. The subjective sensation of nasal obstruction is a complex phenomenon that can differ from objective assessments of resistance. Among others Gleeson et al. [20] found that subjective sensation is a poor guide to the state of patency of the nasal airways. Therefore, it is not possible to replace rhinomanometry with nasal stuffiness subjectively assessed by a VAS scale.

CONCLUSION

In this study, we found that rhinomanometric NAR values varied significantly long term but not short term after decongestion and standard procedure investigations according to the guidelines of ICSR. Thus, anterior rhinomanometry readings are potentially prone to large errors and each researcher using such equipment must make sure that their methodology has an acceptable variation (CV) and reproducibility. Every rhinomanometric measurement should be preceded by rhinoscopic examination the same day to eliminate every little crust. We recommend that future research focuses on methodology, and that the international standardisation committee will produce guidelines on how to sufficiently decongest the nasal mucosa to guarantee reproducible rhinomanometric measurements. In that way, rhinomanometry can play an important part in rhinologic practice. The final decision to do nasal surgery must still be based on the triad of rhinomanometry, patient history and rhinoscopy.

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AUTHORSHIP CONTRIBUTION

Substantial contribution to conception and design, acquisition of data was made by Thulesius and Jessen. Analysis and interpretation of data, drafting and revising of article was made by all 3 authors together. The final approval of the article was made by Jessen and Cervin.

CONFLICT OF INTEREST

There was no conflict of interest in this study.

REFERENCES

1. Zwaardemaker H. Ademmaanslag al diagnosticum der nasal stenoe. Nederlands Tijdschrift voor Geneeskunde 1889; 25: 297-300.
2. Clement PA, Gordts F. Consensus report on acoustic rhinometry and rhinomanometry. Rhinology 2005; 43: 169-179.
3. Clement PA. Committee report on standardization of rhinomanometry. Rhinology 1984; 22: 151-155.
4. Broms P. Rhinomanometry. III. Procedures and criteria for distinction between skeletal stenosis and mucosal swelling. Acta Otolaryngol 1982; 94: 361-370.
5. Sipila J, Suonpaa J, Laippala P. Evaluation of nasal resistance data in active anterior rhinomanometry with special reference to clinical usefulness and test-retest analysis. Clin Otolaryngol Allied Sci. 1992; 17: 170-177.
6. Jessen M, Ivarsson A, Malm L. Nasal airway resistance after decongestion with a nasal spray or a bellows device. Rhinology 1996; 34: 28-31.
7. Silkoff PE, Chakravorty S, Chapnik J, et al. Reproducibility of acoustic rhinometry and rhinomanometry in normal subjects. Am J Rhinol. 1999; 13: 131-135.
8. Jones AS, Lancer JM, Stevens JC, et al. Nasal resistance to airflow (its measurement, reproducibility and normal parameters). J Laryngol Otol. 1987; 101: 800-808.
9. Carney AS, Bateman ND, Jones NS. Reliable and reproducible anterior active rhinomanometry for the assessment of unilateral nasal resistance. Clin Otolaryngol Allied Sci. 2000; 25: 499-503.
10. Baumann I, Baumann H. A new classification of septal deviations. Rhinology 2007; 45: 220-223.
11. Guyuron B, Uzzo CD, Scull H. A practical classification of septonasal deviation and an effective guide to septal surgery. Plast Reconstr Surg. 1999; 104: 2202-2209; discussion 2210-2.
12. Jessen M, Malm L. Use of pharmacologic decongestion in the generation of rhinomanometric norms for the nasal airway. Am J Otolaryngol. 1988; 9: 336-340.
13. Broms P, Ivarsson A, Jonson B. Rhinomanometry. I. Simple equipment. Acta Otolaryngol. 1982; 93: 455-460.
14. Broms P, Jonson B, Malm L. Rhinomanometry. IV. A pre- and postoperative evaluation in functional septoplasty. Acta Otolaryngol. 1982; 94: 523-529.
15. Hanif J, Jawad SS, Eccles R. The nasal cycle in health and disease. Clin Otolaryngol Allied Sci. 2000; 25: 461-467.
16. Flanagan P, Eccles R. Spontaneous changes of unilateral nasal airflow in man. A re-examination of the 'nasal cycle'. Acta Otolaryngol. 1997; 117: 590-595.
17. Caenen M, Hamels K, Deron P, et al. Comparison of decongestive capacity of xylometazoline and pseudoephedrine with rhinomanometry and MRI. Rhinology 2005; 43: 205-209.
18. Driver HS, McLean H, Kumar DV, et al. The influence of the menstrual cycle on upper airway resistance and breathing during sleep. Sleep 2005; 28: 449-456.
19. Grillo C, La Mantia I, Triolo C, et al. Rhinomanometric and olfactometric variations throughout the menstrual cycle. Ann Otol Rhinol Laryngol. 2001; 110: 785-789.
20. Gleeson MJ, Youlten LJ, Shelton DM, et al. Assessment of nasal airway patency: a comparison of four methods. Clin Otolaryngol Allied Sci. 1986; 11: 99-107.

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