Rhinology, 39, 93-97, 2001

Evaluation of the importance of head and probe stabilisation in acoustic rhinometry*

Andrew M. Wilson[1], Stephen J. Fowler[1], Simon W. Martin[1], Paul S. White[2], Quentin Gardiner[2], Brian J. Lipworth[1]

[1] Asthma & Allergy Research Group, Department of Clinical Pharmacology & Therapeutics, University of Dundee, Scotland, UK
[2] Department of Otolaryngology, Ninewells Hospital & Medical School, University of Dundee, Scotland, UK

SUMMARY

As yet there is no established procedure to ensure the repeatability of acoustic rhinometry measurements although anecdotal evidence suggests that instrument fixation improves repeatability. The aim of this study is to validate the methodology of acoustic rhinometry and determine whether instrument fixation and head stabilisation is necessary. Four methods were compared in fifteen healthy volunteers, after nasal decongestion: A) Patient holding the probe (patient-held), B) Probe fixed in a probe stand (probe-stand), C) Probe fixed in stand and head stabilised in head rest (head-rest), D) Examiner holding the probe (examiner-performed). The two minimum cross-sectional areas and volume between 0 and 5 cm were recorded. The examiner-performed and probe-stand methods were consistently less variable than the other methods. With examiner-performed method, this was significant ($p<0.05$) versus head-rest and patient-held methods for both measures of minimum cross-sectional area. For nasal volume the examiner-performed method was significantly ($p<0.05$) less variable than the head-rest method. In conclusion, examiner-performed acoustic rhinometry is more repeatable than combined head stabilisation and instrument fixation and therefore the use of a head-rest may be unnecessary. Instrument fixation or examiner performed test is also preferable to allowing the patient to position the probe. The repeatability of the probe-stand method was similar to the examiner-performed method.

Key words: acoustic rhinometry, head-rest, nasal volume, probe-stand, variability

INTRODUCTION

Nasal obstruction is an important feature of seasonal allergic rhinitis (Lund, 1994). This can be assessed subjectively by symptom scoring or objectively by measurement of nasal resistance with rhinomanometry, nasal volume with acoustic rhinometry, or nasal flow with a peak inspiratory flow meter. Both acoustic rhinometry and rhinomanometry have been validated as sensitive measures of assessing nasal airway patency (Fisher, 1997), and peak inspiratory flow rate has been shown to closely follow patients symptoms (Fairley et al., 1993; Wilson et al., 2000).

There is currently a debate as to the best measurement to perform during nasal challenge testing. Rhinomanometry was previously used but acoustic rhinometry is considered to be simpler to perform and less invasive (Miyahara et al., 1998). Furthermore, many subjects cannot tolerate rhinomanometry if they have severe nasal blockage (Scadding et al., 1994) and acoustic rhinometry is more sensitive in discriminating mucosal changes than rhinomanometry (Austin and Foreman, 1994; Taverner et al., 1999).

Although acoustic rhinometry has been validated using high resolution computerised tomography scanning and magnetic resonance imaging (Prasun et al., 1999; Corey et al., 1997) technical difficulties have been acknowledged. For example, artifacts may arise from positioning the probe and from acoustic leaks at the nostril (Hamilton et al., 1997). Other authors (Fisher and Boreham, 1995; Roth et al., 1996) have suggested that greater reproducibility is achieved by the use of both instrument and head fixation as changes in the angle between the sound wave tube and the nostril during measurement are said to increase the test-retest variability.

* Received for publication August 31, 2000; accepted December 15, 2000

It is not known whether head fixation is required or whether using a probe stand is adequate to achieve reliable results. The results of this investigation will be used to determine the most suitable method of performing acoustic rhinometry in nasal challenge testing.

METHODS AND MATERIALS

Subjects

Fifteen healthy volunteers (4 males), mean (SE) age 34 (±3.7) years, were recruited into the study at the Asthma and Allergy group, Clinical Pharmacology, Ninewells Hospital, Dundee, Scotland. Following a screening interview it was established that none of the subjects had a history of rhinitis or asthma, symptoms or signs of allergic or infectious rhinitis or nasal pathology, for example major nasal septum deviation or major polyposis. Ethical approval for the study was obtained from Tayside committee on Medical Research Ethics.

Visits

Each subject attended the laboratory on three separate days and each visit was at the same time of day. On arrival the absence of nasal symptoms was first established, i.e. runny nose, congestion, itchiness, sneezing. The subjects were decongested with 2 drops of Otrivine (Novartis Consumer Health, Horsham, UK) applied to each nostril. This was followed by a 15 minute acclimatisation period in a dedicated room which had controlled humidity, temperature and a noise level less than 65 dB (Spilia et al., 1996; Tomkinson and Eccles, 1996). The rhinometer was calibrated daily.

Acoustic Rhinometry

An interrupted spark (averaging) Acoustic Rhinometer was used (GM Instruments Ltd., Kilwinning, UK). This acoustic rhinometer is accompanied by a package for computation of the nasal area and volume (A1 Rhino V 4.5, GM Instruments Ltd, Kilwinning, UK). With the subject sitting, a conical nose piece was placed 0.5cm into the subjects nostril. The size of the nose piece was chosen with a diameter (8, 10 or 12mm) to provide an acoustic seal without distorting the nostril. All of the nose pieces were 7 cm in length. Water soluble gel was applied to the end of the probe to take up any remaining gap between the probe and the nostril and so form a good acoustic seal when performing all of the tests. The subject checked the seal by occluding the free nostril whilst inhaling gently. Two consecutive measurements were made. After the first measurement, the probe was removed from the nose, reconnected, and another measure taken. The results were considered suitable if the coefficient of variation (CV) between the two measurements was less than 10%. The data was analysed by a personal computer with specialised software to generate the graphs and calculate the volume estimates.

The following methods (see Figure 1) were compared on each of the three study visits. All of the methods were performed by the same person throughout the study.

A. Patient-held probe (patient-held) method. The patient held the probe in order to achieve an acoustic seal and to angle the probe along the floor of the nose.
B. Probe stand instrument fixation (probe-stand) method. The probe stand was used to allowed probe fixation and control of its transverse and longitudinal angles. The angles giving the optimum seal were recorded at the first visit and reproduced at each subsequent visit.
C. Probe stand plus head fixation (head-rest) method. A customised head rest was used to stabilise the head. The head was fixed in position by lightly tightening the clamp from the side. The probe stand was then positioned to give the optimum seal with the minimum nostril distortion. The trans-

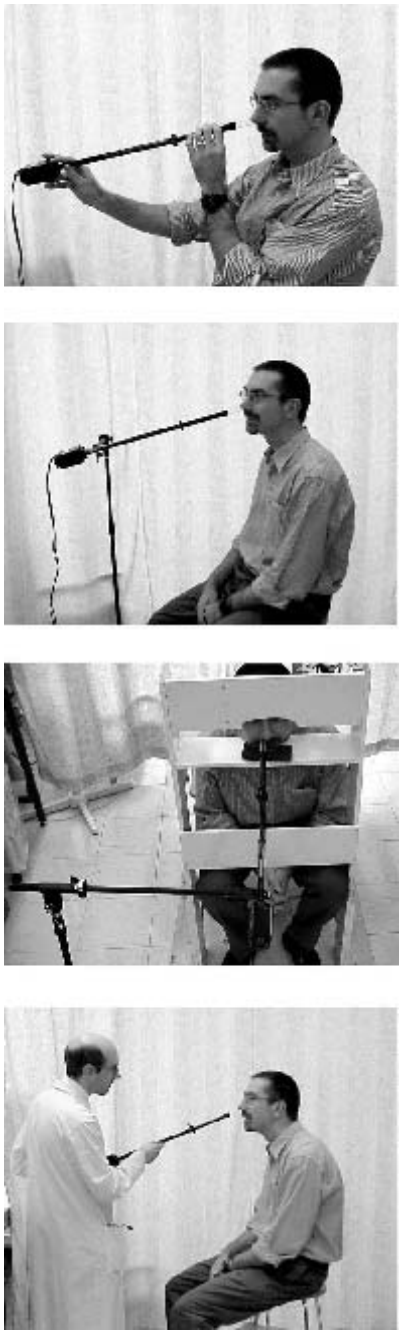

Figure 1. Pictures of the four methods of probe fixation used in the study A) Patient held, B) probe-stand fixation C) probe-stand and head-rest fixation D) examiner held.

verse and longitudinal angles were again recorded and subsequently reproduced.

D. Examiner-held probe (examiner-performed) method. The examiner held the probe in order to achieve an acoustic seal and to angle the probe correctly.

Parameters measured

For each nostril the computer software (A1 Rhino V 4.5, GM Instruments Ltd, Kilwinning, UK) was programmed to record:

1. Two minimum cross-sectional areas (MCAs). The first MCA represented the second notch on the acoustic rhinometry trace (the nasal isthmus). The second MCA corresponded to the third notch seen on the acoustic rhinometry trace (the head of the inferior turbinate).
2. A volume estimate between 0 and 5 cm.

In this study the nasal cavity as a whole was of interest so the sum of the left and right values was used for the analysis.

Statistical Analysis

The aims of the analysis were as follows:

A. To compare the precision i.e. variability of the four acoustic rhinometry methods:
For each parameter (MCA1, MCA2, volume) a one-way analysis of variance (ANOVA) was calculated for the four methods of acoustic rhinometry. The error mean square obtained from this analysis measures the repeatability of the method. To simultaneously test whether all the methods were of the same repeatability, the chi-squared (χ^2) distribution was used to form a 95% confidence interval (CI) for the true variance (χ^2) of a method. Due to the relatively small sample size the sample variance will be different from the population variance. Therefore, the 95% CI was more powerful than calculating the sample variance since it gives us a range in which we are 95% confident that the true method variability lies. If the 95% CI for any of the methods overlap then we conclude that the variability is the same. When the 95% CIs do not overlap we conclude that the variability is different. This difference is significant at the 5% level of probability (two-tailed).

B. To assess the relative accuracy of the methods:
A two-way ANOVA was calculated for each parameter using methods and subjects as factors. The F score for method variability indicated the variability of the absolute values of the four methods. If the F score was close to one then the methods were equally accurate ie similar absolute measurements. The 'p' value indicated the probability of getting such an F score by chance. Without a "gold standard" of known measurements it was not possible to assess the absolute accuracy of any method. The two-way ANOVA compared the relative accuracy of the different methods. Knowledge of the relative accuracy allowed the comparison of method variability in (1).

The software used for the statistical analysis was Minitab version 12.0 (Minitab Inc. 3081 Enterprise Drive, State College, PA, USA).

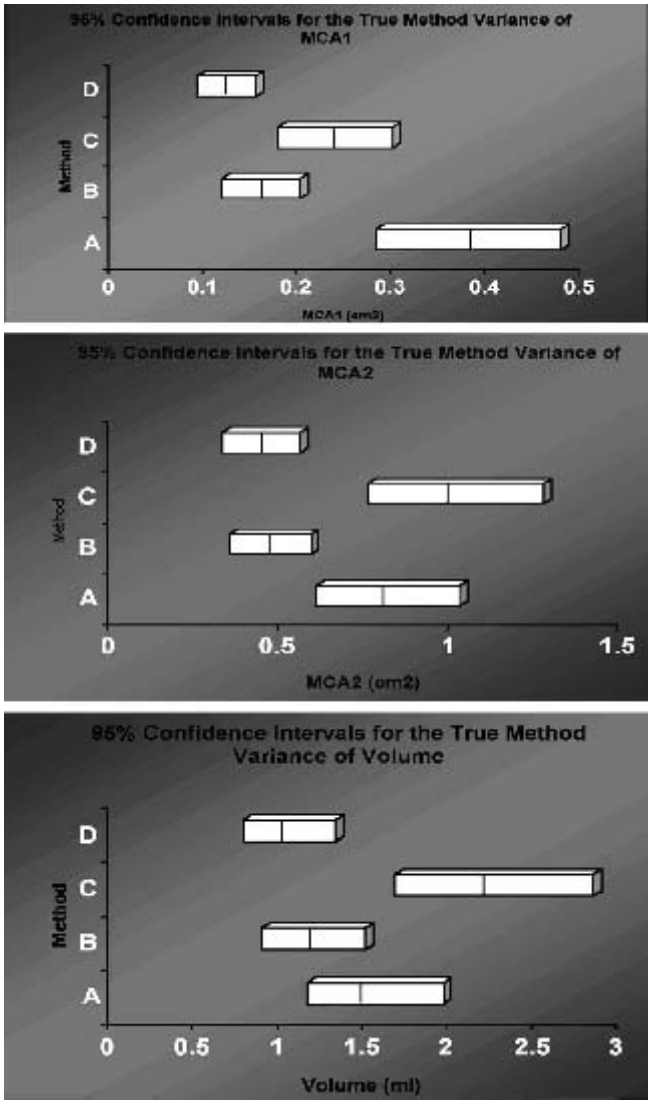

Figure 2. Confidence intervals for the true method of variance for a) the first minimal cross-sectional area (MCA1) b) the second minimal cross-sectional area (MCA2) and c) the nasal volume between 0 and 5 cm (Volume) for the four different methods: Patient-held method (A), the use of probe-stand (B), the use of a probe-stand plus head fixation (C) and examiner-performed method (D).

Table 1. Square root of error mean squares.

Method	MCA1 (cm^2)	MCA2 (cm^2)	Volume (cm^3)
A	0.350	0.752	1.439
B	0.146	0.430	1.095
C	0.219	0.940	2.090
D	0.111	0.405	0.966

RESULTS

1. Method Repeatability

The error mean squares obtained from the one-way ANOVAs were squares of the original units. The square roots were taken to convert the error mean squares back to the original units (Table 1). The 95% confidence intervals presented in Figure 2 test whether the differences in variability observed in Table 1 are significant.

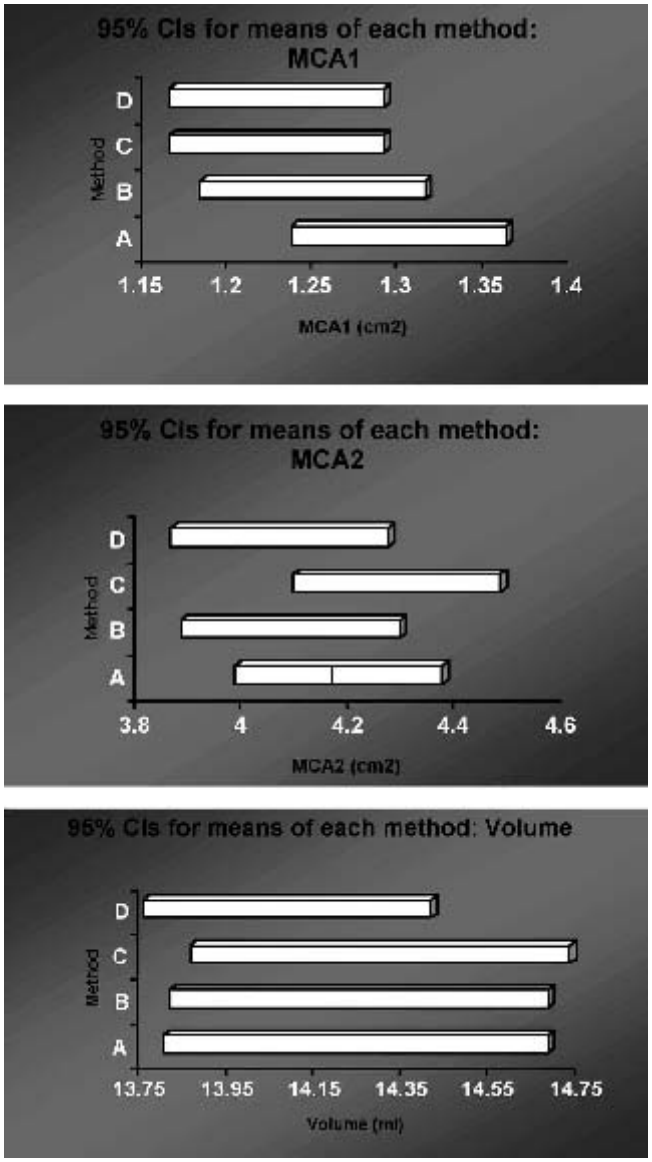

Figure 3. 95% confidence intervals for the means of each method. Legend as Figure 2.

First minimum cross-sectional area

The order of repeatability, i.e. least variable method first: examiner-performed > probe-stand > head-rest > patient-held methods.

The examiner method was less variable than head-rest or patient-held methods ($p < 0.05$).

The probe-stand method was less variable than patient-held method ($p < 0.05$).

Second minimum cross-sectional area

Order of repeatability: examiner-performed > probe-stand > patient-held > head-rest methods. The examiner-performed and probe-stand methods were less variable than patient-held or head-stand methods ($p < 0.05$).

Nasal volume between 0 and 5 cm

Order of repeatability: Examiner-performed > probe-stand > patient-held > head-rest. The examiner-performed and probe-stand methods were less variable than the head-rest method ($p < 0.05$). The examiner-performed and probe-stand methods were less variable than the method patient-held method but the difference was not significant.

2. Method Accuracy

The 95% confidence intervals for mean values are presented in Figure 3. For every parameter measured, there were no significant differences in accuracy of the four methods.

DISCUSSION

We have shown that examiner-performed acoustic rhinometry measurements were less variable than acoustic rhinometry performed with head stabilisation plus instrument fixation. This difference was observed for both the cross-sectional areas and the volume estimate. In contrast, Fisher et al. (Fisher and Boreham, 1995) and Roth et al. (Roth et al., 1996) state that instrument fixation and head stabilisation are required to improve repeatability. We have also shown that the patient held method also introduces variability. This is not surprising as it is technically difficult for a patient steady in the correct position due to the spark generator being at the end of the probe.

We have shown that the repeatability is poorer with both instrument and head stabilisation than using a probe-stand alone. Therefore the head-rest introduced variation. One possible source of this variation is that with the head and wave tube fixed, the subject lost the ability to make fine head movements. These fine movements allowed the subject to form an effective seal between the nose piece and nostril without distorting the nostril which is important for the maximising accuracy (Grymer et al., 1991). The quality of the seal and amount of distortion was inevitably worse with the head fixed because the examiner was forming the seal by making fine adjustments to the probe stand.

Our results are similar to those of Djupesland et al. (1999) who performed a study which evaluated the effect of varying the angle from 0 to 50 degrees between the sound wave tube and the cavity to be measured. They found that this had minimal influence on the nasal results with a coefficient of variation of less than 3%. However, in their study they used an artificial tubular model to represent the nose which contrasts to our in vivo methodology.

There was no significant difference between the variability of probe-stand data and the variability of examiner-performed data which is against the argument for instrument fixation. However, in our study one examiner performed all the tests and it is likely that the variability would have been greater with many examiners as occurs in clinical practice. A probe stand may be desirable, therefore, when data obtained by different examiners. In this respect we found that the examiner-performed acoustic rhinometry was significantly less variable than subject-held acoustic rhinometry. Further studies are required to compare the repeatability of acoustic rhinometry results obtained by different examiners.

This study is limited by the fact that true repeatability can only be assessed in models with fixed dimensions. Even in normal individuals there will be variation in nasal measurements because of real changes in vasomotor activity. Decongestion

in vivo will rarely reproduce exactly the same nasal dimensions, even when the dose and timing are standardised. Nasal airway volume is unstable due to spontaneous changes in the airway blood vessels, especially the venous sinuses at the anterior tip of the inferior turbinate and anterior nasal septum which contribute to the dynamic nasal valve.

Due to the 'nasal cycle' (the centrally generated pattern of alternating congestion and decongestion), these spontaneous changes can be very large if measurements are confined to a single nasal cavity. In the present study the variability introduced by these spontaneous changes was less important since the nasal cavity as a whole was measured, i.e. the sum of the left and right data was used in the analysis.

In conclusion, examiner-performed acoustic rhinometry was more repeatable than the combination of head stabilisation and instrument fixation. However there was no difference between the examiner held and probe stand method. If multiple investigators are performing the test it seems sensible to use the probe stand for measurement of acoustic rhinometry in nasal allergen challenge.

ACKNOWLEDGEMENT

The authors would like to thank TENOVUS (Scotland) for their sponsorship and Dr. R.A. Brown for his expert help with the statistical analysis of this study.

REFERENCES

1. Austin CE, and Foreman JC (1994) Acoustic rhinometry compared with posterior rhinomanometry in the measurement of histamine and bradykinin-induced changes in nasal airway patency. British Journal of Pharmacology 37:33-37.
2. Corey JP, Gungor A, Nelson R, Fredberg J, and Lai V (1997) A comparison of the nasal cross-sectional areas and volumes obtained with acoustic rhinometry and magnetic resonance imaging. Otolaryngology - Head & Neck Surgery 117:349-354.
3. Djupesland PG, Qian W, Furlott HG, Rotnes JS, Cole P, and Zamel N (1999) Acoustic rhinometry: a study of transient and continuous noise techniques with nasal models. Am J Rhinol 13:323-329
4. Fairley JW, Durham LH, and Ell SR (1993) Correlation of subjective sensation of nasal patency with nasal inspiratory peak flow rate. Clin Otolaryngol Allied Sci 18:19-22.
5. Fisher EW (1997) Acoustic rhinometry. Clin Otolaryngol Allied Sci 22:307-317.
6. Fisher EW, and Boreham AB (1995) Improving the reproducibility of acoustic rhinometry: a customized stand giving control of height and angle. J Laryngol Otol 109:536-537.
7. Grymer LF, Hilberg O, Pederson OF, and Rasmussen TR (1991) Acoustic rhinometry: values from adults with subjective normal nasal patency. Rhinology 29:35-47.
8. Hamilton JW, McRae RD, and Jones AS (1997) The magnitude of random errors in acoustic rhinometry and reinterpretation of the acoustic profile. Clin Otolaryngol Allied Sci 22:408-413.
9. Lund VJ (1994) International consensus report on the diagnosis and management of rhinitis. International rhinitis management working group. Allergy 49 (Suppl 19):1-34.
10. Miyahara Y, Ukai K, Yamagiwa M, Ohkawa C, and Sakakura Y (1998) Nasal passage patency in patients with allergic rhinitis measured by acoustic rhinometry: nasal responses after allergen and histamine provocation. Auris, Nasus, Larynx 25:261-267.
11. Prasun D, Jura N, Tomi H, Pertti R, Markus R, and Erkki L (1999) Nasal airway volumetric measurement using segmented HRCT images and acoustic rhinometry. Am J Rhinol 13:97-103.
12. Roth Y, Furlott HG, Coost C, Roithmann R, Cole P, Chepnik J, and Zamel N (1996) A head and tube stabilising apparatus for acoustic rhinometry measurements. Am J Rhinol 10:83-86.
13. Scadding GK, Darby YC, and Austin CE (1994) Acoustic rhinometry compared with anterior rhinomanometry in the assessment of the response to nasal allergen challenge. Clin Otolaryngol 19:451-454.
14. Spilia J, Nyberg-Simola S, Suonpaa J, and Laippala P (1996) Some fundamental studies on clinical measurement conditions in acoustic rhinometry. Rhinology 34:206-209.
15. Taverner D, Bickford L, Shakeb S, and Tonkin A (1999) Evaluation of the dose-response relationship for intranasal oxymetaxonline hydrochloride in normal adults. Eur J Clin Pharmacol 55:509-513.
16. Tomkinson A, and Eccles R (1996) The effect of changes in ambient temperature on the reliability of acoustic rhinometry data. Rhinology 34:75-77.
17. Wilson AM, Dempsey OJ, Sims EJ, Coutie WJ, Patterson MC, and Lipworth BJ (2000) Evaluation of treatment response in patients with seasonal allergic rhinitis using domiciliary nasal peak inspiratory flow. Clin Exper Allergy. 30:833-838.

Prof. B.J. Lipworth
Asthma & Allergy Research Group
Department of Clinical Pharmacology & Therapeutics
Ninewells Hospital & Medical School
DUNDEE
SCOTLAND, UK
DD1 9SY

E-mail: b.j.lipworth@dundee.ac.uk