The Journal of Laryngology & Otology (2009), ***123***, *407–411*.

doi:10.1017/S0022215108004076

Main Article

Relationship between nasal cavity volume changes and nasalance

H Birkent, U Erol, M Ciyiltepe, T L Eadie*, A Durmaz, F Tosun

Abstract

Objectives: The patency and volume of the nasal cavity affect the acoustic characteristics of the voice. The aim of this study was to investigate the effect of a nasal decongestant on nasal volumes and nasalance scores, and to determine the relationship between these measures.

Methods: Acoustic rhinometry and nasometry were performed in a group of 21 adult volunteers both prior to and following application of a nasal decongestant. The relationship between changes in nasalance scores and acoustic rhinometric parameters was investigated.

Results: After the application of nasal decongestant, statistically significant increases were observed in nasalance scores and in all of the acoustic rhinometric parameters assessed (i.e. minimal cross-sectional area, three cross-sectional areas, three volumes and total volume). However, no significant correlation was found between the changes in nasalance scores and acoustic rhinometric parameters.

Conclusions: Nasal decongestion causes an increase in nasalance scores and nasal cavity volumes. However, the findings of this study indicate that changes in nasalance scores may result from factors other than nasal cavity volume changes.

Key words: Nasal Cavity; Voice; Acoustic Rhinometry

Introduction

The nasal cavity and its related structures significantly affect the acoustic characteristics of the speech signal, such as nasalance.[1] Nasalance may be affected by several conditions. For example, allergic rhinitis, upper respiratory infection and structural obstructive pathologies (such as septal deviation and nasal polyposis) may reduce or eliminate nasality during production of nasal consonants, resulting in hyponasality. In contrast, cleft palate and velopharyngeal insufficiency may cause excessive nasality or hypernasality during production of oral sounds. Traditionally, nasality has been measured using auditory perceptual methods.[2] However, due to the poor reliability of these methods, instrumental analysis of the speech signal has been developed in order to provide objective measurement of nasality and velopharyngeal function. Specifically, the nasometer (Kay Elemetrics, Lincoln Park, New Jersey, USA) was developed to quantify nasalance, a measure of the ratio of nasal acoustic energy to total (oral and nasal) acoustic energy. Nasalance scores have been compared with aerodynamic and physiological measures as well as with perceived nasality, and have been found to be a valid and reliable measure for evaluating velopharyngeal functioning.[3]

Medication and surgery affecting the nasal airway and paranasal sinuses have the potential to change patients' nasalance. While several studies have reported medications (such as nasal decongestants) and surgical procedures (such as endoscopic sinus surgery) to have significant effects on nasalance scores,[4–8] the mechanism of these changes remains unclear. That is, it is not known whether nasalance changes are the result of an increase in nasal cavity size or a decrease in nasal airway resistance. Given the clinical utility of nasometry in corroborating perceptual assessments and measuring treatment outcomes, it is important to understand the mechanism of any potential change in nasalance. One way to determine the mechanism for any observed changes in nasalance is to compare such changes with other physiological measures, such as nasal airflow, resistance and estimation of nasal volumes via acoustic rhinometry. The aim of this study was therefore to investigate the effects of nasal decongestion on nasal cavity volumes and nasalance scores, as well as to evaluate the relationship between these measures, in order to begin to determine the mechanism for changes in nasalance.

From the Department of Otolaryngology–Head and Neck Surgery, Gulhane Military Medical Academy, Ankara, Turkey, and the *Department of Speech and Hearing Sciences, University of Washington, Seattle, Washington, USA.
Accepted for publication: 21 August 2008. First published online 12 November 2008.

Materials and methods

Subjects

Twenty-one Turkish-speaking, adult volunteers (16 men, five women; age range, 19–28 years) were enrolled in this study. All of the participants were healthy adults and were free of nasal and voice symptoms. None reported taking any type of medication for at least one week prior to study participation.

Anterior rhinoscopic and endoscopic examinations were performed prior to study participation. These examinations ensured that participants with a history of previous nasal surgery, allergic rhinitis, sinusitis, nasal polyposis, severe septal deviation or speech disorders were excluded.

All procedures were approved by the institutional review board of Gulhane Military Medical Academy, Ankara, Turkey.

Study design

All investigations were performed in the same room at a consistent room temperature and low levels of ambient noise, in order to control for environmental factors that could affect instrumental measures.

All subjects were administered two sprays of 50 μg oxymetazoline in each nostril, via an atomiser spray bottle, in order to obtain volumetric change in the nasal cavities. Acoustic rhinometric and nasometric measurements were performed before and 15 minutes after the applications.

Acoustic rhinometry

An Eccovision acoustic rhinometer (Hood Laboratories, Pembroke, Massachusetts, USA) was used for rhinometric assessment. Subjects were invited to rest in the study room for 30 minutes before the test in order to adapt to the environment. After calibration of the system, subjects were seated upright in an ENT examination chair, and faced the examiner with their head supported by the head rest. A properly fitted nosepiece was selected and a thin layer of ointment was applied to the nosepiece to prevent any acoustic leakage from the junction between the nostril and nosepiece. Special care was taken not to distort the nasal valve anatomy, and also to position the nosepiece such that it was only in light contact with the nostril during the assessment. After the nosepiece was fitted, subjects were asked to stop breathing for about five seconds while the probe tube was applied to the nostril and the measurements were performed.

Rhinograms with irregular tracings or discrepant measurements, due to swallowing, head movements or inadequate sealing of the nostrils, were discarded. Values for each subject were based upon an average of three measurements derived from technically acceptable curves. All of the measurements were performed by the same clinician. The rhinometric measures included: the minimal cross-sectional area; three cross-sectional areas (CSA1, CSA2 and CSA3) and three volumes (V1, V2 and V3), which corresponded to the anterior, middle and posterior regions of the nasal airway; and the total volume. Mean values were defined as the average of left and right nasal passage values.

Nasometry

Nasalance scores were obtained using a Nasometer II instrument (model 6400; Kay Elemetrics). Calibration, data recording and calculation of nasalance scores were performed according to the nasometer instruction manual.[9] Each participant practised production of the speech samples before recordings were obtained. Only productions that were accurate for both articulation and voicing were included for analysis.

Speech stimuli

The subjects were asked to read three Turkish passages, which were comparable to the three types of English passages that are part of standard nasometric evaluations (i.e. the Zoo passage, Rainbow passage and nasal sentences). The oral passage 'zilli kedi' is similar to the Zoo passage and is devoid of nasal consonants. The oronasal passage 'dedem' is similar to the Rainbow passage and is loaded with a mixture of oral and nasal consonants that are proportional to everyday speech (i.e. it contains 14.67 per cent nasal consonants). The nasal passage 'manav' is similar to the nasal sentences loaded with nasal consonants. The ratio of nasal consonants to the total number of consonants in the nasal passage was 48.83 per cent. The three passages were created by following the criteria established in the three English language passages and the frequency of sounds used in daily conversation, but modified for the Turkish language.

Data analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences version 13.0 software program (SPSS Inc, Chicago, Illinois, USA). Group means and standard deviations were determined to describe the nasalance scores and rhinometric values observed under each condition (i.e. before and after decongestion). A paired samples *t*-test was performed to determine the effect of the decongestant on both nasalance and nasal volume measures, for each individual and under each condition. Pearson correlation coefficients were then calculated to determine the strength of the relationship between the changes in nasalance scores and the acoustic rhinometric measurements. *A priori*, a p value of less than 0.05 was determined to be statistically significant.

Results

Results were obtained from 21 participants prior to and after application of the decongestant. Group means and standard deviations of acoustic rhinometric parameters (i.e. the minimal cross-sectional area, the three cross-sectional areas CSA1, CSA2 and CSA3, the three volumes V1, V2 and V3, and the total volume) for each condition (i.e. before and after decongestion) are presented in Table I. All parameters

TABLE I

ACOUSTIC RHINOMETRIC PARAMETERS DETERMINED BEFORE AND AFTER APPLICATION OF NASAL DECONGESTANT

Parameter	Pre (mean ± SD)	Post (mean ± SD)	t	p
MCA (cm^2)	0.48 ± 0.17	0.67 ± 0.14	5.82	0.000*
CSA1 (cm^2)	0.73 ± 0.27	1.13 ± 0.35	−4.28	0.000*
CSA2 (cm^2)	1.74 ± 0.47	2.61 ± 0.68	−7.03	0.000*
CSA3 (cm^2)	3.23 ± 0.83	4.32 ± 1.22	−3.39	0.003*
V1 (cm^3)	1.54 ± 0.36	1.93 ± 0.45	−5.49	0.000*
V2 (cm^3)	1.66 ± 0.52	2.90 ± 0.78	−9.02	0.000*
V3 (cm^3)	2.64 ± 0.70	4.22 ± 1.22	−6.33	0.000*
TV (cm^3)	5.86 ± 1.40	9.10 ± 2.04	−9.41	0.000*

Mean values are averages of left and right nasal passage values. *Statistically significant difference between pre- and post-decongestant measurements. Pre = pre-decongestant; post = post-decongestant; SD = standard deviation; MCA = mean cross-sectional area; CSA = cross-sectional area; V = volume; TV = total volume

showed statistically significant increases after the application of nasal decongestant ($p < 0.05$).

Table II presents the group means and standard deviations of nasalance scores calculated for the three reading passages before and after decongestion. Nasalance scores for all three passages showed statistically significant increases after nasal decongestion ($p < 0.05$).

Finally, relationships between the measures were calculated to determine how well changes in volume measures could predict changes in nasalance. No significant correlations were found between the changes in acoustic rhinometric parameters and nasalance scores ($p > 0.05$). The r^2 values are presented in Table III.

Discussion

The nasal cavity and paranasal sinuses play an important role in shaping the resonant characteristics of the vocal tract.[10] It is well known that an obstruction in the nasal cavity or nasopharynx can result in hyponasality, while an inability to close the velopharyngeal port and increased nasal air escape may lead to hypernasality. The nasal cavity is reported to provide as much as 50 per cent of the total resistance to nasal airflow, implying that relatively small changes in nasal patency can affect the total airway resistance significantly.[11]

TABLE II

NASALANCE SCORES DETERMINED FOR THREE VOCAL PASSAGES, BEFORE AND AFTER DECONGESTION

Passage	Pre (mean ± SD)	Post (mean ± SD)	t	p
'Zilli kedi'	9.33 ± 5.12	10.71 ± 5.75	−2.35	0.029*
'Dedem'	33.09 ± 6.45	35.66 ± 6.51	−3.32	0.003*
'Manav'	45.09 ± 7.37	47.76 ± 7.02	−2.35	0.029*

Data represent nasalance score percentages; mean values are averages of left and right nasal passage values. *Statistically significant difference between pre- and post-decongestant measurements. Pre = pre-decongestant; post = post-decongestant; SD = standard deviation

Several studies have investigated the effects of nasal decongestion on nasalance scores. For example, Pegoraro-Krook *et al.*[4] investigated the effect of nasal decongestion on nasalance scores in a group of 100 individuals (41 with hyponasality and 59 with hypernasality). They reported significantly higher nasalance scores for both groups after the application of decongestant. Williams *et al.*[5] measured the effect of a topical nasal decongestant on nasalance scores in a group of 52 normally speaking subjects, and found a significant increase in nasalance scores after the application of decongestant. Although these studies reported significant changes in nasalance scores, none of them investigated the source of the change in nasalance.

There is some evidence to suggest that nasal cavity size could relate to subsequent changes in nasalance. Three previous studies have examined the relationship between nasalance and nasal cavity size. Mayo *et al.*[12] examined the effect of race on nasalance scores and nasal cross-sectional area values in normal African-American and Caucasian adults. They reported a weak correlation between measures of nasalance and nasal cross-sectional areas. Litzaw and Dalston[13] investigated the effect of gender upon nasalance scores among normal adult speakers. Like Mayo *et al.*, they found that nasalance scores were not highly correlated with nasal cross-sectional area. However, one limitation of these two studies was their use of a pressure-flow method to determine nasal cavity changes. Thus, the effect of dynamic nasal cavity changes on nasalance scores could not be determined. Jiang and Huang[8] investigated the influence of functional endoscopic sinus surgery on nasalance and volumetric changes, and found that after surgery both nasalance scores and nasal volumes significantly increased. They also reported that increased nasalance scores were moderately correlated with increased midnasal and postnasal volumes, suggesting that nasalance was only somewhat affected by changes in nasal volume.

In the present study, we investigated the effects of nasal decongestion on measures of nasalance and nasal cavity volume. In addition, we determined the relationship between subsequent changes in nasal cavity volume and nasalance. The distinctive part of our study was the addition of acoustic rhinometry to enable objective measurement of the change in nasal cavity volume after decongestion, in order to determine one possible mechanism for nasalance alteration. By using acoustic rhinometry, we calculated nasal volumes and examined whether volume changes resulted in increased nasalance scores. Our results showed that application of nasal decongestant resulted in statistically significant increases in nasalance scores. All acoustic rhinometric parameters also showed statistically significant increases after decongestion. However, despite increases in both measures, no significant correlation was found between changes in nasalance and nasal cavity volumes. These results might suggest that other factors also contribute to nasalance score changes; this is consistent with results from previous studies.[8,12,13]

TABLE III

CORRELATIONS BETWEEN CHANGES IN NASALANCE SCORES FOR THREE VOCAL PASSAGES AND CHANGES IN ACOUSTIC RHINOMETRIC PARAMETERS

Passage	MCA	CSA1	CSA2	CSA3	V1	V2	V3	TV
'Zilli kedi'	0.1375	0.0355	0.0063	0.0058	0.0000	0.0122	0.0170	0.0036
'Dedem'	0.0970	0.0990	0.0003	0.0368	0.0229	0.0130	0.0002	0.0080
'Manav'	0.0723	0.1014	0.0042	0.0576	0.0277	0.0192	0.0048	0.0246

Data represent r^2 values; $p > 0.05$ for all comparisons. MCA = mean cross-sectional area; CSA = cross-sectional area; V = volume; TV = total volume

Nasal decongestion can affect nasalance scores by causing an increase in nasal cavity volume and/or a decrease in nasal airway resistance, resulting in increased nasal acoustic energy.[4] We did not measure the nasal airway resistance in this study. Instead, we measured nasal sectional areas and nasal volumes by acoustic rhinometry. However, the rhinometric measures were not sensitive predictors of change in nasalance scores. Litzaw and Dalston[13] noted that nasal acoustic energy is affected by the overall shape and volume of the nasal cavity and therefore may not show a strong relationship between sectional acoustic rhinometric values and nasalance scores. Although this would explain the weak relationship found between sectional volumetric measures and nasalance in our study, it does not explain why total volume also significantly increased after decongestion, but did not demonstrate any strong relationship with changes in nasalance scores.

The relationship between nasalance and nasal airway resistance was investigated by Williams *et al.*[5] After the application of a topical nasal decongestant, significant changes were reported both in nasal airway resistance and nasalance, with a significant inverse correlation. This study showed that nasal airway resistance could influence nasality. On the other hand, Keck *et al.*[14] investigated the changes in nasal cavity size and nasal airway resistance in patients with perennial allergic rhinitis before and after a nasal provocation test. They reported a significant increase in nasal airway resistance, but no significant change in nasal cavity measurements. These results suggest that nasal airway resistance may change without any accompanying change in nasal cavity size. Results from the present study, as well as those reported by Williams *et al.* and Keck *et al.*, are consistent with the hypothesis that nasalance may be more strongly affected by changes in nasal airway resistance than changes in nasal cavity size. Although we did not measure the nasal airway resistance in this study, we hypothesise that topical nasal decongestion causes a decrease in nasal airway resistance which results in an increase in nasal acoustic energy and therefore nasalance.

Although the results of our study would suggest that factors other than nasal cavity volume contribute to nasalance, caution is warranted in generalising these results, due to the relatively small number of subjects in our study as well as the known limitaions of nasometry and acoustic rhinometry.[15–17] However, the fact that both measures changed similarly following application of decongestant in our study appears to support the validity of the results. It is obvious that the addition of rhinomanometry, to measure nasal airway resistance, would be valuable for interpreting the results of our study. Future studies that employ a combination of nasal airway resistance, nasal cavity volume and nasalance measures would help determine the relative contribution of both nasal airway resistance and nasal volume to changes in nasalance.

- **Medication or surgery which alters the patency or volume of the nasal cavity can affect the acoustic characteristics of the voice, e.g. its nasalance**
- **Changes in nasalance may develop due to an increase in nasal cavity volume or a decrease in nasal airway resistance**
- **This study found no correlation between changes in nasal cavity volume and nasalance**
- **Changes in nasalance seem to be the result of factors other than nasal cavity volume change**

The findings of the present study may have some useful clinical applications. We demonstrated that nasalance scores can be affected by nasal decongestion. Thus, clinicians must be aware that patients who use nasal decongestants prior to nasometric assessment may demonstrate higher nasalance scores. Conversely, the presence of nasal congestion due to allergies or upper respiratory infections will result in lower nasalance scores. Thus, clinicians should be careful, both in their interpretation of normal values when assessing these patients and in their determination of the effects of treatment, when patients report recent use of nasal decongestants or drugs having similar effects (e.g. topical nasal steroid sprays) prior to nasometric evaluation. Our study findings may also be relevant for patients with concerns about the effects of nasal decongestants on their vocal quality, such as singers and professional speakers. Future investigations should address how changes in nasalance, nasal airway resistance and nasal volume relate to perceptual changes in voice quality and resonance.

Conclusions

Nasal decongestion causes an increase in both nasal cavity volume and nasalance scores. However, no significant relationship was found between volumetric change of the nasal cavity and nasalance, indicating that other measures may be more sensitive predictors of nasalance.

References

1 Lee GS, Yang CC, Wang CP, Kuo TB. Effect of nasal decongestion on voice spectrum of a nasal consonant-vowel. *J Voice* 2005;**19**:71–7
2 Kent RD. Hearing and believing: some limits to the auditory-perceptual assessment of speech and voice. *Am J Speech Lang Pathol* 1996;**5**:7–23
3 Dalston RM, Warren DW, Dalston ET. Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. *Cleft Palate Craniofac J* 1991;**28**:184–9
4 Pegoraro-Krook MI, Dutka-Souza JC, Williams WN, Teles Magalhães LC, Rossetto PC, Riski JE. Effect of nasal decongestion on nasalance measures. *Cleft Palate Craniofac J* 2006;**43**:289–94
5 Williams RG, Eccles R, Hutchings H. The relationship between nasalance and nasal resistance to airflow. *Acta Otolaryngol* 1990;**110**:443–9
6 Hong KH, Kwon SH, Jung SS. The assessment of nasality with a nasometer and sound spectrography in patients with nasal polyposis. *Otolaryngol Head Neck Surg* 1997;**117**:343–8
7 Soneghet R, Santos RP, Behlau M, Habermann W, Friedrich G, Stammberger H. Nasalance changes after functional endoscopic sinus surgery. *J Voice* 2002;**16**:392–7
8 Jiang RS, Huang HT. Changes in nasal resonance after functional endoscopic sinus surgery. *Am J Rhinol* 2006;**20**:432–7
9 Kay Elemetrics. *Nasometer II Model 6400 Installation, Operations, and Maintenance Manual*. Lincoln Park, New Jersey: Kay Elemetrics, 2003
10 Proctor DF. *Breathing, Speech and Song*. Vienna: Springer-Verlag, 1980
11 Wetmore RF. Importance of maintaining normal nasal function in the cleft palate patient. *Cleft Palate Craniofac J* 1992;**29**:498–506
12 Mayo R, Floyd LA, Warren DW, Dalston RM, Mayo CM. Nasalance and nasal area values: cross-racial study. *Cleft Palate Craniofac J* 1996;**33**:143–9
13 Litzaw LL, Dalston RM. The effect of gender upon nasalance scores among normal adult speakers. *J Commun Disord* 1992;**25**:55–64
14 Keck T, Wiesmiller K, Lindemann J, Rozsasi A. Acoustic rhinometry in nasal provocation test in perennial allergic rhinitis. *Eur Arch Otorhinolaryngol* 2006;**263**:910–16
15 Cakmak O, Celik H, Ergin T, Sennaroglu L. Accuracy of acoustic rhinometry measurements. *Laryngoscope* 2001;**111**:587–94
16 Watterson T, Lewis KE. Test-retest nasalance score variability in hypernasal speakers. *Cleft Palate Craniofac J* 2006;**43**:415–19
17 Bressmann T. Comparison of nasalance scores obtained with the Nasometer, the NasalView, and the OroNasal System. *Cleft Palate Craniofac J* 2005;**42**:423–33

Address for correspondence:
Dr Hakan Birkent,
Department of Otolaryngology–Head and Neck Surgery,
University of Washington,
1959 NE Pacific St,
Box 356515,
Seattle,
Washington 98195-6515, USA.

Fax: +1 206 5435152
E-mail: hbirkent@yahoo.com

Dr H Birkent takes responsibility for the integrity of the content of the paper.
Competing interests: None declared