

Original Paper

Nasal Expiratory Sound Analysis for Evaluation of Nasal Patency in Perennial Allergic Rhinitis Patients Treated with Nasal Corticosteroids

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Key Words

Nasal obstruction · Perennial allergic rhinitis · Nasal corticosteroids · Inferior turbinate hypertrophy · Nasal sound analysis

Abstract

Purpose: To assess the efficacy of nasal expiratory sound analysis in determining the degree of nasal obstruction. **Materials and Methods:** We have analyzed and recorded the expiratory nasal sounds in 18 healthy controls and in 30 patients with inferior turbinate hypertrophy before and after the administration of nasal corticosteroid treatment. Analysis consisted of the time-expanded waveform, spectral analysis with time-averaged fast Fourier transform and waveform analysis of nasal sound. **Results:** Before treatment, an increase in sound intensity at high frequency was observed in the sound analyses of the patients, whereas after treatment, a decrease in sound intensity at high frequency was noted in the sound analyses of the patients. The differences between the patients and the control group were statistically significant. Data obtained with the Odiosoft-Rhino method were correlated with symptom scores and endoscopic examination. **Conclusion:** Expiratory nasal sound is a practical and objective tool, which can be reliably used not only for the assessment of the degree of nasal blockage but also for the comparison of different treatment alternatives.

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Introduction

Nasal physiology is affected by anatomic deformities and their effects on the congestion, drainage, and olfaction [1]. Inferior turbinate hypertrophy (ITH) can affect the airflow through the nasal cavity, possibly by transforming its laminar pattern to a more turbulent form. Turbulence generates audible sound waves, and these sounds become even louder whenever nasal respiratory flow is increased across a narrowing nasal passage where the turbulence becomes more evident [2].

Allergic rhinitis can result in nasal obstruction through an increased inflammatory process, which subsequently may lead to ITH [3]. The Odiosoft-Rhino (OR) method uses a software to analyze the original sounds of nasal airflow [4]. Since nasal air flows in a laminar pattern in a smooth tube, the frequency of the sound of the airflow is low. When the air passage in this tube is impeded (as in case of an ITH), laminar flow becomes turbulent and the sound of the airflow shifts to higher frequencies.

In this study, we investigated the OR findings on the pattern of nasal expiratory sound spectra in healthy controls and in patients with ITH before and after treatment.

Materials and Methods

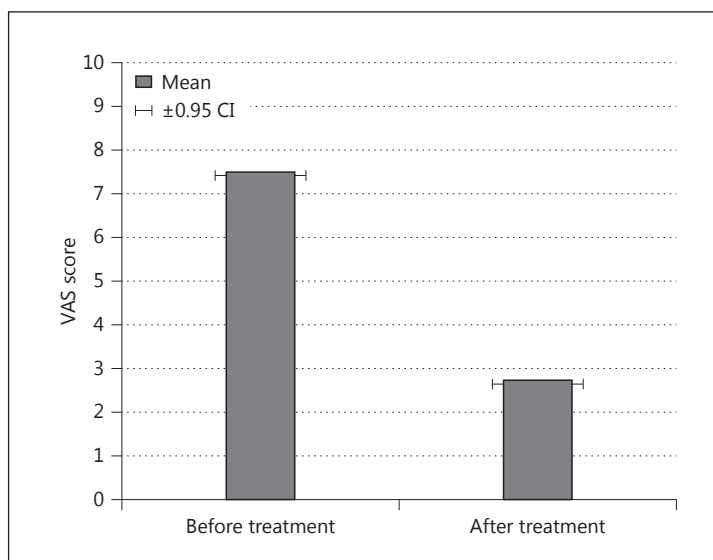
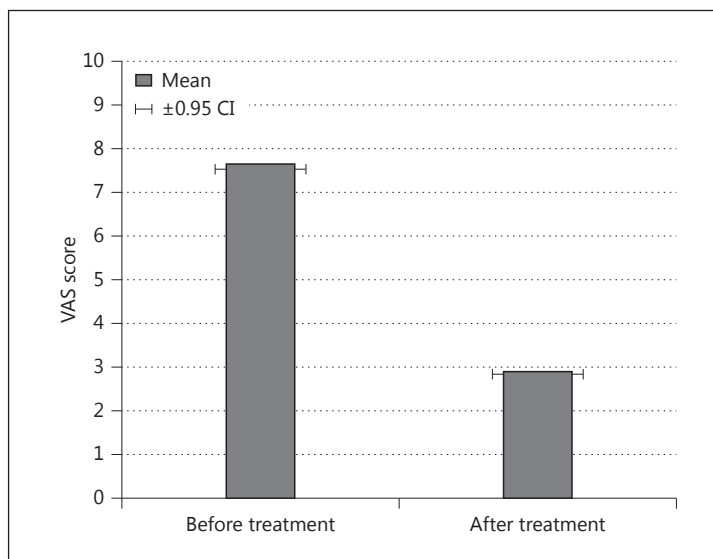
A total of 30 patients with perennial allergic rhinitis (PAR) and 18 healthy controls were included in this study. Approval was obtained from the local institutional review board of the Osmangazi University School of Medicine, Eskişehir, Turkey. OR records and visual analogue scale (VAS) scores were obtained for nasal obstruction on both sides (fig. 1, 2). Nasal endoscopic examination was performed routinely in all subjects. Those subjects with symptoms of allergic rhinitis and sensitivity to mites (*Dermatophagoides pteronyssinus* and *Dermatophagoides farina*), as documented by a skin prick test (ALK-Abello test panel, Horsholm, Denmark, which includes 28 aeroallergens and 12 food allergens) and serum-specific immunoglobulin E (IgE) levels, constituted the patient group. The patient group consisted of cases with PAR who had nasal obstruction as their chief complaint due to bilateral ITH in the absence of a septal deviation or any other nasal problem. The control group consisted of 18 healthy adults without any nasal complaints, negative skin prick test results and normal serum-specific IgE levels. In this series, nasal endoscopic examination revealed the ITH as the main cause of their complaint. Subjects in the patient group had experienced nasal obstruction for at least 2 years and showed no hypersensitivity to allergens other than mites.

Nasal Sound Analysis

Acoustic rhinometry and OR were performed in all subjects in the same quiet room. Crusts and/or secretions in the nasal cavities of the subjects were cleaned before the measurements were performed. Subjects were accepted into the test room 25–30 min before the tests were started to minimize the effects of environmental change.

In the OR test method, the nasal probe connected to the microphone was situated 1 cm away from the nostril, and the subject was directed to close the other nostril without distorting the shape of the nose. The subject was asked to give a nonforced expiration, and the nasal sound was processed by the software. The time required for recording was between 2 and 3 s.

Frequency measurements were performed at intervals of 200–500, 500–1,000, 1,000–2,000, and 2,000–6,000 Hz for each nasal cavity. The OR equipment consisted of a microphone, nasal probe, and sound card (Yamaha AC-XG WDM Audio, Japan), which samples and digitizes the signals representing the nasal sounds. The nasal probe stands 1 cm outside the nose. The sound which is caused by the nasal airflow is recorded with a microphone, was low-pass filtered at a cutoff frequency of 10 kHz, high-pass filtered at 150 Hz, and amplified by 20 dB. We connected a microphone to the sound card, then recorded the nasal sound which was converted to analog signals on the PC; then the signal was digitized using a 16-bit analog-to-digital converter. The digital recording of the sound was stored as a small wave file.

Fig. 1. VAS scores before and after treatment of the right nasal passage. CI = Confidence interval.**Fig. 2.** VAS scores before and after treatment of the left nasal passage. CI = Confidence interval.**Table 1.** Degree of ITH and OR findings of the patients at *Lf*, *Mf*, and *Hf* intervals

	Number	<i>Lf</i> 500–1,000 Hz	<i>Mf</i> 1,000–2,000 Hz	<i>Hf</i> 2,000–4,000 Hz	4,000–6,000 Hz
<i>Left side</i>					
Mild ITH	2	21.18±5.23	19.53±7.41	10.23±3.34	7.64±2.13
Moderate ITH	12	15.32±7.54	13.24±8.27	21.67±8.12	26.17±3.78
Severe ITH	16	11.56±4.67	14.12±4.35	29.12±6.23	38.23±6.34
<i>Right side</i>					
Mild ITH	4	23.34±5.25	20.34±5.78	12.23±4.24	9.12±2.11
Moderate ITH	9	18.45±5.19	14.45±8.35	23.45±7.67	25.45±4.16
Severe ITH	17	12.65±6.34	12.35±4.37	31.34±4.67	36.26±5.45

Sound Spectral Analyzer

Signal processing of the OR is performed by a mathematical tool called the fast Fourier transform (FFT), which analyzes the spectral content of a signal. The sound signal can be represented as a combination of sine waves of various frequencies. It calculates a Fourier transform of a digital signal using the divide-and-conquer method.

Study and Control Groups

A total of 30 patients complaining mainly of nasal obstruction attributed to ITH without any evidence of a coexisting pathology were studied. The patient group consisted of 9 men and 21 women (mean age: 23.2 ± 3.7 years; range: 21–35). Patients with a history of nasal surgery, treatment for allergic rhinitis, trauma and an additional clinical or radiological nasal pathology such as nasal septal deviation, nasal polyposis, or who had systemic diseases were excluded from the study.

ITH blocking of <50% of the nasal passage was considered as mild, blockage of $\geq 50\%$ of the nasal passage was considered as moderate, and total obstruction of the nasal passages was considered as severe. The degree of ITH was mild in all subjects of the control group. In the patient group, left-side analysis revealed that 2 subjects (6.7%) showed mild ITH, 12 subjects (40.0%) had moderate ITH, and 16 subjects (53.3%) had severe ITH. Right-side analysis revealed 4 subjects (13.3%) with mild ITH, 9 subjects (30.0%) had moderate ITH, and 17 subjects (56.7%) had severe ITH.

The control group consisted of 18 (10 females, 8 males) healthy, nonsmoking volunteers (mean age: 21 ± 4.1 ; range: 20–36). Subjects with a history of chronic nasal disease, or nasal surgery or those on medications that could modify nasal function were excluded from the study. All subjects were free of any nasal complaints and nasal endoscopic examination did not exhibit any pathological findings.

Treatment

Mometasone furoate was prescribed to all patients at a dose of 2 puffs (50 μg /puff) in each nostril and application in the morning was suggested. The medication was continued for 2 consecutive months.

Statistical Analysis

Numerical data [the nasal sound frequency in low frequency (*Lf*), medium frequency (*Mf*) and high frequency (*Hf*)] of the patients and the control group were tabulated and analyzed using Mann-Whitney U tests as appropriate with a commercially available statistical package (Statgraph 5.0 for Windows, Manugistics, Inc., USA). The level of significance was set at a p value of <0.05. All data were expressed as means $\pm$ standard deviation.

Results

Before treatment, a correlation between the degree of turbinate hypertrophy and the OR findings at *Hf* interval of the patients was observed (table 1) ($p < 0.05$). The average sound intensity values of the patients and the control group at *Lf*, *Mf*, and *Hf* (before and after treatment) are given in table 2. It has been found that before treatment, the sound intensity at *Hf* was above 32 dB in the patients, while the results after treatment were below 12 dB in the patients and the control group (fig. 3). In terms of the *Lf*, *Mf*, and *Hf* values, there was no significant difference after treatment between the patients and the control group ($p = 0.176$).

Discussion

Nasal obstruction is not simply one of the main complaints of PAR, but it has been reported as a ‘key symptom’ because it is deeply associated with an impaired quality of life, and it reflects more directly the allergic inflammation in the nasal mucosa [5].

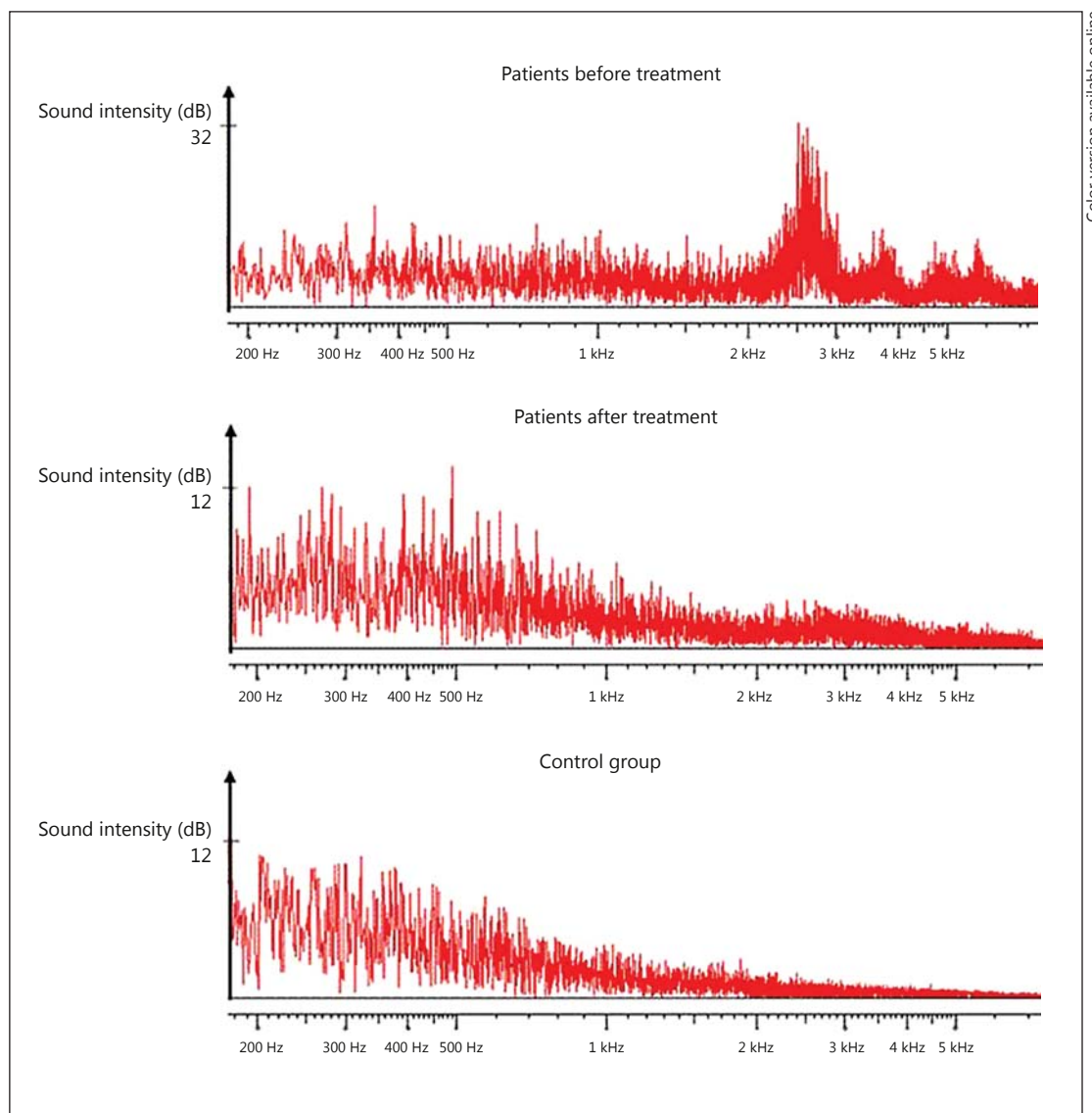


Fig. 3. Sound intensities at *Hf* before and after the topical steroid treatment in the control group and the patients.

Table 2. Average sound intensity values at *Lf*, *Mf*, and *Hf* of the patients and control groups (before and after treatment)

	Cavities	<i>Lf</i> 500–1,000 Hz	<i>Mf</i> 1,000–2,000 Hz	<i>Hf</i> 2,000–4,000 Hz 4,000–6,000 Hz	
ITH patients before treatment	left	15.22±5.67	13.35±6.21	27.32±5.23	33.27±4.51
	right	13.42±7.12	11.23±4.11	26.14±4.21	35.23±4.71
ITH patients after treatment	left	23.34±6.35	20.12±7.56	12.45±3.45	8.45±3.67
	right	24.54±4.38	18.56±6.76	14.52±5.43	8.34±3.23
Control group	left	23.39±6.67	22.34±4.72	12.54±3.79	5.15±2.61
	right	25.61±9.19	21.18±9.63	13.26±4.22	8.19±3.45

Topical corticosteroids, including mometasone furoate, are commonly used to relieve nasal obstruction in both seasonal rhinitis and PAR patients [6]. Mometasone furoate is a highly potent, clinically effective and well-tolerated intranasal corticosteroid with negligible systemic activity. It is available not only for the treatment but also prophylaxis of the nasal symptoms of seasonal rhinitis and PAR [7]. It can be safely used even in children as young as 2 years of age in some countries and 6 years of age in others [7].

Maxwell [8] describes the VAS to be an easy, practical, sensitive, and accurate method, which can be used to test differences within subject comparisons. Lund [9, 10] has popularized the use of linear visual scales in the office evaluation of nasal obstruction, noting that they are of great value for comparing sequential evaluations. Objective testing with acoustic rhinometry and rhinomanometry was considered but not used due to their questionable reliability and reproducibility [9, 10]. Acoustic rhinometry results in distortion of the nasal valve area during testing, and rhinomanometry shows up to 50% day-to-day variation in results [8]. Therefore, we have not used these objective measurements in our study.

Wandalsen et al. [11] have evaluated the impact of nasal steroids on nasal congestion in children and adolescents with PAR. PAR showed benefit from intranasal mometasone furoate treatment. Symptom scores, nasal hyperreactivity and nasal volumes improved at the end of a 3-week treatment course [11]. Similarly, Yamada et al. [12] have prospectively investigated the effectiveness of the mometasone furoate nasal spray in improving the total nasal symptom score, sleep quality and quality of life in subjects with PAR. Their results indicated that treatment with intranasal mometasone furoate improved nasal symptoms, upper airway condition, sleep quality and quality of life in Japanese PAR patients [12]. Meltzer et al. [13] have suggested that the use of the mometasone furoate nasal spray improved nasal symptoms, sleepiness, and impairment in daily activities in PAR.

A relationship has been postulated between nasal Th2-related inflammation and nasal airflow in seasonal allergic rhinitis patients [14]. Nasal airflow is affected by interleukin-5 concentration and eosinophil infiltration in PAR [15]. ITH is a main component of nasal obstruction in allergic rhinitis, and it may respond to medical or surgical treatment modalities [3].

The cross-sectional area of the nose is a major determinant of airflow, the airflow increases in proportion to the increasing cross-sectional area. The cross-sectional area varies along the length of the nose. The effect of turbulence in the nasal airway has not been precisely quantified previously [16].

Nasal sound analysis utilizes a software program that calculates sound frequency and intensity. Since the diameter of the nasal airway is the most important factor determining the type of the nasal airflow (laminar or turbulent), this is reflected as a change in the sound of the airflow [4, 17]. In this study, we have shown that nasal steroid treatment resulted in a diminished size of inferior turbinates leading to increased cross-sectional areas in the nasal cavity. Thereby, the amount of air passing through the nasal passage was found to be increased [18]. The pattern of airflow is affected by the turbulence and the more turbulent the airflow, the louder the nasal sounds occur [2, 19]. Sound wave spectra are clearly linked to the respiratory airflow rate. Sound increases in parallel to the increase in turbulence and decrease in airflow, engendering a marked upward shift in the frequencies of the spectra [20]. As a result of this study, OR appears to be a safe and practical method for the objective evaluation of nasal passage without the necessity of a strict cooperation with the patient.

The small sample size and lack of usage of other measures of evaluation of nasal patency are limitations of this study.

Thus, the efficacy of different treatment regimens can be easily compared, and more effective therapeutic algorithms can be developed. Moreover, OR can constitute a reliable

measure in cases of medicolegal circumstances which can occur after nasal surgical procedures. Further trials with larger series may yield the actual diagnostic potential of nasal sound analysis.

Conclusion

Expiratory nasal sound is a practical and objective tool, which can be reliably used not only for the assessment of the degree of nasal blockage but also for the comparison of the efficacy of the different treatment alternatives.

Disclosure Statement

The authors have no conflicts of interest or financial disclosure regarding this article.

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