

Effect of the radiofrequency volumetric tissue reduction of inferior turbinate on expiratory nasal sound frequency

Erdal Seren, M.D.*

ABSTRACT

Background: We sought to evaluate the short-term efficacy of radiofrequency volumetric tissue reduction (RFVTR) in treatment of inferior turbinate hypertrophy (TH) as measured by expiratory nasal sound spectra. In our study, we aimed to investigate the Odiosoft-rhino (OR) as a new diagnostic method to evaluate the nasal airflow of patients before and after RFVTR.

Methods: In this study, we have analyzed and recorded the expiratory nasal sound in patients with inferior TH before and after RFVTR. This analysis includes the time expanded waveform, the spectral analysis with time averaged fast Fourier transform (FFT), and the waveform analysis of nasal sound.

Results: We found an increase in sound intensity at high frequency (Hf) in the sound analyses of the patients before RFVTR and a decrease in sound intensity at Hf was found in patients after RFVTR.

Conclusion: This study indicates that RFVTR is an effective procedure to improve nasal airflow in the patients with nasal obstruction with inferior TH. We found significant decreases in the sound intensity level at Hf in the sound spectra after RFVTR. The OR results from the 2000- to 4000-Hz frequency (Hf) interval may be more useful in assessing patients with nasal obstruction than other frequency intervals. OR may be used as a noninvasive diagnostic tool to evaluate the nasal airflow.

(Am J Rhinol Allergy 23, 316–320, 2009; doi: 10.2500/ajra.2009.23.3323)

Key words: Inferior turbinate hypertrophy, nasal airflow, nasal obstruction, nasal sound analysis, nasal sound spectra, Odiosoft-rhino, radiofrequency

Several factors may influence the sensation of comfortable nasal breathing, including the amount and type of nasal airflow, the sensation registered from the intranasal skin or mucosa by the passing air, and the condition of the nasal mucosa. The major portion of the airstream after the vestibule passes through the middle meatus and over the inferior turbinates.^{1,2}

Nasal obstruction is the most common symptom in patients with sinonasal pathologies, unfavorably influencing various daily activities and reducing the quality of life.³ Hypertrophy of the inferior turbinate is a common cause of nasal obstruction. To treat this problem, there are different surgical approaches including anterior turbinoplasty, laser application, cryogenic surgery, electrical cauterization, and vidian neurectomy. A relatively new technique to treat turbinate hypertrophy (TH), radiofrequency volumetric tissue reduction (RFVTR) uses radiofrequency energy to shrink the turbinate. Tissue is ablated by heat desiccation created by frictional energy. RFVTR is a significant improvement for nasal obstruction in patients with TH.⁴ Assessments of nasal flows are useful indicators of nasal resistance. The timing, pitch, and waveform of nasal sound reflect us nasal flow under various conditions. Sound intensity increases with the airflow, causing a marked upward shift in frequencies in the sound spectra.⁵

This obstruction affects the pattern of nasal airflow and transforms the turbulent pattern. Turbulent airflow causes louder nasal sounds. The spectral analysis of the nasal sound

is an indicator of the nasal airflow pattern.^{6–8} The primary objective of this study was to evaluate the short-term efficacy of RFVTR on the expiratory nasal sound spectra.

MATERIALS AND METHODS

This study was performed with the permission of the Ethic Committee of Giresun State Hospital and with informed consent from the subjects. No funding support was required for this study. Those subjects who had symptoms of allergic rhinitis and sensitivity to mites (*Dermatophagoides pteronyssinus* and *D. farinae*) were determined by a skin-prick test panel (ALK-Abello, Hørsholm, Denmark), which include 28 aeroallergens and 12 food allergens and were accepted into the patient group; subjects with no nasal complaints and negative skin-prick tests were included in the control group. Patients with perennial allergic rhinitis who had nasal obstruction as their chief complaint caused by bilateral hypertrophy of the inferior turbinates without septal deviation or any other nasal problem were chosen. All patients had a history of nasal obstruction for >1 year. In this report, physical and endoscopic examination of these patients found that TH was the main cause of symptoms.

Patient Group

Nasal sound spectral analysis was performed on 26 patients with bilateral nasal obstruction (11 female patients [42.3%] and 15 male patients [57.7%]) who had nasal obstruction as their chief complaint. The ages of the patients ranged between 18 and 51 years, with a mean of 30.17 ± 9.36 years.

The inclusion criteria for patients included significant symptoms of nasal obstruction, evidence of bilateral inferior TH, absence of smoking history, and medical treatment for allergic symptoms for at least 6 months. Exclusion criteria included a history of bleeding disorders, prior radiation ther-

From Giresun Devlet Hastanesi, Giresun, Turkey

Address correspondence and reprint requests to Erdal Seren, M.D., Giresun Devlet Hastanesi Kulak-Burun-Bogaz Servisi, Giresun, Turkey

E-mail address: eseren@yahoo.com

Copyright © 2009, OceanSide Publications, Inc., U.S.A.

Table 1 The results of the nasal sound fast Fourier transform analyses in the patients without radiofrequency volumetric tissue reduction and their physical examination findings (degree of TH) were seen in this table

	Lf	Mf	Hf	
	500–1000 Hz	1000–2000 Hz	2000–4000 Hz	4000–6000 Hz
Mild TH	23.27 ± 6.33	20.25 ± 6.53	11.86 ± 3.13	8.78 ± 1.14
Moderate TH	17.45 ± 9.15	15.14 ± 9.26	20.24 ± 7.70	24.13 ± 3.19
Severe TH	13.62 ± 6.63	14.33 ± 5.35	26.62 ± 3.54	34.56 ± 4.29

Hf = high frequency; Lf = low frequency; Mf = medium frequency; TH = turbinate hypertrophy

apy to the nose, insulin-dependent diabetes, smoking, or a history of chronic sinusitis, pregnancy, septal deviation affecting the nasal valve region, polyps or other nasal masses, poorly controlled hypertension, and evidence of prior turbinate surgery.

TH was described as follows⁹: <50% of nasal passage was considered mild, >50% of nasal passage was considered moderate, and total obstruction of the nasal passages was considered severe. The degree of TH was mild in all subjects of the control group. In the patient group, left-side analysis, 2 subjects (7.7%) showed mild TH, 10 subjects (38.5%) had moderate TH, and 14 subjects (53.8%) had severe TH. Right-side analysis revealed 1 subject (3.8%) with mild TH, 9 subjects (34.6%) had moderate disease, and 16 subjects (61.6%) had severe TH.

Control Group

This study was performed in 30 healthy nonsmoking volunteers (14 women [46.6%] and 16 men [53.4%]). The ages of the subjects ranged between 20 and 49 years, with a mean of 27.52 ± 11.16 years. None of these subjects had a history of nasal complaints, nasal trauma, or nasal surgery, and they were not using any nasal medications that could modify nasal function and bias the results. All subjects had normal clinical and endoscopic examination of the nasal fossa.

Surgical Technique

The mucosa of the inferior turbinate was anesthetized with 2% topical pantocaine followed by injection of 1.5 mL of 1% lidocaine into the anterior end of each turbinate. The RFVTR probe was inserted into the anterior end of the inferior turbinate until the 1.0-cm active tip was completely submucosal. RFVTR was then performed with the turbinate probe (Celon-ProBreath) and an RFVTR unit (CelonLab ENT; Celon AG Medical instruments, Berlin, Germany). The unit was set at partially rectified current and the power was set at 10. Using the foot switch, 10-second bursts of electrical current were used. Every patient received (each nasal cavity) 100 J into turbinate.

A physical examination was performed to evaluate the inferior turbinate and assess for crusting, bleeding, and ulceration. Each patient had an initial edematous response after RFVTR was increased during the early postoperative period for an average of 1 week. During the 1st postoperative days some fibrous exudation and scab formation was seen on anterior rhinoscopy in all individuals at the site of puncture. The

patients were then discharged and advised to use over-the-counter acetaminophen as directed for any postprocedure pain. Nasal sound analyses of the subjects were evaluated 8 weeks after treatment.

Equipments

A microphone (diameter, 18 mm; frequency range in 50 Hz to 20 kHz) with amplifier and low-pass filters with variable cutoff frequencies, and a nasal probe (made from cylindrical Plexiglas tubes of 11-mm diameter) is mounted; and a computer for the analysis of data acquisition. A 16-bit sampling sound card (AC-XG WDM Audio; Yamaha Corp., Hamamatsu, Japan) sampled the signals.

The nasal probe stands 1 cm outside the nose. The sound, which is occurred from the nasal airflow, was recorded with a microphone (low-pass filtered at a cutoff frequency of 10 kHz, a high-pass filtered at 150 Hz, and amplified by 20 dB). We connect the microphone to the sound card, and then record the nasal sound as a digital sample.

Software

Computer software was developed using Microsoft Visual 6.0 languages. The software program called “Odiosoft-rhino” (OR) provided analysis of the nasal sound waves using the fast Fourier transform (FFT). We easily calculated sound intensity and sound frequency of nasal sound with the help of this program. A new descriptive parameter was created to characterize the frequency spectrum, as previously described.^{5,6} These parameters include low frequency (Lf; 500–1000 Hz), medium frequency (Mf; 1–2 kHz), and high frequency (Hf; 2–4 kHz, 4–6 kHz).

Nasal Sound Recording

1. The patient must be relaxed and before starting the test all crusting and mucous in the nasal cavity must be removed.
2. Artifacts were identified (rubbing sounds of the microphone cable, background noise, computer fan noise, etc.) and removed with help from a spectrogram overview FFT. Four consecutive expirations were held, and then the most suitable one was chosen from every recording.
3. Performance of the sound card must be good. The peak level (PL) is calculated by the program that is ready in the OR program to analyze performance of the sound card. PL is a maximum value of noise amplitude. We

Table 2 Spectral analysis of nasal expiration sounds of the patient and control groups showing the mean values of the sound intensities of the left and right nasal cavities

	Cavities	Lf	Mf	Hf	
		500–1000 Hz	1000–2000 Hz	2000–4000 Hz	4000–6000 Hz
Patient with before RFVTR	L	16.12 ± 6.32	14.65 ± 5.23	24.12 ± 4.12	31.16 ± 3.74
	R	14.34 ± 6.78	12.21 ± 6.32	22.11 ± 3.37	27.26 ± 4.33
Patient with after RFVTR	L	26.75 ± 7.15	21.18 ± 9.06	14.14 ± 4.50	9.23 ± 3.86
	R	29.15 ± 5.52	20.18 ± 5.83	13.52 ± 3.57	7.62 ± 2.39
Control Group	L	25.30 ± 7.81	21.16 ± 5.22	11.54 ± 3.72	6.15 ± 1.61
	R	27.26 ± 9.36	20.17 ± 8.61	12.27 ± 3.28	7.18 ± 2.21

Hf = high frequency; Lf = low frequency; Mf = medium frequency; L = left nasal cavity; R = right nasal cavity; RFVTR = radiofrequency volumetric tissue reduction.

accepted the computer PL values of the sound card performance below 10 dB. The testing room had a very low background noise level.

- While the right side of the nose is being tested, the thumb finger of the left hand closes the left nostril of the nose. During the test, the probe at the right hand is held parallel to the right nasal cavity. The nasal probe must not be inserted into the nasal cavity, it must be 1 cm away from the nose. Before the test, deep breaths are made two or three times. The recording starts during nasal expiration. Then, this same procedure is applied to the other nostril.
- The test procedure was applied to 26 patients and 30 control group subjects (including a total of 112 nasal cavities).

Statistical Analysis

Numerical data (the nasal sound frequency in Lf, Mf, and Hf) of 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, Rockville, MD). A value of $p < 0.05$ was considered statistically significant. All data were expressed as mean value standard deviation.

RESULTS

Before RFVTR, a correlation was observed between the degree of TH and the OR findings at Hf intervals of the patients. (Table 1; $p < 0.05$). The average sound intensity values at Lf, Mf, and Hf of the patients (before and after RFVTR) and control groups are shown in Table 2. It has been found that the sound intensity at Hf was above 30 dB in the patients before RFVTR while the results were found below 10 dB in the patients after RFVTR and in the control group (Fig. 1). Despite the fact that the sound intensity values at Hf decreased significantly after the RFVTR, the decrease in the sound intensity values at Lf and Mf were insignificant. In terms of Lf, Mf, and Hf values, there was no significant difference between the patients after RFVTR and the control groups ($p > 0.005$).

We found that the sound intensity at Hf in the patients with the moderate and severe TH was highly significantly more increased than the mild TH. However, the sound intensities at

Lf and Mf were significantly decreased more in the severe and moderate TH than in mild TH.

DISCUSSION

Many physiological factors and pathological conditions can affect the amount of airflow through the nose. The nasal pathological conditions include mucosal hyperreactivity and septal or other structural deformities. The rate of airflow through the nose depends on the length and cross-sectional area of the nasal airway, the pressure gradient across the nose, and the character of the airflow.^{1,10} The cross-sectional area of the nose is a major factor in determining airflow, with airflow increasing as the cross-sectional area increases. The cross-sectional area varies along the length of the nose. The effect of turbulence in the nasal airway has not been precisely quantified. Laminar flow occurs in a smooth-walled, straight tube at low flow rates, but turbulence occurs when irregularities are encountered in the tube, as would happen in the nose.^{10,11}

Through vascular congestion and decongestion, the inferior turbinate acts as the fourth and final flow-limiting segment. As air enters this constricted segment of the airway, acceleration of the airflow occurs.¹² This conduction affects the pattern of nasal airflow and transforms the turbulent pattern of it.¹³ This turbulent airflow causes louder nasal sounds.¹⁴ Sound wave spectra are clearly linked to respiratory airflow rate. Sound increases with the airflow, engendering a marked upward shift in frequencies in the spectra.⁵

Analysis of nasal sound sample was defined in another study⁶ as a simple, easy, and noninvasive method for evaluation of nasal airflow. Other recent studies revealed that flow modifies both the intensity and the frequency distribution in the spectrum.^{15–17} However, the mean amplitude and the mean frequency are increasing functions of the flow.¹⁸ OR uses pure nasal sounds and utilizes a software program that calculates sound frequency and intensity. Because the diameter of the nasal airway is the most important factor that determines the type of the nasal airflow (laminar or turbulent), this is reflected as a change in the sound of the airflow. In this manner, OR can be used as a method to evaluate nasal obstruction. OR provides the analysis of the nasal airflow and the efficacy of RFVTR.

This study was designed to evaluate the short-term efficacy of RFVTR for the treatment of nasal obstruction in patients

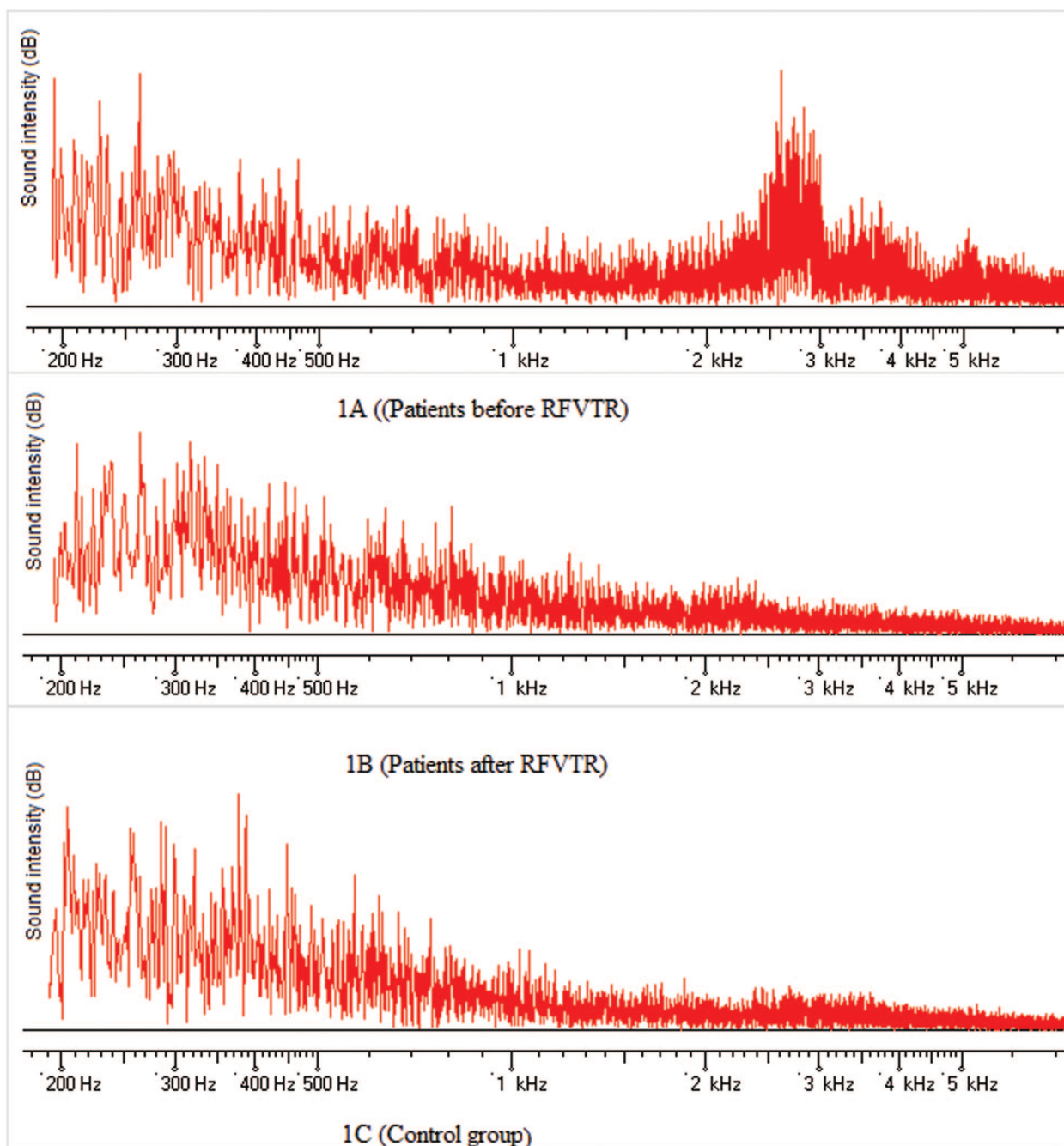


Figure 1. The nasal sound fast Fourier transform analyses sample of the patients (before and after radiofrequency volumetric tissue reduction [RFVTR]) and control group. (A) Patients before RFVTR. The sound intensity shows a shift upward in high frequencies (Hfs); a decrease was seen in low frequencies (Lfs) and medium frequencies (Mfs). (B) Patients after RFVTR. We found significant decreases in the sound intensity level at Hf in the sound spectra after RFVTR. (C) Control group. We did not find statistically significant sound intensity values between healthy people and in the patients after RFVTR.

with inferior TH. In this study, we found that in the patients before RFVTR there is a positive correlation between the degree of TH and the OR findings at a Hf interval. We found significant decreases in the sound intensity level at high frequency in the sound spectra after RFVTR. This study confirmed the efficacy of RFVTR for treatment of nasal obstruction due to inferior TH. RFVTR causes the enlargement of the nasal cross-sectional area, which leads to the decrease of nasal

airflow velocity. Airflow transforms the turbulence into a laminar pattern and the sound intensity level at Hf decreases in the sound spectra. We have shown that the Hf of the nasal sounds may be an indicator of the intensity of the nasal airflow.

OR, which is noninvasive, rapid, low cost, and even applicable for small children, requires little cooperation from the subjects. We have shown that OR results from the 2000- to

4000-Hz frequency interval may be more useful in assessing patients than other frequency intervals.

CONCLUSION

RFVTR is effective for the treatment of the patients with nasal obstruction due to inferior TH. Volumetric tissue reduction of inferior turbinate affects airflow into the nasal cavity, transforming it from a turbulent pattern to a more laminar pattern. We found significant decreases in the sound intensity level at Hf in the sound spectra after RFVTR.

REFERENCES

1. Cole P. Biophysics of nasal airflow: A review. *Am J Rhinol* 14:245–249, 2000.
2. Kelly JT, Prasad AK, and Wexler AS. Detailed flow patterns in the nasal cavity. *J Appl Physiol* 89:323–333, 2000.
3. Passali D, Passali FM, Damiani V, et al. Treatment of inferior turbinate hypertrophy: A randomized clinical trial. *Ann Otol Rhinol Laryngol* 112:683–688, 2003.
4. Nease CJ, and Krempel GA. Radiofrequency treatment of turbinate hypertrophy: A randomized, blinded, placebo-controlled clinical trial. *Otolaryngol Head Neck Surg* 130: 291–299, 2004.
5. Charbonneau G, Sudraud M, and Soufflet G. Method for the evaluation of flow rate from pulmonary sounds. *Bull Eur Physiopathol Respir* 23:265–270, 1987.
6. Seren E. Frequency spectra of normal expiratory nasal sound. *Am J Rhinol* 19:257–261, 2005.
7. Seren E. Effect of nasal valve area on inspirator nasal sound spectra. *Otolaryngol Head Neck Surg* 134:506–509, 2006.
8. Tahamiler R, Yener M, and Canakcioglu S. Efficacy of Odio-soft-Rhino in assessment of nasal obstruction: A comparative study with acoustic rhinometry after treatment with budesonide nasal spray in patients with perennial allergic rhinitis. *Am J Rhinol* 21:711–715, 2007.
9. Tahamiler R, Edizer DT, Canakcioglu S, et al. Nasal sound analysis: A new method for evaluating nasal obstruction in allergic rhinitis. *Laryngoscope* 116:2050–2054, 2006.
10. Yu S, Liu Y, Sun X, and Li S. Influence of nasal structure on the distribution of airflow in nasal cavity. *Rhinology* 46:137–143, 2008.
11. Chung SK, Son YR, Shin SJ, and Kim SK. Nasal airflow during respiratory cycle. *Am J Rhinol* 20:379–384, 2006.
12. Wexler D, Segal R, and Kimbell J. Aerodynamic effects of inferior turbinate reduction: computational fluid dynamics simulation. *Arch Otolaryngol Head Neck Surg* 131:1102–1107, 2005.
13. Mlynski G, Grutzenmacher S, Plontke S, et al. Correlation of nasal morphology and nasal respiratory function. *Rhinology* 39:197–201, 2001.
14. Moin P, and Bewley T. Feedback control of turbulence. *Appl Mech Rev* 47:3–13, 1994.
15. Kraman SS, Pasterkamp H, Kompis M, et al. Effects of breathing pathways on tracheal sound spectral features. *Respir Physiol* 111:295–300, 1998.
16. Kiyokawa H, Greenberg M, Shirota K, et al. Auditory detection of simulated crackles in breath sounds. *Chest* 119:1886–1892, 2001.
17. Homs-Corbera A, Fiz JA, Morera J, et al. Time-frequency detection and analysis of wheezes during forced exhalation. *IEEE Trans Biomed Eng* 51:182–186, 2004.
18. Soufflet G, Charbonneau G, Polit M, et al. Interaction between tracheal sound and flow rate: A comparison of some different flow evaluations from lung sounds. *IEEE Trans Biomed Eng* 37:384–391, 1990. □

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.