Changes in Acoustic Parameters of Voice After Endoscopic Sinus Surgery in Patients with Nasal Polyposis

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Abstract Our aim was to evaluate acoustic voice analysis of patients diagnosed with nasal polyps before and after endoscopic sinus surgery. Forty-three patients diagnosed with nasal polyposis who had undergone endoscopic sinus surgery were included in this prospective study. Patients were divided into three groups according to the stage of nasal obstruction before the surgery. Acoustic voice analyses were performed on each patient before the endoscopic sinus surgery and six weeks following the surgery with the multi-dimensional voice program. Jitter, shimmer, F_0 frequency, and noise to harmonic ratio (NHR) parameters were obtained for acoustic analysis. Our investigation showed that Jitter, shimmer and NHR values decreased, and F_0 value increased in the postoperative period in patients that had a partial nasal obstruction before the surgery. Non-significant increases were also observed in these four parameters after the surgery in cases with total or near-total nasal obstruction. We also found that the post-operative changes in shimmer values between the Stage III patients and the patients in other stages were statistically significant ($P = 0.027$). Voice changes that became more marked with increasing stages of the nasal polyposis. According to our results, patients should be informed of the

possible alterations in speech following major surgical interventions on the paranasal sinuses.

Keywords Nasal polyp · Endoscopic surgery · Voice · Acoustic analyses

Introduction

Nasal polyposis affects 0.5–4 % of the world's population and is present in approximately 20 % of patients with chronic rhinosinusitis [1, 2].

Nasal obstruction is the primary complaint of most patients with nasal polyps. In a study documenting quality of life (QOL), declines in QOL associated with nasal polyps are on a par with conditions such as chronic obstructive pulmonary disease, obstructive sleep apnea, and congestive heart failure [3].

Voice is a powerful and expressive communication tool; hence, voice disorders affect an individual's life in many ways. Acoustic analysis of the speech (voice) waveform is a common assessment technique used in the study of vocal dysfunction. In general, instrumental acoustic voice analysis refers to a family of computer-based techniques that measure acoustic signal properties of a spoken (prolonged) vowel or speech. It has the advantage of potentially providing objective information about the human voice, a phenomenon that is otherwise described by subjective methods (e.g., perceptual ratings of voice quality) [4, 5].

There are studies about the nasal resonance (nasality) according to the existing pathology (chronic rhinosinusitis, nasal polyposis, velopharyngeal insufficiency or adenoid vegetation) by using devices like nasometer [6–10], and these findings suggest that the sinuses are an important resonator for the voice. However, the effect of resonance

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changes on the sound source of the voice production, the laryngeal glottis and vibrating vocal cords, still remains unclear. There might be subliminal compensatory mechanisms in patients with nasal polyposis on cord vocals and laryngeal glottis due to gain the phonetic feature of normal speech that were familiar to the patient. Therefore, our aim was to evaluate the endoscopic sinus surgery related changes in acoustic voice parameters of the patients with nasal polyposis.

Materials and Methods

Study Design

The study was conducted at otorhinolaryngology clinic of Ankara Numune Training and Research Hospital and informed consent was obtained from all participating subjects. Patients included in this study group were selected among those who received at least one medical therapy treatment and failed to benefit from it. Together with the routine patient otorhinolaryngologic examinations, nasal endoscopy and videolaryngostroboscopic examinations (VLS) were also performed. Paranasal sinus tomographies were obtained, and patients were staged with regard to nasal polyposis according to nasal endoscopy. Preoperative staging of nasal polyposis, created by Lildholdt in 1997, was used in grouping the subjects (Table 1) [11]. We ensured that none of our patients had undergone previous nasal surgery and no pathological changes were found in their laryngeal examinations. Following the acoustic voice analysis, functional endoscopic sinus surgery (FESS) was applied to the patients within one week. Postoperative acoustic voice analysis were repeated within the 6th postoperative week. And before the postoperative acoustic voice analysis, VLS were performed again to exclude patients with postoperative vocal fold changes due to endotracheal intubation, and also nasal endoscopy was used to evaluate nasal passage. Only patients without nasal polyps after the FESS operation (Stage 0) included in the study. Forty three patients that meet the criteria were included in the study. Preoperative acoustic analysis parameters were compared with postoperative.

Table 1 Staging of nasal polyps

Stage 0	No polyps
Stage I	Polyp restricted within the middle meatus
Stage II	Polyps projecting out of the middle meatus and obstructing the passage partially
Stage III	Polyps obstructing the nasal cavity completely or near-completely

Acoustic Analysis

Voice is the acoustic output from the vocal tract that results from the vibration of the vocal folds. In order to define voice disorders objectively, computerized voice analysis techniques that measure acoustic signal properties of a spoken vowel or speech are generally used.

Voice analysis was performed on each patient in the Voice Laboratory of the Otorhinolaryngology Department of Ankara University Faculty of Medicine Hospital. The multi-dimensional voice program (MDVP, Kay Elemetrics, NJ, USA) is an extensively used computer-based software system first introduced in 1982. MDVP provides 33 parameters of vocal signals, of which some are more representative and significant in describing vocal functions [12]. In this study, acoustic analysis was achieved by using MDVP, Model 5105; version 2.5 voice analysis program and voice samples were recorded in a quiet room with a Shure SM81 dynamic microphone. A speech and language pathologist completed all the acoustic measurements for each participant. A standardized protocol was used for each voice assessment session. The subject was positioned adjacent to a microphone held at a fixed distance (10 cm) and at a 45° off-axis position to reduce aerodynamic noise from the mouth. The subject was then instructed to vocalize and sustain (three seconds) the vowel/a/in a flat tone, and original acoustic signal data were sampled at a rate of 44.1 kHz. The reference fundamental frequency value of the MDVP for male speakers was 145.223 Hz and for females was 243.973 Hz. The four parameters of MDVP used for statistical evaluation were F_0 frequency, jitter, shimmer, and noise to harmonic ratio (NHR).

Acoustic parameters used in this study are described as follows. The number of cycles produced by the vocal folds per second is the fundamental frequency of the voice. Mean F_0 (Hz) is the average number of cycles produced by the vocal folds per second. Jitter (ms) is an evaluation of the period-to-period variability of the pitch period within the analyzed voice sample. Shimmer (%) is a relative representation of the variability of the peak-to-peak amplitude within the analyzed voice sample. NHR is a general evaluation of the noise present in the analyzed signal.

Surgical Procedure

All the patients underwent an endoscopic bilateral trans-nasal sphenoidotomy with a total ethmoidectomy under general anesthesia. This is the approach recommended by Stammberger and Kennedy [13, 14]. After removal of gross polyps, the maxillary ostium is identified (or maxillary antrostomy) and total ethmoidectomy is performed. At this stage, we are confronted with a rectangular window formed

by the lamina papyracea laterally, the superior turbinate and basal lamella inferiorly, the lateral aspect of the superior turbinate medially, and the skull base superiorly, through which the anterior wall of the sphenoid sinus can be visualized. This opening is transected by a diagonal line running from the superomedial to inferolateral, thereby forming two triangles. In order to protect the optic nerve and carotid artery lying in the superolateral region of the sphenoid sinus, entrance to this sinus is safely done inferomedially [15]. Finally, this inferomedial entrance should communicate with the natural ostium.

Statistical Analysis

Data analysis was performed by SPSS 21.0 (Statistical Package for Social Sciences, SPSS Inc. Chicago, IL). Non-parametric tests were used because the groups studied were smaller than 30. Data were expressed as means and standard deviations or as a median and a range, when appropriate. Mann–Whitney U tests and Wilcoxon signed rank tests were used when appropriate. The level of significance was set at 0.05.

Results

Our subjects included 31 males (72 %) and 12 females (28 %) between the ages of 19–70 years. The mean age of the patients was 41 ± 7 . According to the preoperative staging of subjects based on nasal passage obstruction due to nasal polyposis, the patients were divided into three groups: 14 patients were in Stage I, 16 patients in Stage II, and 13 were in Stage III. Preoperative F_0 frequency, jitter,

shimmer, and NHR findings were compared to postoperative findings. There were no differences between the groups in terms of age, gender and cigarette smoking.

After endoscopic sinus surgery in Stage I patients, jitter, shimmer, and NHR values were found to be decreased, whereas the F_0 frequency values increased (Table 2). However, postoperative changes in all parameters missed the criterion of significance. In stage II patients it was found that postoperative jitter, shimmer and NHR values decreased, while F_0 values increased in the postoperative period (Table 3). And as stage I patients, the changes in the acoustic parameters were not significant in stage II patients. All the parameters increased after endoscopic sinus surgery in State III patients (Table 4), but again, postoperative changes were not significant.

Table 3 The comparison of preoperative (preop) and postoperative (postop) voice analysis results in Stage II patients

	Min	Max	Mean	STD	P value
Jitter					
Preop	0.3	3.0	0.9	0.8	0.5
Postop	0.3	1.4	0.7	0.4	
Shimmer					
Preop	2.02	11.9	5.7	3.1	0.05
Postop	2.17	5.7	3.7	1.5	
F_0					
Preop	125	272.5	179.6	49.1	0.7
Postop	118	282.4	181.4	55.4	
NHR					
Preop	0.11	0.16	0.14	0.02	0.2
Postop	0.11	0.14	0.13	0.01	

Table 2 The comparison of preoperative (preop) and postoperative (postop) voice analysis results in Stage I patients

	Min	Max	Mean	SD	P value
Jitter					
Preop	0.3	1.3	0.7	0.3	0.8
Postop	0.27	1.2	0.6	0.4	
Shimmer					
Preop	2.5	7.3	4.1	1.6	0.2
Postop	1.8	4.9	3.4	1.1	
F_0					
Preop	111	286	179.9	58.7	0.9
Postop	130	293.2	185.8	55	
NHR					
Preop	0.11	0.2	0.125	0.02	0.5
Postop	0.11	0.14	0.117	0.01	

Table 4 The comparison of preoperative (preop) and postoperative (postop) voice analysis results in Stage III patients

	Min	Max	Mean	SD	P value
Jitter					
Preop	0.23	1.34	0.68	0.4	0.6
Postop	0.17	1.50	0.75	0.57	
Shimmer					
Preop	2.5	5.43	3.46	1.1	0.13
Postop	1.1	8.91	4.48	2.75	
F_0					
Preop	132.6	264.2	168.8	44.8	0.13
Postop	155.1	256.3	179.9	34.3	
NHR					
Preop	0.12	0.14	0.125	0.008	0.6
Postop	0.12	0.18	0.137	0.23	

We also found that the postoperative changes in shimmer values between the Stage III patients and the patients in other stages were statistically significant ($P = 0.027$).

Discussion

This study was initiated to evaluate the vocal characteristics of the patients with nasal polyposis by using acoustic voice analysis, in area of otolaryngology and speech pathology that few studies have examined. Many clinicians had encountered patients with nasal polyposis who also exhibited a hoarse vocal quality. Although many believe there was an association between reduced voice quality and nasal polyposis, acoustic characteristics of the voice in patients with nasal polyposis were investigated for the first time.

The current investigation produced two major findings; (1) no statistically significant change in voice quality was measured by acoustic analysis of voice after endoscopic sinus surgery (2) the postoperative change in shimmer values between the patients with total nasal obstruction (Stage III) and the patients in other stages was statistically significant.

The production of sound requires four main components: airflow, an oscillator, a resonator, and an amplifier. In voice production, the source of airflow is the lungs. The oscillator is the vocal folds, which vibrate and place the air from the lungs into a wave-like motion. The resonance chamber and amplifier are composed of the remainder of the vocal tract: the supraglottic larynx, the pharynx, the oral cavity including the tongue and palate, the nasal cavity, the sinuses, and the head. Voice production can be thought of as the activation of an entire system of coupled oscillators. We can assume that the system of coupled oscillators contains and releases information about the human body; in particular, about its genetics, development, age, disease, language, culture and response to the environment [16, 17]. The frequency of opening and closing of the vocal folds determines the frequency of the sound waves, the pitch of the voice. Jitter and shimmer assess the involuntary variation (or perturbation) in fundamental frequency (F_0) and voice intensity (sound pressure level) from one vibratory cycle to the next. Both are almost exclusively measured in steady state vowels where the patients are asked to produce a long and continuous vowel (mostly/a//o/or/i/) at comfortable pitch and loudness. Both jitter and shimmer have been described as objective measures of the biomechanical vibratory properties of the vocal folds, which are considered central to the determination of vocal quality [18, 19].

Besides the important function of air-conditioning, olfaction and absorption of foreign micro- particles in the air, the nasal cavity is regarded as an important acoustic

resonator modulating voice sounds. It is well known that the resonance was changed due to ora-nasal pathologies and so the hyponasal or hypernasal speech occurs [6–11, 20, 21]. And the effect of resonance changes due to nasal polyposis and its surgical treatment on the glottic larynx and vibrating vocal cords were examined in this study.

In our study, higher mean voice analysis parameters were detected in the postoperative period compared to preoperative period in the patient group that had near complete obstruction from nasal polyps. This data can also be interpreted as an improvement in the voice quality in the postoperative period. The patient that perceives this change in his/her voice will possibly develop compensatory functional changes in other phonatory or resonatory structures. The history of nasal polyposis patients covers a long period and local or systemic allergies accompany the condition in a significant portion of the patients. Impairments in the resonance due to an allergy prior to the development of the polyposis allows sufficient time for a conscious or unconscious voice change with correction that affect the voice analysis parameters. This view was also supported by Cecil et al. [22]. In their study, they observed non-significant decreases in mean F_0 , mean intensity, and mean perturbation in patients with chronic sinusitis compared to the disease-free control group. These researchers suggested the resulting dysphonia could be attributed to not only the pathology in the nasal cavity or paranasal sinuses, but also to the indirect inflammatory effects resulting from the disease on the level of the vocal folds.

The data from this study also showed that the postoperative changes in shimmer values between Stage III patients and other patients were statistically significant. According to these findings, patients whose nasal passage were completely or near-completely obstructed had different qualities in the voice analysis compared to patients with a partial obstruction. This study found that nasal resonance changes could cause developing adaptive mechanisms large enough to affect the voice in phonatory or resonatory systems. Additionally, voice analysis parameters were changed into various characteristics that could be obtained according to the level of the obstruction.

For all that the study had some limitations. We did not measure the nasalance and make the perceptual evaluation. It might be better to compare the changes in nasalance to changes in acoustic voice analysis parameters. Also, it should be better to make a perceptual evaluation of vocal quality with acoustic analysis in patients with nasal polyposis. Perceptual analysis could provide data for better understanding of clinical relevance of the current study. We believe that further study is needed to work on the correlation between the nasalance, perceptual analysis and acoustic voice analysis especially in patients with nasal polyposis.

Conclusion

Voice changes that became more marked with the increasing stage of the disease were seen in patients with nasal polyposis. Our findings show that patients—and particularly voice professionals—should be informed of the possible alterations in voice quality following major surgical interventions on the paranasal sinuses.

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