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Laryngeal muscle tension in patients with sinonasal diseases; Prevalence and clinical significance

Running Title: Laryngeal muscle tension in sinonasal disease

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All authors reviewed the results and approved the final version of the manuscript.

Abstract

Objective: To determine the prevalence of laryngeal muscle tension in patients with sinonasal diseases.

Methods: The medical records and video-recordings of patients with a history of sinonasal disease were reviewed to identify one of four muscle tension patterns (MTPs) during phonation. A control group with no history of sinonasal diseases was matched according to age and gender.

Results: Seventy-seven patients were divided into a study group (n=47) and a control group (n=30). In the study group, 29 had at least one MTP, vs. only 9 in the control group ($p = 0.007$). The most common MTPs observed in the study and control groups were MTP II, and MTP III. In the study group, 79.3% of patients with at least one MTP reported dysphonia vs. only 33.3% in the control group.

Conclusion: Patients with sinonasal diseases are more likely to exhibit laryngeal muscle tension and dysphonia in comparison to healthy subjects.

Keywords: Laryngeal diseases; Muscle tension pattern; Rhinitis; Sinusitis; Laryngology

Introduction

The sinonasal tract is subject to a variety of diseases. These may be infectious, inflammatory, neoplastic or autoimmune. The clinical presentation of affected patients varies with the etiology of the disease and its duration. The most commonly reported symptoms are nasal obstruction, rhinorrhea, sneezing, lacrimation, and post-nasal drip. More severe and impairing symptoms such as facial pain/pressure, bleeding, and hyposmia/anosmia may also prevail[2]. Sinonasal diseases are associated with many co-morbidities that have detrimental impact on the physical, psychological, and social well-being of patients[3-5]. In a study that included 131 subjects with chronic rhinosinusitis, Hoehle *et al* highlighted the adverse effect of sinonasal diseases on several health-related subdomains including emotional dysfunction. The authors also noted a significant correlation between the Sinonasal Outcome Test-22 (SNOT-22) score and the EuroQol 5-Dimensional survey and visual analog scale (EQ5D-VAS) ($r = -0.53$, $p<0.001$)[6]. In another cross-sectional analysis using the National Interview Survey (NHIS) data, Zhou *et al* noted a correlation between sinusitis/ allergic rhinitis and sleep deprivation, depressive symptoms and number of workdays lost[5].

Given the importance of voice as a means of communication and a source of income to one third of the workforce[7], the impact of sinonasal diseases on voice became a subject of interest to many investigators. The focus has been on nasality because of the paramount role of the sinonasal cavities in sound amplification and resonance[8]. The consensus is that patients with sinonasal diseases have hyponasality in comparison to patients with no sinonasal diseases. Hong *et al* assessed the nasality of patients with nasal polyposis and noted significantly lower nasalance scores[9] in comparison to healthy subjects[10]. In another study that included 81 patients with chronic rhinosinusitis undergoing endoscopic sinus surgery, Jiang *et al* showed a moderate correlation

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between midnasal and postnasal volumes and nasalance score. This latter increased with an increase in nasal volumes[11]. The impact of sinonasal diseases on voice has also been proven in patients undergoing endoscopic sinus surgery using different voice outcome measures such as the Voice Handicap Index, GRBAS, fundamental frequency, jitter, shimmer, noise to harmonic ratio and formants scores[12-22].

The laryngeal behavior during phonation in patients with sinonasal diseases has not been previously described[23-26]. The purpose of this investigation is to report the prevalence of laryngeal muscle tension in a cohort of patients with sinonasal diseases in comparison to a control group with no history of sinonasal diseases. The authors attempt to answer the following question; Are patients with sinonasal diseases more likely to exhibit laryngeal muscle tension compared to healthy subjects? The hypothesis set forth is that patients with sinonasal diseases are more likely to have laryngeal tension, and hence are more prone to develop voice disorders.

Materials and Methods

After having received the approval of the Institutional Review Board, the medical records and video-recordings of patients who presented to the rhinology clinic of a tertiary referral center between January 1, 2020 and June 30, 2022 with history of sinonasal disease and who had filled the SNOT-22 questionnaire were reviewed. The SNOT-22 questionnaire is a self-reported outcome measure commonly used in the evaluation of various rhinologic related diseases[27]. Only those with SNOT-22 score above 7 indicating history of sinonasal disease were included[28]. Exclusion criteria included those with SNOT-22 score below 7, patients with history of laryngeal surgery or manipulation, and/or patients with history of upper respiratory tract infection. Professional voice users were also excluded in view of the confounding effect of high vocal

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loading. A control group with no history of sinonasal diseases was matched according to age and gender.

Demographic data included age, gender, history of smoking, and symptoms such as nasal obstruction, nasal discharge, facial pain or headache, and postnasal drip. The video-recordings of the laryngeal examination of the study group and controls were reviewed by two otolaryngologists for the presence of absence of four muscle tension patterns (MTPs) and inter-rater reliability was computed to assess the consistency of the reported findings. All subjects enrolled in this study had laryngeal examination as part of their work-up using the flexible nasopharyngoscope with distal chip camera (HD Video Rhino-Laryngoscope from KARL STORZ). All patients were diagnosed with primary muscle tension without evidence of an underlying laryngeal pathology or neuromuscular disorder. The muscle tension patterns were categorized according to Koufman *et al* classification[29]. MTP I characterized by the presence of a gap between the vocal fold edges during phonation, MTP II characterized by medial compression of the false folds, MTP III characterized by an antero-posterior shortening of the distance between the petiole and the arytenoids, and MTP IV characterized by complete sphincter-like closure of the supraglottis during phonation. Secondary outcome measures included hoarseness defined as a change in voice quality, globus sensation and repetitive throat clearing/cough. The presence of vocal fold structural abnormalities was also noted.

Results and Analysis

Statistical Analysis

Analyses were performed using Statistical Analysis Package for Social Sciences (SPSS, version 25.0 Chicago, IL, USA). Descriptive statistics were applied for different variable types.

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The Chi-Square test was used to determine the association between categorical variables. The independent t-test was used to determine the association between continuous variables. Data were represented as means±SD (standard deviation) and a p-value < 0.05 was considered significant. The video-recordings were reviewed by two otolaryngologists and inter-rater variability was computed to assess the reliability of the reported findings.

Demographic Data

A total of 77 patients were included in this study. The mean age of the total group was 43±15 years, and the male to female ratio was 3.05. The patients were divided into two groups, a study group (n=47 cases), and a control group (n=30). The prevalence of smoking was similar in both groups. The mean score of the SNOT-22 questionnaire in the study group was 33.06 ±14.97. *See table 1.* When looking at sinonasal symptoms, 27 out of the 47 patients had nasal obstruction, 23 had nasal discharge, 17 had postnasal drip, and 13 presented with facial pain or headache. Regarding nasal findings on endoscopy, 24 out of the 47 patients had septal deviation, 30 had inferior turbinate hypertrophy, and 6 had nasal polyps.

The prevalence of laryngeal muscle tension in patients with sinonasal diseases

Among patients with sinonasal diseases, 29 patients (61.7%) had at least one muscle tension pattern, in comparison to only 9 (30%) among the controls (p-value = 0.007). The most common muscle tension pattern observed in the study group and control group was MTP II (42.5% vs 23.3%, respectively) followed by MTP III (38.3% vs 20%, respectively). Almost one out of five of the study group had both MTP II and MTP III in comparison to 13.3% in the control group. It

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is worth noting that none of the patients and controls had evidence of muscle tension patterns I or IV. *See table 2.*

When categorized by the nature of the sinonasal disease, patients with a structural problem such as a deviated nasal septum were more likely to have an associated laryngeal muscle tension pattern than those without septal deviation (79.2% vs. 43.5%, respectively p=0.012). That significant difference in the prevalence of laryngeal muscle tension was not seen in patients with sinonasal diseases with inflammatory disorders such as ITH and/or nasal polyps in comparison to those without ITH and/or nasal polyps (60.6% vs 64.3%, respectively, p=0.812).

Inter-rater reliability analysis revealed an intra-class correlation coefficient (ICC) of 0.896 indicating excellent reliability between the two otolaryngologists who evaluated the endoscopic laryngeal findings.

The prevalence of laryngeal symptoms in patients with sinonasal diseases and in controls

Twenty five of the study group (53.2%) had hoarseness on presentation in comparison to only 3 (10%) in the control group ($p<0.001$). Additionally, 25 patients of the study group had throat clearing and 22 had globus sensation and cough in comparison to none in the control group. With respect to laryngeal findings, seven patients of the study group had arytenoid edema which was not observed in the control group. No structural vocal fold abnormalities were noted in both the study and control group.

Discussion

The laryngeal behavior during phonation in patients with sinonasal diseases has not been previously reported. The results of this investigation indicate that patients with history of sinonasal

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disease had a higher prevalence of laryngeal muscle tension in comparison to healthy subjects with no history of sinonasal disease. Close to two-thirds of of the study group had at least one muscle tension pattern in comparison to only one-third in the control group. The most common laryngeal muscle tension patterns observed during phonation were medialization of the false vocal fold followed by antero-posterior shortening of the distance between the petiole and inter-arytenoid space. Almost one out of five patients in the study group had two muscle tension patterns. The laryngeal tension observed in our study group is consistent with numerous studies documenting changes in formants frequencies in patients with sinonasal diseases undergoing sinus surgery. Chen *et al* in their investigation on the effect of sinus surgery on speech in 5 patients with chronic sinusitis reported an increase in first formant amplitude and a decrease in nasal peak amplitude of the spectra in /m/ and /n/ post-operatively. These changes correlated with a decrease in nasality for the high vowel/i/[30]. In a study on sound spectrography in patients with nasal polyposis, Hong *et al* reported a decrease in the frequencies of the nasal formants after endoscopic sinus surgery. The authors noted that sound spectrographic analysis is an objective diagnostic tool to assess nasality in subjects with obstruction of the nasal cavity[9]. Similarly, Hoseman *et al* reported a decrease in energy peaks and bandwidths of formants after endoscopic surgery that was commensurate with perceptual change in voice quality in 6 of 21 patients[19].

The results of our investigation also showed a higher prevalence of hoarseness in the study group in comparison to the control group (53.2% vs.10%). More than two-thirds of patients in the study group with at least one muscle tension pattern (n=79.3%) reported hoarseness in comparison to only 33.3% in the control group. Among patients with both MTP patterns II and III, two-thirds of the study group had hoarseness vs. only one half in the control group. These findings corroborate previous studies showing increased prevalence of voice disorders in patients with sinonasal

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diseases. In a cohort of 63 patients with nasal polyposis and nasal obstruction, Arslan *et al* reported a VHI-10 score of 10.47[25]. Hall *et al* in their analysis of 510 patients with nasal polyposis reported a mean VHI-10 score of 17.1 and a SNOT-22 score of 57.6. The authors noted a decrease in these scores following endoscopic sinus surgery[31]. Milqvist *et al* investigated the voice changes in 31 patients with allergic rhinitis and found a significantly higher mean VHI score in comparison to the control group, both in the pollen season (18.3 vs 2.8, respectively) and non-pollen season (13.9 vs. 6.0, respectively)[32]. Similarly, Wu *et al* demonstrated an association between severity of chronic rhinosinusitis and degree of vocal dysfunction and impairment in the voice-related quality of life[33].

The high prevalence of laryngeal muscle tension and hoarseness in patients with sinonasal diseases can be attributed to numerous factors most important of which is trafficking of secretions from the sinonasal cavities to the larynx and laryngeal dessication secondary to nasal obstruction. Post-nasal drip, which was noted in 37.77% of our study group, can instigate throat clearing and cough, leading to an increase in laryngeal sensitivity and tension[34]. Mouth breathing can also result in dryness of the vocal folds leading to an increase in phonatory threshold pressure, that is the pressure needed to set the vocal folds into vibration. As a result, patients have to put more effort to talk which may adversely impact the laryngeal behavior during phonation[35]. Indeed the results of this study showed that patients with septal deviation were more likely to develop laryngeal muscle tension than patients without septal deviation.

Another possible cause for the significantly higher prevalence of MTP in patients with sinonasal disease and septal deviation is the known association between nasal obstruction and increased muscle activity of accessory inspiratory muscles. Hiyama *et al* demonstrated heightened electromyographic (EMG) activity in the suprahyoid and masseteric muscles among individuals

experiencing nasal obstruction compared to oral breathers. Their study involved the examination of 10 healthy Japanese males over a three-hour sleep period[36]. Similarly, Trevisan *et al* investigated the accessory inspiratory muscle activity in 38 nasal-breathing adults using surface EMG, noting increased recruitment during rapid inspiration in comparison to mouth-breathing subjects. This increase in muscle activity was attributed by the authors to aberrant posture and muscular imbalance among nasal breathers[37].

The use of intranasal corticosteroids as a medical treatment for ITH can also be implicated in the pathophysiology of the abnormal laryngeal behavior associated with sinonasal diseases. Although the impact of intranasal steroids on voice has rarely been studied, one can argue that its effect is similar to the inhaled form. Studies have shown that corticosteroid inhalers may induce laryngeal inflammation due to chemical irritation or by promoting opportunistic infections such as candidiasis. The irritation of the laryngeal surface mucosa causes hoarseness followed by a compensatory laryngeal muscle tension[38,39]. Other contributing factors include lower airway disease and laryngopharyngeal reflux disease[40-45]. The etiologic role of each factor could not be analyzed given the retrospective nature of our investigation. Future studies controlling for these confounding factors are warranted.

This study is an addition to the literature showing an association between sinonasal diseases and laryngeal muscle tension and not a causation. However, it has its limitations; One is the small sample size and second is its retrospective nature which explains the lack of objective voice outcome measures such as acoustic and aerodynamic measures. Moreover, potential confounding variables, such as reflux and allergy, that could influence laryngeal muscle tension were not addressed. Future prospective studies are needed to explore the link between sinus diseases and voice.

Summary

- Patients with sinonasal diseases have hyponasality in comparison to patients with no sinonasal diseases
- Laryngeal muscle tension is highly prevalent in patients with sinonasal diseases
- Patients with septal deviation are more likely to develop laryngeal muscle tension
- Comprehensive voice evaluation can help us better understand the laryngeal behavior in patients with sinonasal diseases

Conclusion

This study shows a higher prevalence of laryngeal muscle tension and hoarseness in patients with sinonasal diseases in comparison to healthy subjects with no history of sinonasal diseases. Comprehensive voice evaluation of patients with sinonasal diseases can help us better understand the laryngeal behavior in affected subjects and the pathogenic role of sinonasal diseases in muscle tension dysphonia.

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Competing Interests

The authors declare none.

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Ethical Standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the authors' instution guidelines on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

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Table 1: Demographic characteristics of the study population

Demographic data	Cases (n=47)	Controls (n=30)	*p*-value
Gender (Male/Female ratio)	3.27	2.75	0.833
Age in years (mean±SD)	40.3 ± 13.8	47.2 ± 17.2	0.059
n (%)			
Smoking	22 (46.8)	14 (46.7)	0.990
Sinonasal symptoms			
Nasal obstruction	27 (57.4)	0	<0.001
Nasal discharge	23 (48.9)	0	<0.001
Post-nasal drip	17 (36.2)	0	<0.001
Facial pain/headache	13 (27.6)	0	<0.001
Endoscopic findings			
Nasal polyps	6 (12.8)	0	<0.001
Septal deviation	24 (51.1)	0	<0.001
ITH	30 (63.8)	0	<0.001

SD: Standard Deviation; ITH: Inferior Turbinate Hypertrophy

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Table 2: Prevalence of laryngeal muscle tension pattern in study group and controls

	Patients (n=47)	Controls (n=30)	*p*-value
MTP (n (%))	29 (61.7)	9 (30)	0.007
MTP II	20 (42.5)	7 (23.3)	
MTP III	18 (38.3)	6 (20)	
MTP II/III	9 (19.1)	4 (13.3)	

MTP: Muscle Tension Pattern

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