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Laryngeal and respiratory patterns in patients with paradoxical vocal fold motion

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Summary
The purposes of this study were to determine the differences in spirometric measures obtained from patients with endoscopically-documented paradoxical vocal fold motion (PVFM) and to compare them to a group of normal subjects without endoscopically-documented paradoxical vocal fold motion during non-provocative breathing and following speech. Thirty eight subjects with documented paradoxical vocal fold motion using transnasal flexible laryngoscopy (TFL) and no history of asthma and 21 normal subjects with documented normal breathing patterns and normal findings on endoscopy underwent flow-volume loop studies. Endoscopic judgments of vocal fold motion from three breathing conditions were made by two observers. The results of the endoscopic judgments indicate that paradoxical motion occurs whether breathing through the nose or mouth in the PVFM subjects, mainly after speaking and inhalation. In addition, the spirometry results indicated that the inspiratory measure of FIVC%, FVC% and $FIV_{0.5}$/FIVC were significantly lower in the PVFM group compared to the normal subjects. The data supports the hypothesis that in patients with PVFM, inspiratory spirometric values play a role in identifying patients with PVFM. The finding of vocal fold closure following a speech utterance in the majority of the PVFM subjects but not in the normal control group warrants further investigation.

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Introduction

Paradoxical vocal fold movement (PVFM) is a condition characterized by upper airway obstruction secondary to the paradoxical complete or partial adduction of the vocal folds, occurring primarily on inhalation, and occasionally during exhalation. PVFM is the current term used by otolaryngologists and speech-language pathologists while vocal cord dysfunction (VCD) is the term used primarily by pulmonologists and allergists. Throughout the allergy, asthma, otolaryngology and speech pathology literature, these terms are used interchangeably. The term PVFM will be used consistently in this study. .Diagnosis of PVFM is based on case history, pulmonary function testing and the visualization of the abnormal (paradoxical) movement of the vocal folds during transnasal flexible laryngoscopic (TFL) examination. This movement may be seen while the patient is performing an exercise task such as riding a bicycle or it may occur spontaneously during restful breathing.[1]

Spirometry has been reported as an additional investigational tool in the diagnosis of PVFM. The flow-volume loop pattern in PVFM is characterized by flattening of truncation of the inspiratory limb, compared to a U-shaped pattern in normal subjects.[2] Abnormal expiratory measures and concomitant diagnosis of asthma in patients with PVFM is variable. An incidence of 15%—50% of PFVM concomitant with asthma is described in the literature.[3] Although the majority of the patients with PVFM are known to have normal pulmonary function, treatment of patients with PVFM (misdiagnosed as asthma) often begins with pharmacological management of typical pulmonary symptoms, and in those cases, the results are often unsuccessful.

The flow-volume loop is uniquely helpful in the evaluation of upper airway obstruction in that the site (extra thoracic or intra thoracic), the nature (variable or fixed), and the severity of obstruction can be predicted by the configuration of this loop. The flow-volume loop can assist in accurate differential diagnosis of PVFM versus other respiratory complaints. Vertigan et al.[4] found that those people with a definite diagnosis of PVFM tended to have normal expiratory phases, but attenuation in the inspiratory phase, and those diagnosed with asthma, presented in an opposite manner.

Recently, it has been suggested that the diagnosis of PVFM should include both laryngoscopy and pulmonary function testing, since the sensitivity of the flow-volume loop may be very low.[5] Studies have, in fact, reported a range of incidence of 23%—100% showing an abnormal inspiratory loop in patients diagnosed PVFM.[6] In PVFM subjects with abnormal spirometric measures, earlier findings by Morris and colleagues report a decrease in forced expiratory volume at 1 s/forced vital capacity (FEV1/FVC) compared to normal subjects.[2] They, along with other investigators, also report a significant elevation in the ratio of the mid-vital capacity of the expiratory air flow to the mid-vital capacity inspiratory capacity of inspiratory air flow (FEF_{50}/FIF_{50})[7,8] Moreover, other studies have reported that abnormally large FEF_{50}/FIF_{50} ratios may be present in some but not all patients with PVFM.[3,9] Others have shown that decreased inspiratory flow is the ventilatory characteristic of extra thoracic obstruction and results in higher FEV0.5/FIV0.5.[10—12]

Only cursory observations of endoscopic examinations to identify the presence of paradoxical motion of the vocal folds have been reported in the groups that have been investigated with spirometry and compared to control groups. The purposes of this study were to determine the differences in spirometric measures obtained from patients with endoscopically-documented PVFM and to compare them to a group of normal subjects without endoscopically-documented paradoxical vocal fold motion during non-provocative breathing and following speech.

Materials and methods

Subjects

The Columbia University Internal Review Board approved this study. The subjects of this study included 38 patients diagnosed with PVFM based upon the transnasal flexible laryngoscopic (TFL) examination, case history, and symptomatic complaints, such as shortness of breath, coughing and throat clearing. They were selected based on a retrospective medical chart review of the patients seen at the Voice and Swallowing Center at Columbia University Medical Center between September, 2006 and July 2008. All subjects were adults between the ages of 23—70 years. Subjects were excluded if they were over 70 years of age, had concomitant active diseases of asthma or chronic obstructive pulmonary disease (COPD) or were being medicated for asthma, chronic obstructive pulmonary disease (COPD), diabetes mellitus and neurological disorders such as Parkinson's, cerebral vascular accident or a progressive neurological conditions or with a more than 20 pack/year history of cigarette smoking. No subjects were currently smoking. Patients with a forced vital capacity lower than 75% were also excluded.

A group of 21 healthy non-smoking individuals was selected to compose the control group. They were recruited from individuals visiting the clinic with other patients, and from families and friends of the investigators. Data for both groups of subjects was collected in the time period between September 2006 and July 2008.

Procedure

Following a thorough case history that included inquiring about shortness of breath, coughing, dysphonia, dysphagia and other symptoms, the patients and subjects underwent (TFL). Once the individual was comfortable with the endoscope in place, he/she was asked to breathe through his/her nose for 20—30 s followed by breathing through his/her mouth for 20—30 s. The patient was then asked to say the sound/i/and to repeat a sentence "We see green trees." If there was greater than 50% vocal fold adduction during or after any of the tasks, the subject was considered to be in the PVFM group. The data was stored for later judgment by two individuals familiar with endoscopic views of the vocal folds. In all cases, during the examination, the subjects were not coughing nor were they experiencing acute symptoms of dyspnea.

Following TFL, all patients and subjects underwent standard flow-volume loop spirometry using a calibrated hand held spirometer (Koko). A nose clip was placed over the nose. Subjects were then instructed to "put the spirometer tube in the mouth, take a deep breath, blow it out as fast and as hard as possible and then take a deep breath in again." This was done twice and the best performance was submitted for analysis. Data were stored on an IBM computer using standard software.

Analysis

The TFL exams were reviewed by two speech-language pathologists with experience in viewing TFL examinations. Using a "yes/no decision scheme, the judges rated the presence and the consistency of more than 50% of vocal fold closure during inhalation, during exhalation and after speaking. Inter-judge reliability was obtained. Presence indicated that greater than 50% adduction was seen at least during part of the exam sequence (breathing or speaking). Consistency indicated that adduction was seen consistently during the breathing/speaking sequences.

Results

Thirty eight patients, 13 males and 25 females, with endoscopic evidence of PVFM whose most common complaints were chronic cough, throat clearing and shortness of breath were included in this analysis. The mean age of the PVFM group was 54.5 years with a range of 23—70 years and a standard deviation of 11.7 years. A group of 21 normal subjects with no endoscopic evidence of PVFM and no complaint of shortness of breath or chronic cough acted as the controls (10 males and 11 females). The mean age of the control group was 50.5 years, with a range of 27—69 years and a standard deviation of 11.3 years. No statistical difference was observed between ages of the males and females, therefore the two groups were combined for statistical analysis. Table 1 provides a detailed breakdown of participant's demographics showing the number of patients, gender, most common symptoms and laryngeal signs.

Table 2 shows the inter-judge reliability of the perceptual analysis of the TFL examinations of the PVFM group. According to the data, the judges were reliable in their judgments of adduction of the vocal folds in all situations examined. The results indicate that the adduction of the vocal folds after speaking was the most common abnormality (present in 100% of the patients with a consistency over then 78.9%). The abnormal movement of the vocal folds during inhalation was observed in more than 86% of the patients with a consistency of 76.3%. During exhalation over 65.8% of patients had an abnormal movement of the vocal folds with a consistency of at least 57.9%. The normal subjects selected for the study did not have adductory motion associated with inhalation, exhalation or after speaking.

Table 3 shows the results obtained from the spirometric analysis from the experimental (PVFM) and control groups (normal subjects). The mean FVC% for patients with PVFM was 91.7 (±13.5), while for the normal subjects the FVC% measure was 103.2 (±6). Thus, patients with PVFM showed a statistically significant reduced vital capacity. The FIVC% was also significantly lower in patients with PVFM with a mean value of 87.6 (±19.9), while for the normal subjects the FIVC% measure was 100.2 (±3.5).

Table 1 Number of patients, gender, symptoms and laryngeal signs.

	PVFM Group	
PVFM group	n	%
Male	13	34.2
Female	25	65.8
Symptoms		
Cough	27	71
Throat clearing	20	52.6
Dyspnea	15	39.4
Dysphonia	13	34.2
Dysphagia	8	21
Choking	6	15.7
Laryngospasm	5	13.1
Laryngeal Signs		
Larynx posterior edema	38	100
Vocal fold paresis	7	18.4
Vocal fold atrophy	4	10.5
Granuloma	4	10.5
False vocal fold adduction	2	5.2
Muscle tension dysphonia	1	2.6
Normal controls:		
Male	10	47.6
Female	11	52.4

The $FIV_{0.5}$/FIVC was found to show significant statistical difference between the two groups. All of the patients with PVFM presented with abnormal $FIV_{0.5}$/FIVC ratios, with a mean of 0.66 (±0.15), while the normal group produced the ratio with a mean of 0.94 (±0.03). These results were statistically significant at the 0.05 level. The measures of the forced inspiratory flow weren't statistically different among groups.

Discussion

This is the first study with a large cohort of subjects with PVFM who were compared to a normal group using both endoscopy and spirometry during periods of no exercise. According to Gimenez and Zafra, the need to use both spirometry and laryngoscopy will improve our knowledge of VCD/PVFM since the prevalence of this condition is still not known.[15] In the current study, the patients with PVFM were found to have adductory motion on inhalation, at times during exhalation and following speech. Of significance was the finding of inspiratory motion following a short phrase suggesting that these patients exhibit a paradoxical motion with inspiration following speech more consistently than the other two conditions. The data analyzed in this study indicated the occurrence of PVFM in adults of both genders.

Uncharacteristic pulmonary function measures were noted in those patients with PVFM. The finding of abnormal spirometric measures in patients with adductory motion observed during flexible endoscopy supports the usage of

Table 2 Inter-judge reliability of the perceptual analysis of the abnormal adduction of the vocal folds of the PVFM group.

	Judge 1%	Judge 2%	Inter-judge reliability
Adduction of the vocal folds after speaking			
Presence	100	100	$p < 0.001$
Consistency	84.2	78.9	$p < 0.001$
Adduction of the vocal folds during inhalation			
Presence	86.8	89.5	$p < 0.001$
Consistency	76.3	76.3	
Adduction of the vocal folds during exhalation			
Presence	65.8	76.3	$p < 0.001$
Consistency	71.1	57.9	$p < 0.001$

both flexible endoscopy and certain spirometric measures in the diagnosis of PVFM. Furthermore, the data support the hypothesis both endoscopic evidence and spirometric values for FVC%, FIVC % and $FIV_{0.5}$/FIVC are important measures to further identify the PVFM population.

Studies investigating the role of spirometry in PVFM diagnosis support the finding of abnormal pulmonary function tests in PVFM. Vertigan et al.[13] investigated expiratory versus inspiratory phases of normal subjects and those with PVFM. Their results showed those people with PVFM to have normal expiratory measures; however, an atypical attenuation in the inspiration phase was documented.

The current findings corroborate the earlier work of Vertigan[13] as it relates to PVFM. Results of the present study revealed ratio measures of $FIV_{0.5}$/FIVC in PVFM to be significantly lower than that of a group of normal subjects with endoscopically-documented evidence of no PVFM. Unlike the normal subjects, the PVFM group showed an observable truncating of the inspiratory phase, as well as a clear difference in inspiratory measures. Differing from findings of Campbell et al,[14] the current study suggests that patients with PVFM most often have normal or near normal expiratory patterns with abnormal inspiratory patterns. Nonetheless, the PVFM subjects in the present study had a reduced FVC compared to the normal group. Additionally, results of this study, found that forced expiratory versus inspiratory flow beyond the initiation of inspiration ($FIV_{0.5}$) was not significant. This reveals stronger evidence that spirometric values indicative of inspiratory characteristics are most crucial in identifying patients with PVFM when patients present with symptoms of shortness of breath and cough and a normal expiratory flow-volume loop. Murry et al.[16] compared a group of PVFM patients before and after combined behavioral and pharmacological treatment with proton pump inhibitors and described a statistically significant improvement in $FIV_{0.5}$/FIVC in 95% of patients. However, the mean $FIV_{0.5}$/FIVC following therapy remained persistently lower than that of the normal control group. They reported that these abnormal ratios were consistent with a decrease in inspiratory volume as a result of extra thoracic obstruction, and not due to increased airways obstruction as suggested by Rundel.[3]

Varney et al.[17] reported that amitriptyline also offers successful treatment when combined with psychotherapeutic and behavioral treatments. In that study, confirmation of the diagnosis was by endoscopic evaluation and spirometry. In that study, there was no control group for comparison. A surprising finding in the current study was the identification of the high incidence of adduction of the vocal folds following speech. While the complaints of speech difficulties and hoarseness were relatively low in the PVFM population, the presence of observed irregular

Table 3 Comparison of inspiratory function measures between normal and PVFM subjects.

Inspiratory function measures	PVFM		Normal	
	Mean	Standard Deviation	Mean	Standard Deviation
FVC%[a]	91.7	13.5	103.2	6.0
FIVC%[a]	87.6	19.9	100.2	3.5
$FIV_{0.5}$/FIVC[b]	0.66	0.15	0.94	0.03
FIF50/FEF50	1.04	0.38	1.01	0.29
FIF50	4.3	1.5	5.5	1.16

FVC%: The percent of forced vital capacity
FIVC%: The percent of forced inspiratory vital capacity
$FIV_{.05}$: The forced inspiratory volume at .05 s of the inspiratory phase
FIF 50: Forced inspiratory flow at the 50% point of inspiration
FEF 50: Forced expiratory flow at the 50% point of expiration.
[a] $p<0.001$.
[b] $p<0.05$.

adduction in the current study group was high. Yet, only 13 or the 38 subjects indicated dysphonia on their intake case history form. It may be that the symptoms of shortness of breath and cough mask the issues related to the voice in patients with PVFM.

Discrepancies have been reported as to which spirometric values are associated with airway obstruction versus typically healthy adults. Ratios of $FEF_{50\%}/FIF_{50\%}$ greater than 1 are often believed to be indicative of upper airway obstruction or narrowing.[11] However, one study has reported that ratios over 1.6 have been found in large groups of healthy men.[18] This increased percentage suggests that a wider range of normal values for standard spirometric measures should be considered. In addition, Campbell et al[14] found that spirometric values can vary somewhat depending on body mass index (BMI), age, gender and smoking status. The current groups of subjects did not represent a wide range of weight or body mass.

The results of this study found that the expiratory-inspiratory ratios in the subjects with clinically documented PVFM obtained via TFL at rest were significantly different from the normal group. Thus, the use of the inspiratory phase measures provides an additional indicator of PVFM from other conditions presenting with cough, shortness of breath and other vocal fold anomalies. It should be noted that judges did not see the adductory motion during the entire examination sequence. In some cases, as shown in Table 2, the adductory motion was present but not consistent. Thus, thorough examination with TFL is important when suspecting PVFM.

Conclusion

The present study found that the inspiratory measure of FIVC%, FVC% and $FIV_{0.5}/FIVC$ were significantly lower in the PVFM group compared to the normal subjects Flow-volume curves, specifically inspiratory measures, provide diagnostic evidence to support the findings of the TFL examination. The results of the endoscopic judgments indicate that paradoxical motion occurs whether breathing through the nose or mouth in the PVFM subjects, mainly after speaking and inhalation. The finding of vocal fold closure following speech in the majority of the PVFM group warrants further investigation.

Conflict of interest statement

No author has a conflict of interest associated with the topic of this manuscript or with any of the equipment used in this study.

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