The Laryngoscope

Fiberoptic Videolaryngoscopy During Bicycle Ergometry: A Diagnostic Tool for Exercise-Induced Vocal Cord Dysfunction

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Objectives/Hypothesis: Exercise-induced vocal cord dysfunction is difficult to diagnose because the paradoxical vocal cord adduction should be observed during exercise. Our goal was to develop and validate a new diagnostic method for exercise-induced vocal cord dysfunction by combining continuous fiberoptic laryngoscopy with a bicycle ergometry test.

Methods: Thirty consecutive patients referred to a laryngologist because of suspicion of exercise-induced vocal cord dysfunction and 15 healthy controls underwent the exercise test until dyspnea or exhaustion rated as 18–19/20 on the Borg scale. Laryngeal findings, electrocardiography, blood pressure, heart rate, and respiratory rate were monitored, and forced expiratory flow in the first second was measured before and after the exercise. The medical history was assessed by use of a structured questionnaire.

Results: Among the 30 patients, 27 (90%) performed the test successfully, as did all controls. Diagnostic signs of inspiratory stridor, supraglottic collapse, and vocal cord adduction appeared in five (19%) patients but in none of the controls. Of the 30 patients referred, the laryngologist considered 25 to be suspect. Of them, 9 (36%) showed signs diagnostic or highly suspect for exercise-induced vocal cord dysfunction. Of the 15 patients whose dyspnea could be induced during the test, nine (60%) were suspected of having exercise-induced vocal cord dysfunction.

Conclusions: Fiberoptic videolaryngoscopy during bicycle ergometry was a well-tolerated and relatively easily established diagnostic tool that could induce dyspnea in more than one half the patients examined. If the symptom of dyspnea appeared, the most frequent diagnosis was exercise- induced vocal cord dysfunction.

Key Words: Diagnosis, exercise, paradoxical vocal cord movement, vocal cord dysfunction.

***Laryngoscope*, 119:1776–1780, 2009**

INTRODUCTION

Vocal cord dysfunction (VCD) is a condition with paradoxical closure of the vocal cords typically during inspiration. Such closure limits airflow, causing dyspnea and stridor, a condition often misdiagnosed and mistreated as asthma.[1] Other typical symptoms of VCD are dysphonia, dysphagia, and cough.[2] In some patients, VCD symptoms are related only to exercise, in others only to rest, and some get symptoms both in exercise and rest.[1,3,4] The pathophysiology of VCD is still poorly understood, and its etiology may be multifactorial. Suggested etiological factors, alone or combined, are infections,[5] physical exercise,[6,7] laryngeal sensitivity to various stimuli,[8] and psychosomatic and psychological stress.[7] Visualization of a paradoxical movement of the vocal cords during the dyspnea attack is the gold standard for VCD diagnosis.[3,4,6,7,9] Incidence of VCD in the general population is not widely established, but exercise-induced VCD (EIVCD) in patients with exertional dyspnea in one study showed an incidence of 15%.[3]

Shortness of breath and wheezing during exercise in generally healthy adolescents is often caused by exercise-induced asthma (EIA).[10] However, EIVCD alone or a combination with EIA and EIVCD can also cause these symptoms.[1] EIVCD, a subgroup of VCD, typically appears suddenly during very hard exercise and the symptoms are also resolved within a few seconds or minutes after stopping or just slowing down, and athletes have learned to limit their activity to avoid such attacks.[11] Because EIVCD is an episodic symptom not always appearing in the same exercise surroundings, a negative result in any provocation test does not preclude the diagnosis.[4]

Additional Supporting Information may be found in the online version of this article.

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Editor's Note: This Manuscript was accepted for publication January 28, 2009.

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DOI: 10.1002/lary.20558

TABLE I.
Characteristics/Patient History.

Characteristics*	No. of Patients, n = 30	(%)
Females	24	80
Asthma	13	43
Regular use of inhaled corticosteroids	19	63
Regular use of antireflux medicine	3	10
Chronic cough	5	17
Chronic need for throat clearing	13	43
Nonsmokers	29	97
Chest pain at rest	2	7
Chest pain during exercise	4	13
History of Symptoms Other Than Dyspnea During EIVCD Attack		
Dysphonia	15	50
Dysphagia	7	23
Numbness of hands	5	17
Anxiety	6	20

*Median age of the patients 27.8 years (range, 10.6–69.2 years). EIVCD = excercise induced vocal cord dysfunction.

Heimdal et al. have published promising results of a new diagnostic method for EIVCD based on continuous laryngoscopy during treadmill exercise. However, as all subjects tested were young (ages, 15–29 years) and mostly healthy volunteers, the utility of the procedure in patients in all age groups is unknown.[6] An earlier study of 10 young (16–32 years) healthy volunteers using a stationary bicycle combined with continuous laryngoscopy determined the incidence of exercise-induced laryngomalacia. Its test setting lacked a patient group, and electrocardiogram (ECG), blood pressure, heart rate, and respiratory rate monitoring.[12] The goal of our study was to develop and evaluate a new tool for the challenging diagnostics of EIVCD, appropriate for a laryngeal outpatient department and suitable for patients of various ages and physical conditions by combining fiberoptic videolaryngoscopy with a bicycle exercise test.

MATERIALS AND METHODS

We examined 30 consecutive patients referred to our clinic by pulmonary, allergy, and sports medicine specialists because of a suspicion of EIVCD; 25 of them had symptoms only during hard exercise. Patients' median age was 27.8 years (range, 10.6–69.2); 24 (80%) were female. There were 13 patients with coexisting asthma (Table I). The asthma diagnosis was based on the criteria of Global Initiative for Asthma (GINA).[13]

As controls we examined 15 healthy volunteers. The median control group age was 33.4 years (range, 20.9–54.1); 10 (67%) were female.

All patients and controls underwent the same research protocol. Data from medical history (other possible illnesses and actual medication, subjective symptoms and smoking habits) were collected with a questionnaire.

Informed consent was obtained from all individuals, and the human experimentation guidelines of the Helsinki University Central Hospital were followed. The study was approved by the Ethics Review Board of the Helsinki and Uusimaa Hospital District.

Patient and Test Preparation

None of the patients tested or controls had any ongoing respiratory infection and all patients continued their medications before testing. Calibration of the equipment (ECG device, spirometer) was performed before each test as advised by the manufacturers. Ear, nose, and throat (ENT) examination was performed on all. Forced expiratory volume in the first second (FEV1), baseline 12-lead ECG, blood pressure, heart rate, and respiratory rate were measured before the start of the exercise. The test followed a schedule similar to that of an ordinary work-conducted cardiovascular exercise test (Fig. 1).

Test Set-Up, Protocol, and Result Interpretation

A stationary bicycle (E 80 Tunturi, Tunturi Oy, Turku, Finland) was used for the test, as were transnasal fiberoptic scope (Olympus D ENF type P3, Olympus-Optical, Tokyo, Japan) connected to computer-based videolaryngostroboscopy equipment (Rehder Partners, Hamburg, Germany) and continuous 12-lead-ECG monitoring (Nihon Kohden Cardiofax V, Nihon Kohden

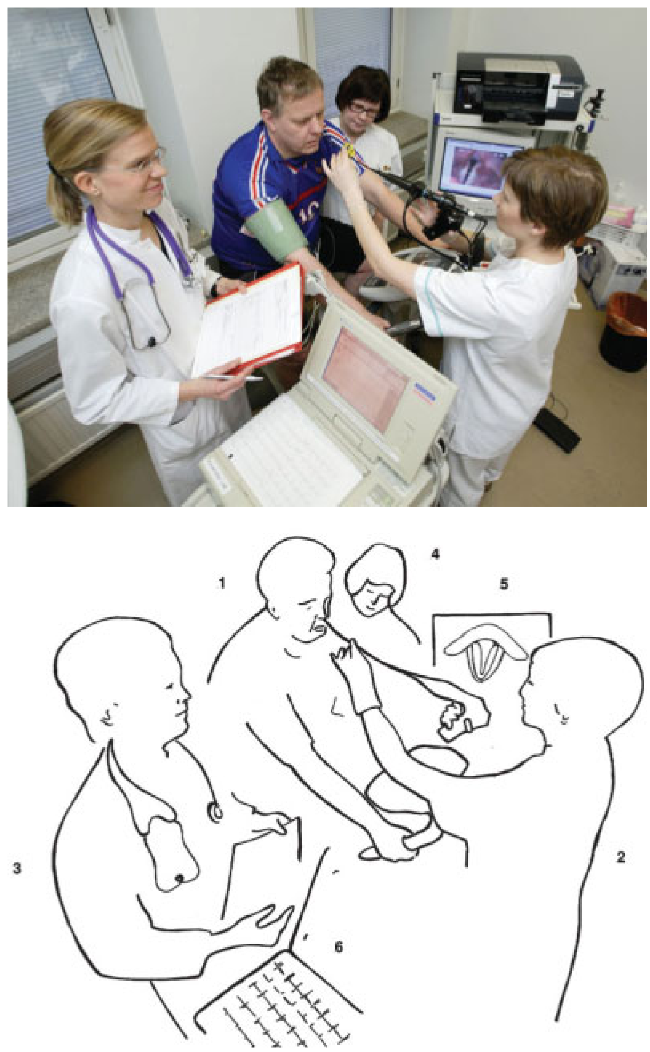

Fig. 1. A photo and a schematic presentation of the laryngeal team performing exercise test. 1 = patient; 2 = ear, nose, and throat specialist; 3 = anesthesiologist; 4 = nurse; 5 = computer-based videolaryngostroboscopy equipment; 6 = 12-lead electrocardiogram monitor. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

TABLE II.
Schematic Test Protocol.

Before the Test	During the Test	Immediately After the Test	10 Min After the Test	Calculated Parameters
Heart rate	Heart rate	FEV1	ECG	Heart rate % of maximum
Respiratory rate	Respiratory rate*	ECG		Changes in respiratory rate
RR*	RR			Changes in RR
FEV1	SaO_2			Changes in FEV1
SaO_2	ECG			Changes in SaO_2
ECG				Total duration of test
Topical anesthesia of the nose				

*No longer measured in routine clinical use.
FEV1 = forced expiratory volume in the first second; ECG = electrocardiogram; RR = blood pressure; SaO_2 = oxygen saturation.

Corp., Tokyo, Japan). Before patients were studied, this set-up was tested on a volunteer staff member from our clinic.

After baseline measurements (FEV1, oxygen saturation, ECG, blood pressure, heart rate, and respiratory rate) topical anesthesia with 2% lidocaine on a cotton stick was applied inside the patient's nostril for 7 minutes to prevent the irritation by the fiberoptic. The lower parts of the nasopharynx and larynx were not anesthetized, to avoid possible masquerading of the symptoms, so no local anesthetic spray was used. Thereafter, the patient mounted a bicycle adjusted to proper height. The transnasal fiberoptic scope connected to computer-based videolaryngoscopy equipment was then inserted to the optimal position for visualization of the larynx, and the patient started pedalling. The fiberoptic scope was held in place by the otorhinolaryngologist to ensure the optimal position of the scope during the whole exercise. The work load started at 40 watts (W) for women and 50 W for men, and the load was added every 4 minutes in 40 W or 50 W increments supervised by an anesthesiologist. Pedalling speed was 60 rpm. Blood pressure, heart rate, and respiratory rate were measured during the 3rd minute at every exercise step (Table II). The patient estimated the rate of perceived exertion at the end of each load step by using the Borg scale. The Borg scale measures perceived exertion in sports, and particularly in exercise testing, and is used to document the patient's subjective exertion during a test. The original scale, introduced by Gunnar Borg, rated exertion on a scale of 6 to 20.[14] All subjects continued pedalling until the typical symptoms of dyspnea appeared or until exhaustion (Borg scale 18–19/20). After completing four exercise steps (160 W for women, 200 W for men), a few highly athletic patients reported tiredness of muscles without respiratory symptoms. They were asked to pedal with no speed limit a load of 120 W/150 W until exhaustion.

The test result was considered diagnostic for EIVCD if inspiratory stridor, supraglottic collapse of arytenoids, and aryepiglottic folds toward the aditus of the larynx and vocal cord adduction were noticed. If all of these signs appeared without vocal cord adduction in the end, the result was considered to be highly suspect for EIVCD. The test was performed and scored every time by the same two physicians who simultaneously made the decision after a short unanimous discussion.

Statistical Analysis

Descriptive parameters were calculated to describe distributions of variables. Two-sided Fisher exact test was used to determine any associations between two categorical variables. By using the Mann-Whitney or Student *t* test, we analyzed differences in mean values for continuous variables. The Kolmogorov-Smirnov test was performed to determine whether two distributions differed. Analyses were performed with SAS software version 8.02 (SAS Institute Inc., Cary, NC).

RESULTS

Test Results: Tolerability, Symptoms and Laryngeal Findings

For all age groups, the test was relatively easy to perform and well tolerated. We had three patients in the age group ≥60 years and eight patients ≤16 years, and the youngest one was a 10-year-old female. The test was successfully performed for 27 (90%) patients and all controls. Three of the 30 patients interrupted the test: one patient's laryngeal spasm was triggered by FEV1 measurement, another experienced a panic attack during the preparation phase, and the third patient's test was interrupted by vasovagal collapse during local anesthesia of the nose.

Laryngeal anatomy and function before exercise test was normal in all patients. During the test, the typical dyspnea in their history could be induced in 15 (56%) of the patients. Of these, nine (60%) had EIVCD (n = 5) or a high suspicion of EIVCD (n = 4), showing collapse of arytenoids and aryepiglottic folds toward the aditus of the larynx; in five EIVCD patients this supraglottic collapse was followed by adduction of the vocal cords. All EIVCD patients showed a glottic narrowing of at least 90%, leaving only a minimal posterior chink open (video is included in the online version of this article). Inspiratory stridor was audible during subjective symptom of dyspnea in all of the nine patients.

Laryngeal function was normal in all controls during the test, and no subjective symptoms of dyspnea appeared. Soon after the test was started, physiological slight and fast adduction of vocal cords during expiration was seen for a short period in 13 (87%) of the 15 controls. This was seen very briefly and only during expiration, caused no subjective symptoms, and did not considerably narrow the glottic level.

Test Results: Other Findings

The median exercise test duration for patients was 18.6 minutes (range, 7.5–34.9), and for controls 15.7 minutes (range, 10.3–21.5). All patients and controls were able to reach the heart rate (HR) minimum of 85% of the predicted maximal HR, (220−age in years)/minutes, by the end of the test.

An asthma-like attack with expiratory stridor and dyspnea, but without reduction in FEV1, occurred in one patient, and another patient showed decreased ST level without chest pain in ECG during the test; in subsequent cardiological examinations, coronary artery disease showed in the latter. No others had severe ECG changes. Blood pressure and breathing rate responses to exercise were normal in all patients and controls. Oxygen saturation momentarily decreased to under 90% in four (15%) of the patients and in one (7%) of the controls. Neither the patients nor the control reported any symptoms during these short periods of decreased oxygen saturation. No control used regular medication or reported any history of dyspnea, continuous cough, or need to clear the throat. One of the controls was a smoker.

No statistically significant differences appeared between patients and controls by age ($P = .0815$, Kolmogorov-Smirnov Test), or by gender ($P = .4639$, Fisher exact test, 2-sided).

DISCUSSION

Of those patients referred to our clinic because of suspicion of EIVCD, our test identified one third. Continuous transnasal fiberoptic videolaryngoscopy during bicycle ergometry proved a well-tolerated and relatively easily performed diagnostic method. It could be performed on patients from 10 to 69 years of age, and the instrumentation needed for testing was easily available. In addition to the physicians, two nurses and a resident were involved in our pilot study, but for the test setting a nurse and two physicians (anesthesiologist and ENT specialist) are required. Our protocol with slowly increasing work load was suitable for elderly patients and for those with impaired physical condition. Younger and more athletic patients needed the fast unlimited pedalling step at the end of the test to create the circumstances at which the symptom typically occurs. It is possible to establish a test setting in an ordinary laryngeal outpatient department at the relatively low extra cost of a stationary bicycle, ECG monitor, and FEV1 measuring equipment. However, because the test set-up is based on two physicians and a nurse, and the number of suspected VCD patients is limited, this diagnostic tool is especially suitable for tertiary care units and offices of the academic laryngologists. Our test's benefit in comparison with the test from Heimdal is that it can be performed on the patients in different age groups and physical conditions. In addition, our test set-up is technically less demanding, and space requirements favor an ergometer as compared to a treadmill in the often crowded facilities.

Our patients stated that the exercise-induced dyspnea does not appear every time identically, even if the level, mode, and the surroundings of the exercise are the same, in accordance to previous studies.[4] This leads us to the conclusion that most probably no single optimal way to test EIVCD exists, and variations in testing method in different surroundings might be required for this complicated diagnosis. Therefore, in this series, the negative test result did not rule EIVCD out, but the positive result ruled it in. Reproducibility of our test was not tested. Our test set-up is intended for both clinical and research applications.

ECG monitoring throughout the test was very informative and important also in the aspect of safety, whereas in blood pressure and breathing rate responses no significant differences between patients and controls occurred. Findings from the study allowed us to simplify the procedure; we no longer measure blood pressure and respiratory rate during the test. The nonsymptomatic short periods of blood oxygen level decreases were most likely due to equipment bias; oxygen level was measured from the fingertip, and the equipment did not always remain optimally in place, especially after sweating.

In line with previous studies, EIVCD findings resolved within a few seconds when the exercise slowed or stopped.[7] This confirms the value of direct visualization of the vocal cords during the symptoms in the diagnosis of laryngeal dyspnea.[3,4,6,7,9] On the other hand, the patient's subjective feeling of dyspnea at laryngeal level was not always accurate; six (40%) of the patients who reported subjective laryngeal dyspnea had a wide open larynx visualized simultaneously in fiberoptic videolaryngoscopy.

In our series the fiberoptic videolaryngoscope was held manually to maintain optimal positioning. The head piece holding the laryngo-fiberscope used by Heimdal et al.[6] would allow the test to be done with only one physician, but visualization of the vocal cords might sometimes be lost, and the in-place fixed headpiece itself can lead to a panic reaction, especially for patients who can hardly bear the fiberoptic scope alone. Moreover, because our test was performed with a stationary bicycle, patient movement was limited so that the scope could be manually held. It is possible to instruct a nurse on holding the fiberoptic instead of the ENT specialist, who is able to check the test result later from the digital video. A quantitative measurement of glottic narrowing is needed, and we are working further to solve this problem in our future studies.

In all five EIVCD patients, the laryngeal signs began with the collapse of the posterior supraglottic structures and aryepiglottic folds, followed by an adduction of the vocal cords. Four other patients, considered highly suspicious of EIVCD, showed similar supraglottic adduction without progression to vocal cord adduction. Staging and the relevance of other laryngeal findings, such as slight adduction of arytenoid cartilages without subjective symptom of dyspnea during the exercise test, still remain challenging; are they presymptoms for EIVCD, prognostic for the later progress to EIVCD, or just normal physiological variants?

In line with previous studies, we had a dominance of female patients, and coexisting asthma was diagnosed in almost one half of the patients.[9] Infection can also trigger VCD.[5] Interestingly, we had one male patient with a serologically confirmed pertussis found in one of his family members about 3 months before at the time his own cough and dyspnea symptoms began. Unfortunately, the patient himself was not tested at that time, although his symptoms were evidence for the disease. His laryngeal spasm was induced after forced expiration to the spirometer.

Of patients with established EIVCD in our study, 19% (5/27) was a low prevalence. However, the typical symptom of dyspnea appeared only to 15 patients during the test. This result may reflect the limited sensitivity of our test, but perhaps also the difficulties in the diagnosis of dyspnea. It is possible that some of those 12 patients without symptoms during the test could have been diagnosed with a treadmill test or by retesting them with a more individually modified version of our test set-up. Individual modifying means shorter exercise steps (3 minutes) and/or the possibility to pedal with no speed limit and with a lesser load than 120 W/150 W until exhaustion. One should also remember that some of these 12 patients are most likely true negative cases whose symptoms are not induced by exercise, although the feeling of dyspnea is present during physical exercise. Although examined by many physicians specialized in airway problems, those with exercise-induced dyspnea, not being asthma or EIA, often remain without an accurate diagnosis. On the other hand, after we had interviewed all patients referred to us for the exercise test, five (17%) of the 30 had a history of dyspnea that did not quite meet the criteria of EIVCD. However, the exercise test was still administered all the patients referred. These five patients were included in the group of 12 patients whose symptoms were not induced during the test; it seems evident that the test detected no false positive cases.

The classification of laryngeal disorders is difficult. Laryngospasm is defined as a spasmodic closure of the glottic aperture or a sudden forceful and abnormal closing of the vocal cords causing sudden brief episodes of dyspnea and stridor. VCD is characterized by involuntary, paradoxical adduction of the vocal cords and false cords typically during inspiration, with closure of the vocal cords maintained sometimes during an entire respiratory cycle.[15] The relationship between VCD and laryngeal spasm is not clear; are they separate conditions or different manifestations of specific laryngeal pathology? However, in EIVCD the trigger of the symptom is physical stress and the patients are otherwise free of symptoms.

There has not been a clinically relevant test method for EIVCD before the one introduced by Heimdal et al.[6] Using that method or our test set-up will definitely improve diagnostic accuracy of EIVCD because methods used earlier for diagnostic purposes in EIVCD, such as laryngoscopy after the exercise or spirometry, are far from optimal. Diagnosis of EIVCD requires visualization of the paradoxical movement of the vocal cords during exercise. To verify this, some effort and costs are needed. On the other hand, a better differential diagnostics of dyspnea often saves money and other resources. Moreover, the potentially severe side effects of high-dose corticosteroids and other asthma drugs are avoided. Therefore a consultation with an ear, nose, and throat specialist in diagnosing unclear exercise-induced dyspnea is recommended.

CONCLUSION

Fiberoptic videolaryngoscopy during bicycle ergometry was a well-tolerated and relatively easily established diagnostic tool that induced dyspnea in more than one half the patients examined. If the symptom of dyspnea appeared, the most frequent finding was exercise-induced vocal cord dysfunction. The test was suitable for a laryngeal outpatient department and applicable to patients of various ages and physical conditions.

Acknowledgments

The authors thank the staff of the Phoniatric and Laryngological Outpatient Department and ENT Clinic Research Laboratory, especially Tuula Säämänen, Eija Nenye, Leena Juvonen, and Kirsi Käppi for excellent technical assistance and coordination of the study, and acknowledge Sonja Lumme for statistical analysis.

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