An unusual cause of exertional dyspnea in a 55 years old man

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\textbf{ABSTRACT}

A 55-year-old former professional athlete reported out of proportion dyspnea on exertion. After a detailed cardiac investigation, a cardiopulmonary exercise test on an ergocycle demonstrated an abnormal and non-physiological ventilatory response characterized by a sharp rise in ventilation followed by a decrease while exercise workload was progressively increasing. This was accompanied by noisy breathing. A laryngoscopy with direct visualisation of larynx and vocal cord during voluntary eucapnic hyperventilation confirmed the diagnosis of exercise-induced laryngeal obstruction. The patient was treated with speech therapy and all the symptoms resolved. A second cardiopulmonary exercise test showed a normalisation of the ventilatory pattern during exercise. This case demonstrates the importance of recognizing the symptoms of an exercise-induced laryngeal obstruction regardless of age, and the effectiveness of the speech therapy on symptoms and on exercise testing.

1. Case report

A 55-year-old man was referred to the cardiology department of the \textit{Institut universitaire de cardiologie et de pneumologie de Québec} (Quebec, Canada) in 2014 for the evaluation of an incapacitating dyspnea at intense exercise that had been noted for the past six months. This patient was an ex-professional athlete who was operated in 1983 for a traumatic rupture of the aorta following a car accident. The patient was treated for high blood pressure for the past five years with bisoprolol 5mg die, amlodipine 5 mg die, and telmisartan 20 mg combined with hydrodiuril 12.5 mg die.

Physical exam was unremarkable except for systolic murmur at the aortic region. An echocardiography at time of evaluation demonstrated a normal left ventricle ejection fraction over 60% and a left ventricular aortic region. An echocardiography at time of evaluation demonstrated a normal left ventricle ejection fraction over 60% and a left ventricular aortic region. A second stress echocardiography showed severe aortic stenosis (70%) with an aortic valve area of 0.6 cm\textsuperscript{2}, peak gradient of 45 mmHg, and an ejection fraction of 63%.

Between June 2015 and March 2017, the patient had three stress echocardiography tests on a treadmill (Bruce protocol) that were negative for ischemia; however, the duration of those stress tests decreased from 12 minutes to 8 minutes 15 seconds from the first to the third evaluation. During the last treadmill, the patient complained of shortness of breath without any evident respiratory noise. Except for a calcified aortic valve, consistent with the aortic stenosis already described the year before, no other anomalies were discovered, and the worsening of dyspnea remained unexplained.

In March 2017, the patient had a complete pulmonary evaluation. His pulmonary function tests, including spirometry, lung volumes, and diffusion capacity were normal. A cardiopulmonary exercise test (CPET) on an ergocycle was also performed (see Fig. 1). The test was stopped due to the patient’s dyspnea. Consistent with his previous athletic career, peak VO\textsubscript{2} reached 35.5 ml/kg/min, for a predicted peak VO\textsubscript{2} of 29.8 ml/kg/min. An atypical ventilation pattern was noted, with an inappropriately high ventilation (VE) at the beginning of exercise that was followed by an abnormal drop toward the end of exercise. Ventilatory equivalents (VE/VO\textsubscript{2} and VE/VCO\textsubscript{2}) and the end-tidal pressure (PETCO\textsubscript{2}) showed a steep increase followed by a fall, consistent with the decrease in minute ventilation (Fig. 1, plot 1, 6 and 9). The tidal volume had a disproportionate and abnormal increase toward the end of the exercise (Fig. 1, plot 7). VE/VCO\textsubscript{2} slope was elevated at 43.6 (Fig. 1, plot 4). The cardiovascular response was unremarkable.

The patient was referred to the pulmonology department to rule out...
exercise-induced asthma. Upon questioning, he described a rapidly occurring dyspnea with inspiratory noise at intense physical exertion. However, the methacholine challenge test and the voluntary eucapnic hyperventilation (EHV) tests were both negative. Because the patients’ symptoms, particularly the inspiratory noise, were suggestive of an exercise-induced laryngeal obstruction (EILO), he was referred to the otolaryngology department.

The otolaryngologist performed an indirect laryngoscopy while the patient was undergoing another EHV test. He visualized a diffuse laryngeal contraction occurring 1–3 minutes after the beginning of the hyperventilation with paradoxical movements of the aryepiglottic fold and a supra-glottal flaccidity. These findings were consistent with a diagnosis of EILO. (See Video, Supplemental Digital Content 1).

He was referred to a speech therapist. She recommended speech therapy that had both technical and behavioral components. This therapy was mainly based on patient education, on anatomy and laryngeal physiology and on breathing and relaxation exercises. The goal was to allow the patient to recognize the warning signs of an episode of laryngeal dysfunction, to apply respiratory techniques to better control or prevent the onset of symptoms. With this intervention, the patients’ symptoms became well controlled.

Following speech therapy, the patient underwent another CPET in

![Fig. 1. Cardiopulmonary exercise testing (CPET) before treatment; Vertical dashed lines in panels 1–3 and 6, 8, and 9 indicate the beginning of loadless pedaling, the start of loaded exercise and of the beginning of the recovery period. Horizontal dashed lines in panels 2, 3, 5, and 6 indicate the peak predicted values. Plot 1: ventilation in liter per minute (VE, L/min) versus time (minute); Plot 2: Heart rate (HR) and O₂ pulse (Oxygen uptake [VO₂]/HR) versus time; Plot 3: VO₂, carbon dioxide output (VCO₂) in L/min and work rate (watts) versus time; Plot 4: VE versus VCO₂; Plot 5: VCO₂ and HR as a function of VO₂; Plot 6: Ventilatory equivalent for O₂ (VE/O₂) and CO₂ (VE/VCO₂) versus time; Plot 7: Tidal volume (Vt) in liter versus VE (L/min); Plot 8: Respiratory exchange ratio (RER) versus time (minute); Plot 9: End-tidal pressure for O₂ (PETO₂) and CO₂ (PETCO₂) and O₂ pulse saturation % (SpO₂) versus time.](http://doi.org/10.1016/j.rmcr.2020.101004)
2018. With his EILO controlled through speech therapy, peak VO\textsubscript{2} increased to 40.7 ml/kg/min, a considerable 14% improvement from 2017, with complete resolution of the atypical ventilation pattern during exercise (see Fig. 2).

The patient has fully consented to have his case published.

2. Discussion

We report the case of a 55-year-old former professional athlete with typical features of EILO. EILO is a condition where inappropriate glottis or supra-glottic closure occurs during exercise, producing upper airway obstruction without any symptoms at rest [1].

Fig. 2. CPET after treatment; Vertical dashed lines in panels 1–3 and 6, 8, and 9 indicate the beginning of loadless pedaling, the start of loaded exercise and of the beginning of the recovery period. Horizontal dashed lines in panels 2, 3, 5, and 6 indicate the peak predicted values. Plot 1: ventilation in liter per minute (VE, L/min) versus time (minute); Plot 2: Heart rate (HR) and O\textsubscript{2} pulse (Oxygen uptake [VO\textsubscript{2}/HR] versus time; Plot 3: VO\textsubscript{2}, carbon dioxide output (VCO\textsubscript{2}) in L/min and work rate (watts) versus time (minute); Plot 4: VE versus VCO\textsubscript{2}; Plot 5: VCO\textsubscript{2} and HR as a function of VO\textsubscript{2}; Plot 6: Ventilatory equivalent for O\textsubscript{2} (VE/VO\textsubscript{2}) and CO\textsubscript{2} (VE/VCO\textsubscript{2}) versus time; Plot 7: Tidal volume (VT) in liter versus VE (L/min); Plot 8: Respiratory exchange ratio (RER) versus time (minute); Plot 9: End-tidal pressure for O\textsubscript{2} (PET\textsubscript{O2}) and CO\textsubscript{2} (PET\textsubscript{CO2}) and O\textsubscript{2} pulse saturation % (SpO\textsubscript{2}) versus time.

The present EILO case is of particularly interest because of three main reasons. Firstly, because of the atypical age of presentation, secondly because the condition was not recognised mainly because the typical inspiratory noise was not reproduced by the traditional stress echocardiography test, and thirdly because we were able to document the response to exercise before and after speech therapy.

First described in 1984 [2], this entity is still commonly unrecognized today. EILO is characterised by dyspnea in more than 95% of patients and stridor, a harsh inspiratory sound due to turbulent air flow, in 54% of patients [3]. Unlike asthma, the symptoms are maximal towards peak of exercise whereas in exercise-induced asthma respiratory symptoms often reach their maximum during recovery [4]. Wheezing,
chest pain or tightness and throat discomfort are also commonly encountered symptoms in EILO. Because of the similarity of the symptoms, EILO and exercise induced bronchoconstriction (EIB) are difficult to distinguish amongst each other and questionnaire may not differentiate between both conditions [5].

Dyspnea at intense exertion is a common complaint in athletes. In some series, up to 70% of athletes report problems with their breathing [6]. While exercise-induced bronchoconstriction (EIB) is the first diagnostic to consider, the prevalence of EILO in young athletes is also important. In some trials, the prevalence of EILO among adolescents and young adults is around 5–10% [5,7]. More importantly, in an athlete population with respiratory symptoms, it was reported that 35% had an EILO while 43% had EIB. EILO is about four times more common among women than man (OR 4.09 P < 0.01) [7].

Continuous fiberotic laryngoscopy during exercise test (CLE test) is currently the gold standard diagnostic test, allowing visualisation of the vocal cords and larynx during symptomatic periods [1,3,8,9]. The visible abnormalities resolve quickly during recovery, making a continuous laryngoscopy during exercise more sensitive than when only performed during recovery [10]. Eucapnic voluntary hyperventilation (EVH) is an alternative method to elicit symptoms and laryngeal anomalies seen in EILO, as demonstrated by Turmel et al. [11]. Treatment of EILO is primarily non-pharmacological, although surgical procedures exist [12]. Speech-language therapy focuses on respiratory control with breathing exercises to optimize laryngeal aperture and muscle strengthening and relaxation. This has been demonstrated as being effective in treating exercise-induced laryngeal obstruction [13–15].

EILO is typically diagnosed among young women [4,5,7,16]. The anatomy of the larynx in adolescents as well as in women’s post-puberty is slightly different from adults, notably with a narrower opening [17]. This can explain the increased prevalence in this population. EILO is also typically seen in younger people in whom athletic performance allowing them to reach high inspiratory flows during exercise can promote laryngeal obstruction. Of note, the present EILO patient was a former professional athlete and with the increasing practice of high intensity sports in the aging population, EILO prevalence is likely to increase in this specific age group.

Several hypotheses have been put forward to explain the occurrence of EILO. Firstly, EILO can be caused by the fatigue of the muscles that support the larynx. This would partly explain why laryngeal obstruction tends to occur at the end of intense exertion and not at lower exercise intensities. Secondly, some individuals may exhibit disadvantageous anatomical predispositions to EILO such as smaller size or increased flexibility of the larynx, as demonstrated in young women [18].

The Bernoulli effect seems to play a primary role in EILO [4]. This phenomenon occurs when inward forces are created by the high airflow velocity taking place in a narrower passage such as the laryngeal structures. In this situation, weakness of the upper airway dilators, ligaments or cartilage would promote an inward movement of the larynx. This could partly explain why the EILO occurs at the end of the exertion, when minute ventilation is at its peak [4,9,20].

Although there is no evidence to support this hypothesis, alteration in the neural reflex loops that coordinate the proper functioning between breathing, swallowing and protection against aspiration could also play a role [11]. Mechanical or chemical stimulations such as gastroesophageal reflux can activate this loop [21]. It has also been hypothesized that the hyperventilation described in people with EILO could contribute to this phenomenon [20,22]. It has been demonstrated that the prevalence of inspiratory stridor and EILO in the outdoor athlete subpopulation is much higher than the general population [23,24]. This suggests a relationship between exercising in cold weather and airway sensitivity.

There is a paucity of data on the pulmonary response to exertion in patients with EILO. One study [20] examined the ventilatory response and respiratory neural control (by measurement of transdiaphragmatic pressures, diaphragmatic electromyography, and respiratory flow) in 6 patients with EILO and 6 control subjects. Authors of this report observed an inappropriately increase in ventilation, related to tidal volume, which preceded the closing of the glottis. Surprisingly, the patients with EILO were able to perform the same total exercise capacity as the control group.

What we observed in our patient before speech therapy was an abnormal progression of his ventilatory pattern with a minute ventilation higher than expected as described by Wasted and al [20]. This was followed by an unexpected drop in ventilation toward the end of the exercise. This explains the unusual pattern of ventilatory equivalents (VE/VO2 and VE/VCO2), consistent with the decrease in minute ventilation caused by the glottic obstruction (Fig. 1 plot 1 and 6).

Following speech-language intervention to treat EILO, there was a clear improvement in the ventilatory pattern and exercise performance during CPET. In fact, not only did the patient show a 12.8% increase in peak VO2 (40.7 vs 35.5 ml/kg/min), this was accompanied by a substantial 14.8% increase in peak exercise capacity from 247 W to 290 W. Even more interestingly, the ventilatory profile was completely normalized with a VE/VCO2 slope of 31.7 (Fig. 2, plot 4) and a minute ventilation that progressed as expected with the ramp exercise protocol.

3. Conclusion

This case represents a 55 year-old professional athlete with dyspnea on exertion secondary to an EILO that was highlighted by CPET. EILO should be suspected in any patient who has respiratory symptoms during exercise, especially when they occur at peak exertion and even more when a stridor is present. Although typically described in young athletes, with increasing interest in physical activity and high-endurance sports at all ages, EILO has a potential to be diagnosed more frequently at later ages. CPET is a good diagnostic tool when a patient complains of a symptom during exercise, specially at high exercise intensity. As demonstrated in the literature and by our case, patients with EILO may have an abnormal ventilatory pattern and an inappropriate increase in ventilation for the attained watts. The comparison between the pre and post treatment tests strengthens the findings and emphasizes the importance of speech therapy that are effective in correcting the symptomatology and normalizing exercise performance.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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The patient has fully consented to have his case published. His case was presented without any modification of reality. No details have been changed. There is no conflict of interest on the part of the authors or any grant that may affect the results. The present study result do not constitute an endorsement by ACSM.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rmcr.2020.101004.

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