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CASE REPORT

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An example of ventilatory limitation during cardiopulmonary exercise testing in a patient with COPD

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Abstract

A 64-year-old obese gentleman attended for further evaluation of ongoing dyspnoea in the context of a previous diagnosis of moderate COPD treated with dual long-acting bronchodilators. A cardiopulmonary exercise test (CPET) was performed, which demonstrated reduced peak work and oxygen consumption with evidence of dynamic hyperinflation, abnormal gas exchange and ventilatory limitation despite cardiac reserve. The CPET clarified the physiological process underpinning the patient's dyspnoea and limiting the patient's activities. This, in turn, helped the clinician tailor the patient's management plan.

KEYWORDS
cardiopulmonary exercise test, COPD, CPET, Dyspnoea, ventilatory limitation

INTRODUCTION

A 64-year-old gentleman presented for assessment of exertional dyspnoea that had become more pronounced over the last 2 years. He was able to climb two flights of stairs before needing to rest. The breathlessness was interfering with his ability to work as a gardener. He reported attending the gym twice weekly. He was obese with BMI at 40 $kg.m^{-2}$ but his weight had been relatively stable in recent years. He quit smoking 10 years earlier with an estimated 40-packet year history. Past medical history included well-controlled hypertension and hyperlipidemia on pharmacological treatment. Cardiac assessment was conducted with no apparent abnormality identified. A myocardial perfusion scan did not reveal any inducible cardiac ischemia with peak heart rate reached at 137 bpm (87% reference). Static lung function revealed moderate airflow limitation (FEV_1/FVC −4.54, FEV_1 −3.69 z-score), gas trapping (RV 4.98 z-score) and mild reduction in gas transfer factor (−1.72 z-score). Symptoms persisted despite treatment with dual long-acting bronchodilators and participation in a pulmonary rehabilitation program. The patient was referred for a cardiopulmonary exercise test (CPET).

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A CPET was performed for the assessment of exertional dyspnoea using a cycle ergometer with an incremental load of 10 watts min^{-1} ramp that included arterial blood gas sampling and inspiratory capacity manoeuvres (Figure 1, Table 1). The patient exercised for 7:01 minutes and was ceased due to patient report of breathlessness and an inability to maintain cadence. Peak work (73 watts [>183 watts is healthy reference]) and oxygen uptake (15.1 mL min^{-1}.kg^{-1}, 61% reference) were reduced. Anaerobic threshold

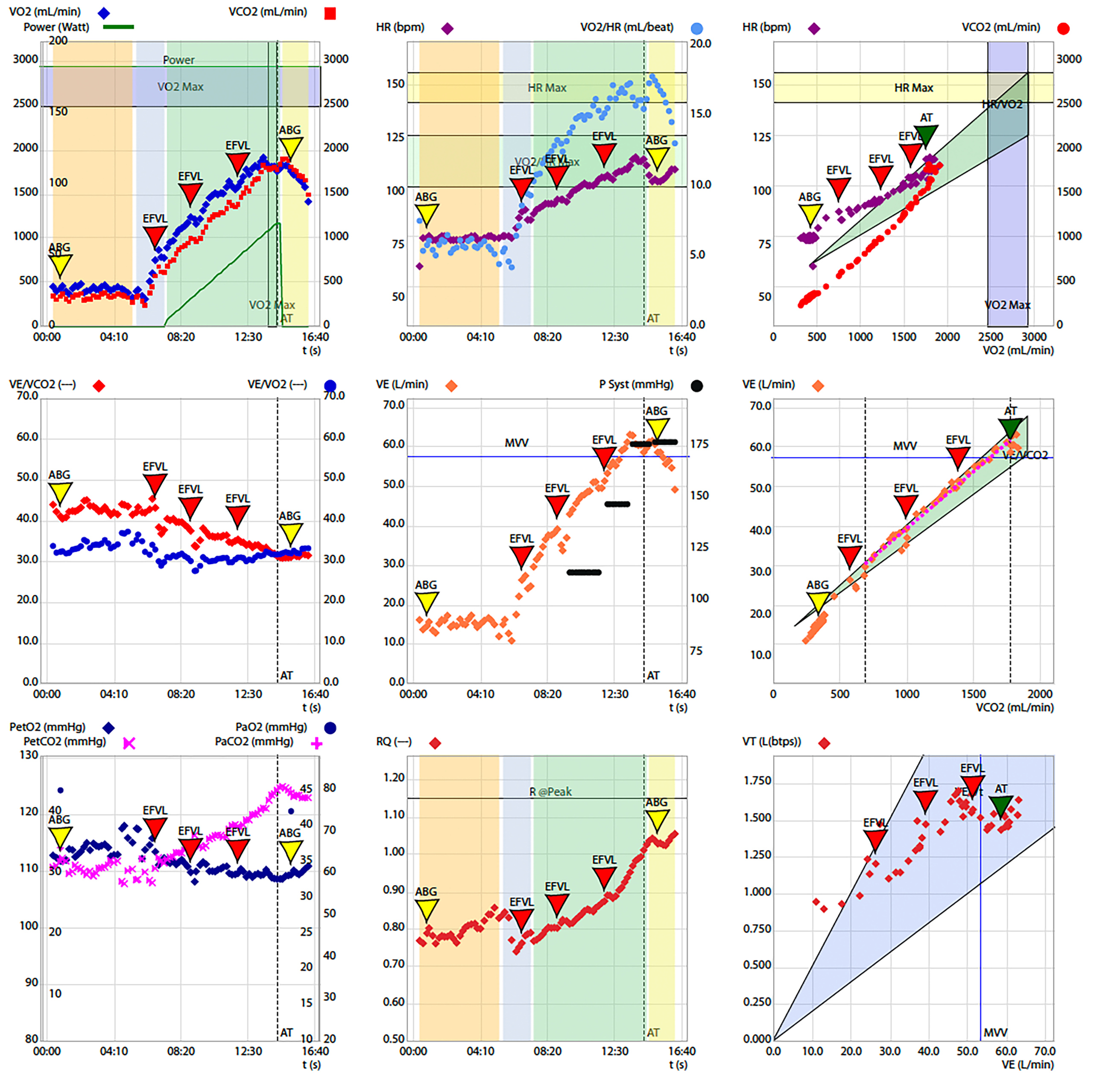

FIGURE 1 Continuous cardiopulmonary exercise testing, 9-panel plot (5th edition)[2] data from a 64-year-old male. Block colours denotes resting, unloaded, incremental and recovery phases. Dotted vertical line is selected anaerobic threshold (AT). Horizontal bars are reference ranges. Arterial blood gas sampling (ABG) and inspiratory capacity manoeuvres (EFVL) collected as marked.

was reached at the end of the test. Lactate increased from baseline of 1.1 mmol L^{-1} at baseline to 5.9 mmol L^{-1} at peak exercise. There was cardiac reserve at the end of the test with maximum heart rate of 110 bpm (71% reference). Heart rate and blood pressure response increased appropriately with incremental exercise. ECG was sinus rhythm during exercise and recovery. Arterial blood gas was normal at baseline (pH 7.43, $PaCO_2$ 37 mmHg, PaO_2 80 mmHg, SaO_2 97%) with an elevated arterial-alveolar pressure gradient ($P[A\text{-}a]O_2$ 23mmHg). Physiological dead space was elevated at baseline (V_D/V_T 0.4). Gas exchange worsened during exercise (pH 7.28, $PaCO_2$ 45 mmHg, PaO_2 75 mmHg, SaO_2 94%), and V_E/VCO_2 slope, V_D/V_T and $P[A\text{-}a]O_2$ were abnormally elevated (36, 0.35 and 31 respectively). The patient reached ventilatory limitation during the test (minute ventilation $\left[\dot{V}_E\right]$ 111% of estimated maximal voluntary $\dot{V}_E$) with an observed increase in $PaCO_2$ and $P_{ET}CO_2$ at maximal exercise. In addition, $\dot{V}_E$ increased predominantly by an increase in respiratory frequency rather than tidal volume. Inspiratory capacity decreased by 1.08L during the test (IC 2.99L at baseline and 1.91L near peak exercise).

TABLE 1 Arterial blood gas and inspiratory capacity at rest and near maximal exercise during a cardiopulmonary exercise test.

		Resting	Maximal exercise	Normal range (max. Exercise)
$PaCO_2$	mmHg	37	45	
PaO_2	mmHg	80	75	≤10 mmHg reduction from resting
pH	–	7.43	7.28	
SaO_2	%	97	94	≤5% reduction from resting
HCO_3^-	meq/L	24.0	21.0	
La^-	mmol/L	1.1	5.9	
BE	meq/L	0.0	−6.0	
Hb	g/dL	15.2		
V_D/V_T	–	0.40	0.35	<0.23
$P(A\text{-}a)O_2$	mmHg	23	31	≤30
Inspiratory capacity	L	2.99	1.91	<150 mL reduction from resting

Abbreviations: A-a, alveolar to arterial; BE, base excess; Hb, haemoglobin; HCO_3^-, bicarbonate; La^-, lactate; $PaCO_2$, arterial carbon dioxide pressure; PaO_2, arterial oxygen pressure; SaO_2, arterial oxygen saturation; V_D/V_T: ratio of physiological deadspace to tidal volume.

DISCUSSION

In this case, there are several factors that may have been contributing to the patient's breathlessness. Possibilities include lung disease, diastolic dysfunction from long standing systemic hypertension, deconditioning, obesity or perhaps symptom misperception. In this case, the patient has clear evidence of ventilatory limitation as a major physiological process limiting exercise despite good effort with cardiac reserve at the end of the test. The CPET provides an objective measure of the patient's exercise capacity, which was clearly reduced, validation of the patient's ongoing symptoms despite first line treatment for COPD and the potential to guide further interventions. The result was helpful for the patient and treating clinician to further assess the lung disease with a high-resolution CT chest and explore the possibility of endoscopic lung volume reduction if deemed anatomically suitable, rather than simply dismissing the patient's symptom as potentially being secondary to deconditioning or obesity.

This case provides a clear pattern of ventilatory limitation to exercise (link to Respirology review). The reduced exercise capacity was limited by the patient reaching their $\dot{V}_E$ ceiling with cardiac reserve. In addition, dynamic hyperinflation was seen with a reduction in inspiratory capacity of more than 150 mL.[1] Arterial blood gas analysis confirmed inadequacy of $\dot{V}_E$ with increasing $PaCO_2$. The elevated A-a gradient and V_D/V_T also points to impaired gas exchange. Lactate is elevated confirming good patient effort.

AUTHOR CONTRIBUTIONS

CF, LS, CI, GK, and DC all conceived, contributed to, reviewed, and approved the final manuscript.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

ETHICS STATEMENT

The authors declare that appropriate written informed consent was obtained for the publication of this manuscript and accompanying images.

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