Cardiopulmonary exercise testing (CPET) – Royal College Review

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Objectives

- To know the indications for CPET
- To know the contraindications for CPET
- Understand how to choose the incremental protocol
- To know the indications for exercise termination
- Understand the criteria of maximal effort
- To be able to do a CPET report
  - Is there exercise intolerance?
  - What is the mechanism?

Radtke T, Crook S, Kaltsakas G, Louvaris Z, Berton D, Urquhart DS, et al. ERS statement on standardisation of cardiopulmonary exercise testing in chronic lung diseases. Eur Respir Rev. 2019;28(154).

ERS OFFICIAL DOCUMENT
ERS STATEMENT

ERS statement on standardisation of cardiopulmonary exercise testing in chronic lung diseases

Thomas Radtke [1,2], Sarah Crook [1], Georgios Kaltsakas [3,4], Zafeiris Louvaris [5], Danilo Berton [6], Don S. Urquhart [7], Asterios Kampouras [8], Roberto A. Rabinovich [9,10], Samuel Verges [11], Dimitris Kontopidis [12], Jeanette Boyd [13], Thomy Tonia [14], Daniel Langer [5,15], Jana De Brandt [16], Yvonne M.J. Goërtz [17], Chris Burtin [16], Martijn A. Spruit [16,17,18], Dionne C.W. Braeken [17], Sauwaluk Dacha [5,15,19], Frits M.E. Franssen [17,18], Pierantonio Laveneziana [20,21], Ernst Eber [22], Thierry Troosters [23,24], J. Alberto Neder [25], Milo A. Puhan [1], Richard Casaburi [26], Ioannis Vogiatzis [4,27,29] and Helge Hebestreit [28,29]

Radtke T, Crook S, Kaltsakas G, Louvaris Z, Berton D, Urquhart DS, et al. ERS statement on standardisation of cardiopulmonary exercise testing in chronic lung diseases. Eur Respir Rev. 2019;28(154).

American Thoracic Society/ American College of Chest Physicians

ATS/ACCP Statement on Cardiopulmonary Exercise Testing

THIS JOINT STATEMENT OF THE AMERICAN THORACIC SOCIETY (ATS) AND THE AMERICAN COLLEGE OF CHEST PHYSICIANS (ACCP) WAS ADOPTED BY THE ATS BOARD OF DIRECTORS, MARCH 1, 2002 AND BY THE ACCP HEALTH SCIENCE POLICY COMMITTEE, NOVEMBER 1, 2001

ATS/ACCP Statement on Cardiopulmonary Exercise Testing. Am J Respir Crit Care Med. 2003 Jan 15;167(2):211–77.

Indications of CPET

- Evaluation of exercise intolerance
- To identify the mechanism of exercise intolerance and use it as a target for therapeutic interventions
- Quantify the level of impairment
- To assess the impact of an intervention
- To help evaluate prognosis
- Research tool

Usefulness in chronic respiratory disease

- Evaluation of “out-of-proportion” (to resting functional impairment) exertional dyspnoea and limited exercise tolerance
- Assessment before a surgery
  - Lung resection, surgical or bronchoscopic lung volume reduction, heart-lung transplantation
- Pulmonary rehabilitation
- Disability evaluation, prognosis and response to treatment
- Assessment of exercise-induced desaturation and underlying mechanisms

CPET

- Incremental exercise testing with recording of many physiological variables to assess changes of those variables over time during an exercise
- The limitations come from the symptoms during a maximal progressive effort
- Respiratory exchange measurement
  - VO2 – O2 uptake
  - VCO2- CO2 production
  - VE – minute ventilation
  - Pulse oximetry
  - Sometimes arterial blood sample
- Cardiac measurement
  - ECG – rythm and frequency
  - Blood pressure

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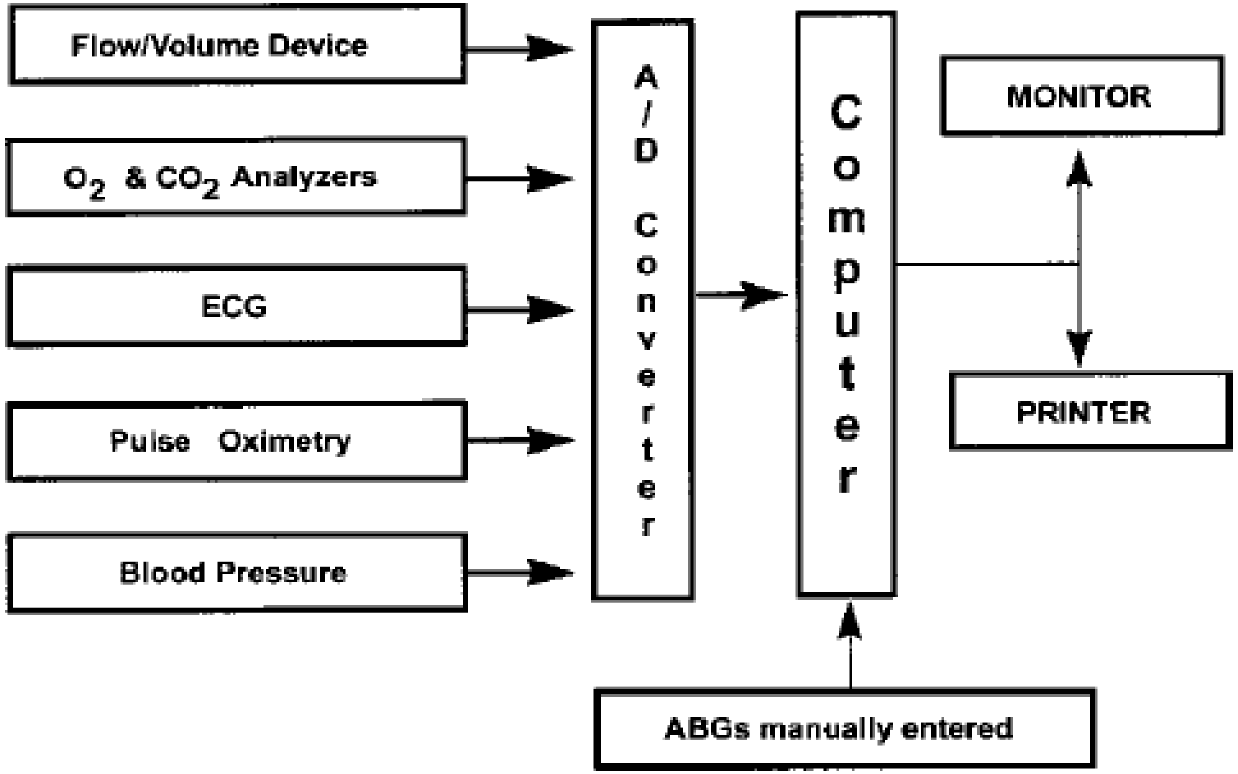

Figure 1. Diagram of the instruments and computer system used for the measurement of cardiopulmonary variables in a breath-by-breath mode (automated system). *ABGs* = Arterial blood gases; *A/D* = analog to digital; *ECG* = electrocardiogram.

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CPET

- Global assessment of the integrated exercise response of many systems
  - Lung
  - Cardiovascular
  - Hematopoietic
  - Neuropsychologic
  - Musculoskeletal

TABLE 8. ABSOLUTE AND RELATIVE CONTRAINDICATIONS FOR CARDIOPULMONARY EXERCISE TESTING

Absolute	Relative
Acute myocardial infarction (3–5 days)	Left main coronary stenosis or its equivalent
Unstable angina	Moderate stenotic valvular heart disease
Uncontrolled arrhythmias causing symptoms or hemodynamic compromise	Severe untreated arterial hypertension at rest ($>$ 200 mm Hg systolic, $>$ 120 mm Hg diastolic)
Syncope	Tachyarrhythmias or bradyarrhythmias
Active endocarditis	High-degree atrioventricular block
Acute myocarditis or pericarditis	Hypertrophic cardiomyopathy
Symptomatic severe aortic stenosis	Significant pulmonary hypertension
Uncontrolled heart failure	Advanced or complicated pregnancy
Acute pulmonary embolus or pulmonary infarction	Electrolyte abnormalities
Thrombosis of lower extremities	Orthopedic impairment that compromises exercise performance
Suspected dissecting aneurysm	
Uncontrolled asthma	
Pulmonary edema	
Room air desaturation at rest $\leq$ 85%*	
Respiratory failure	
Acute noncardiopulmonary disorder that may affect exercise performance or be aggravated by exercise (i.e. infection, renal failure, thyrotoxicosis)	
Mental impairment leading to inability to cooperate	

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Contraindications 2019

- **Absolute**
- Uncontrolled cardiovascular conditions
- Uncontrolled respiratory conditions
- Uncontrolled non-cardiorespiratory conditions (infection, acute bleeding, renal failure, thyrotoxicosis)
- Advanced or complicated pregnancy

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Contraindications 2019

- **Relative**
- Resting oxygen saturation $SpO_2 \leq 85\%$ on room air
- Orthopaedic impairment that compromises exercise performance
- Mental or cognitive impairment leading to inability to cooperate

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CPET - methodology

- CPET
  - Treadmill test
  - Cycle test
- Walking advantage
  - Typical activity ; in contrast to cycling
- Cycling advantage
  - work rate is easier to quantify and control
  - allows more convenient intra-test procedures such as blood sampling and blood pressure (BP) monitoring
  - Less likely to fall
  - Cycle ergometer cheaper and requires less space than a treadmill
- Measurement between treadmill and cycle test are not interchangeable

Differences between treadmill and cycle

Variables	Cycle test	Treadmill test
VO2 peak		VO2 higher
Peak lactate concentration	Lower	
Anaerobic threshold	Higher VO2 level	
Saturation		Greater systemic desaturation
Breathlessness as a function of VO2 and VE		Higher
Most frequent reason to stop	Quadriceps fatigue	Breathlessness

Test protocol

- Increment
  - By ramp - continuous
  - By steps (minute by minute) – discontinuous

TABLE 1 Exercise mode and protocols used for cardiopulmonary exercise testing

Lung diseases/lung conditions	Studies n	Cycle test			Treadmill test		
		1-min stages	Ramp	Unclear	1-min stages	Ramp	Unclear
COPD/emphysema	323	162 (50.2)	92 (28.5)	36 (11.1)	27 (8.4)	4 (1.2)	2 (0.6)
Asthma	19	7 (36.8)	6 (31.6)	1 (5.3)	5 (26.3)	0	0
Interstitial lung disease	18	5 (27.8)	12 (66.7)	1 (5.6)	0	0	0
Pulmonary arterial hypertension	64	24 (37.5)	37 (57.8)	3 (4.7)	0	0	0
Cystic fibrosis	78	51 (65.4)	22 (28.2)	0	3 (3.8)	2 (2.6)	0
Primary ciliary dyskinesia	1	1 (100)	0	0	0	0	0
Sarcoidosis	12	2 (16.7)	6 (50.0)	4 (33.3	0	0	0
Lung cancer	39	9 (23.1)	21 (53.8)	7 (17.9)	2 (5.1)	0	0
Unclear respiratory diagnosis	3	3 (100)	0	0	0	0	0
Patients undergoing lung transplant or volume reduction surgery or other thoracic surgeries	23	6 (26.1)	10 (43.5)	4 (17.4)	1 (4.3)	0	2 (8.7)
Other#	15	2 (13.3)	10 (66.7)	2 (13.3)	0	1 (6.7)	0
Total	595	272 (45.7)	216 (36.3)	58 (9.7)	38 (6.4)	7 (1.2)	4 (0.7)

Data are n (%) for each disease/disease condition. No data were available for tuberculosis and irradiation of the lung. #: this group contains a mix of different lung diseases (*i.e.* restrictive and obstructive), asbestosis and obstructive sleep apnoea–hypopnea syndrome.

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TABLE 2 Reported protocol specifications during cardiopulmonary exercise testing

Protocol specification	Cycle test			Treadmill test		
	n (%)#	Median (IQR)	n (%)¶	n (%)#	Median (IQR)	n (%)¶
Work rate increments	487 (89.2)			45 (91.8)		
Rest phase	264 (48.4)			10 (20.4)		
Rest phase duration min+	229 (42.0)	3 (3–3)	139 (59)	7 (14.3)	3 (2–3)	4 (57)
Unloaded phase warm-up	329 (60.3)			25 (51.0)		
Unloaded duration min+	314 (57.5)	3 (2–3)	182 (58)	19 (38.8)	3 (3–4)	10 (53)
Incremental phase duration	104 (19.0)			19 (38.8)		
Recovery	71 (13.0)			5 (10.2)		
Recovery duration min+	56 (10.3)	3 (2–6)	18 (32)	4 (8.2)	3 (2–4)	1 (25)

Data are presented as n (%) or median (interquartile range). #: studies reporting test protocol details; ¶: studies using test duration supported by the literature review; +: percentages are calculated of studies that reported on rest, unloaded and recovery phases.

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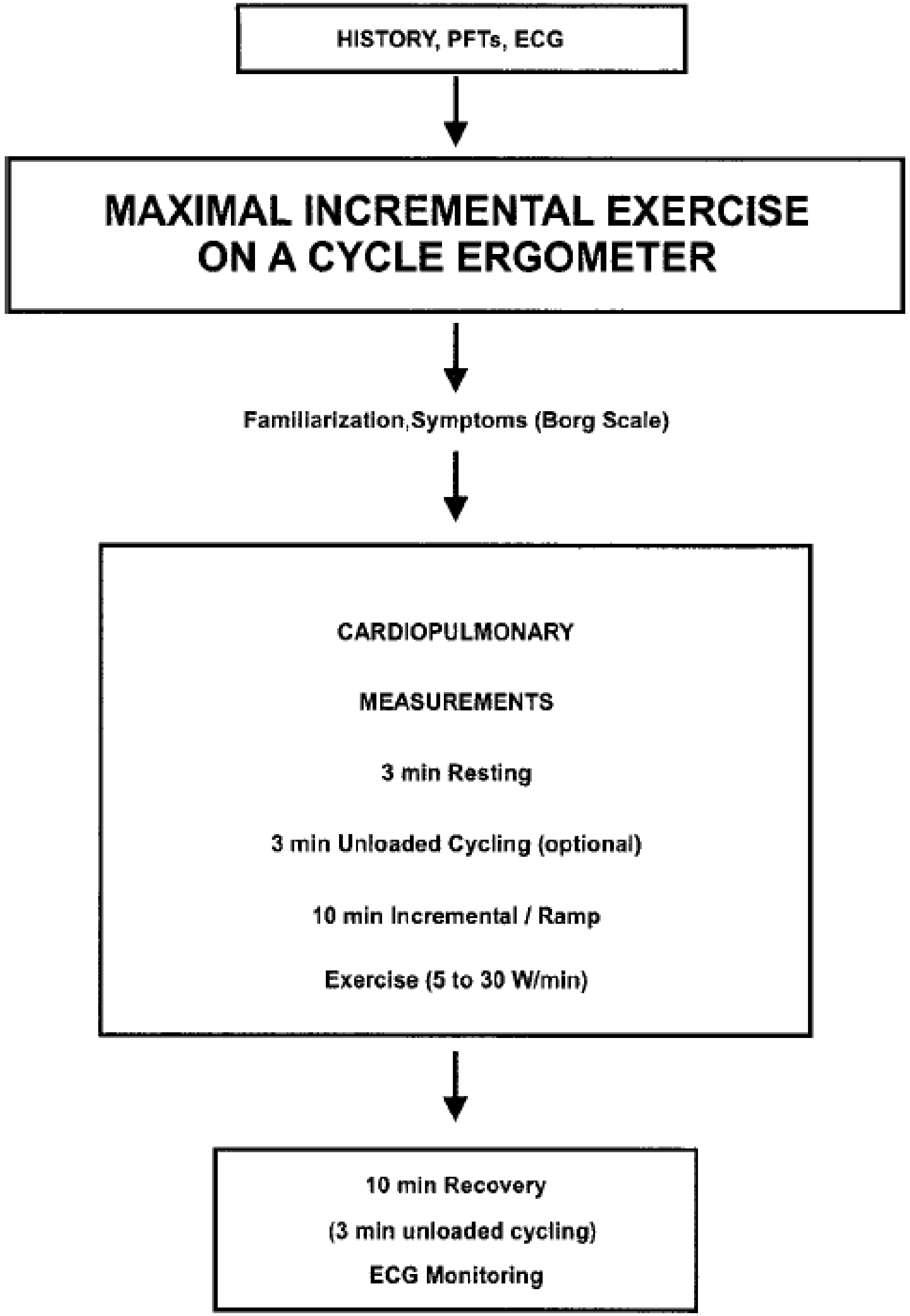

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What we want

- A perfect length
  - Not too long or too short
- A maximal test unless told otherwise
- Need to encourage the patient
  - With vigor!
- Push him to the end!

TABLE 4 Outcome values to report in standard clinical cardiopulmonary exercise testing as employed by the Task Force members

Exercise capacity	Cardiovascular limitation	Gas exchange limitation	Ventilatory limitation
Variable relevance			
V'_{O_2peak}	HR_{peak}	V'_E/V'_{CO_2} slope	V'_{Epeak} in % MVV_{rest}
Peak WR	V'_{O_2}/WR slope	Lowest V'_E/V'_{CO_2} value (nadir)	
AT	O_2pulse_{peak}	S_{pO_2peak}	
	HR/V'_{O_2} slope	Borg symptom scores	
For studies featuring additional measurements			
		V_D/V_T #	V_T/IC ¶
		P_{A-aO_2peak} #	IRV_{peak} ¶

V'_{O_2peak}: peak oxygen uptake; WR: work rate; AT: anaerobic threshold; HR: heart rate; V'_E: minute ventilation; V'_{CO_2}: carbon dioxide production; V'_{Epeak}: peak minute ventilation; MVV_{rest}: maximum voluntary ventilation at rest; V'_{O_2}: oxygen uptake; S_{pO_2peak}: peak arterial oxygen saturation measured by pulse oximetry; V_D/V_T: dead space/tidal volume ratio; IC: inspiratory capacity; P_{A-aO_2peak}: peak alveolar–arterial oxygen tension difference; IRV_{peak}: peak inspiratory reserve volume. #: in studies featuring arterial blood gas measurements; ¶: in studies featuring serial inspiratory capacity measurements.

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Before the test

- Refrain from eating for at least 2h before testing
- Avoid strenuous exercise for at least 24 h before CPET
- Avoid caffeine on the day of the test
- Avoid smoking for at least 8h prior to the test
- To wear comfortable clothing and appropriate shoes

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Before the test

- Medical history and physical examination
- Take the vital signs (SpO_2, HR, BP)
- If diabetes: assess the glycemic control and be sure to have a juice or snack if needed
- Usual medications and inhalers should be taken

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Before the test

- Explain that the goal is a maximal test
- Explain that it is normal to experience breathlessness and a quadriceps fatigue
- Insist that the test has to be maximal
- Explain clearly that the patient can stop at any moment if he experiences discomfort, pain, etc…
- Show Borg scale and explain it
- Obtain a FEV1 to determine the maximal voluntary ventilation (MVV) (FEV1 x 35 or x 40)

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1 – 10 Borg Rating of Perceived Exertion Scale	
0	Rest
1	Really Easy
2	Easy
3	Moderate
4	Sort of Hard
5	Hard
6	
7	Really Hard
8	
9	Really, Really Hard
10	Maximal: just like my hardest race

Typical sequence

Resting phase

3 min (or more if required)
Familiarisation with procedure and equipment:
Recording of resting measurements during the last minute or longer (until stable baseline is reached)

Unloaded phase

3 min (or less in severely impaired patients)
Unloaded or minimum load
Familiarisation with the ergometer and proper warm-up

Incremental phase

About 10 min (8–12 min)
Ramp or minute-by-minute increment
Standardised increment individually determined for each patient and disease

Recovery phase

2–3 min
Unloaded pedaling
Safety monitoring
Prolonged recording of heart rhythm and/or gas exchange during passive recovery, if indicated

Resting phase

- Familiarisation with procedure and equipment
- Arterial blood gas sample if needed
- 3 minutes
  - Obtain stable resting value
    - RER < 1
    - VO2 : 3,5 mL/min/kg

Unloaded phase

- 3 minutes
  - Familiarisation with the ergometer and proper warm-up

Incremental phase

- Standardised increment individually determined for each patient and disease
- Should last about 10 minutes (between 8 and 12)
- Choice of increment related to
  - Disease , age, sex, body dimension, PFT, physical activity, fitness, genetic, medication
- A test that last less than 6 minutes is less useful because the relation between work and VO2 is not necessarily linear

How to choose the starting load and the increment?

- An optimal test should last between 8 and 12 minutes without including the unloaded phase
- General rule for chronic respiratory disease
  - Unloaded phase 10 w
  - Increment between 5 to 10 w
- In the worst case,
  - Test is too short or too long

- VO2 estimated while cycling unloaded = 150+(6 x weight in kg)
- Increment in W/min = VO2 estimated (mL/min) −VO2 estimated while cycling unloaded (mL/min)/92.5

Table S13 Estimated workrate increments per respiratory diagnosis as calculated using the equation given in the main manuscript. Please note that these are selected studies with specific populations. Thus, the estimates provide some general idea but cannot be used unadjusted in clinical testing.

Lung diseases/lung conditions	**Cycle ergometer**						
	No of groups	Age (years)	Gender (% female)	Weight (kg)	FEV_1 (L)	$\dot{V}O_2$peak ($mL.kg^{-1}.min^{-1}$)	Estimated workrate increments ($W.min^{-1}$)
COPD/Emphysema	170	64.8 (61.0; 67.0)	27.4 (7.4; 40.0)	71.0 (65.0; 75.0)	1.27 (1.02; 1.44)	15.6 (14.1; 17.2)	5.6 (3.6, 6.6)
Asthma	8	21.6 (11.6; 30.5)	52.3 (50.0; 52.6)	62.2 (43.5; 71.3)	2.19 (2.03; 2.48)	29.9 (23.5; 39.1)	12.6 (9.5, 17.3)
Interstitial lung disease	1	65.9	51.4	72.5	-	12.9	3.8
Pulmonary arterial hypertension	32	45.7 (38.0; 53.0)	62.3 (50.0; 76.7)	66.5 (58.0; 73.0)	2.27 (2.20; 2.40)	13.9 (11.6; 16.1)	3.5 (2.2, 4.4)
Cystic fibrosis	55	19.5 (14.3; 25.2)	44.5 (31.9; 54.2)	51.5 (44.2; 56.8)	2.52 (2.06; 2.71)	34.4 (30.2; 39.3)	13.7 (10.3, 16.4)
Sarcoidosis	1	38.0	-	75	4.03	27.6	16.5
Lung cancer	10	63.7 (62.0; 66.0)	35.8 (7.1; 40.0)	70.2 (69.0; 75.0)	2.10 (1.66; 2.20)	16.4 (16.4; 17.0)	7.3 (6.1; 8.3)
Patients undergoing LTx and LVRS or other thoracic surgeries	4	62.8 (44.3; 64.1)	12.9 (10.0; 16.1)	61.3 (54.7; 67.5)	2.10 (1.38; 3.03)	19.2 (19.2; 34.9)	6.2 (2.6, 12.8)
Other	8	56.9 (49.5; 57.7)	30.0 (16.7; 63.3)	76.8 (67.8; 85.4)	1.64 (1.17; 2.22)	16.0 (9.5; 22.6)	7.6 (2.4, 11.8)
Total	**308**						

Data are number, percent or median (interquartile range). COPD, chronic obstructive pulmonary disease; LTx, lung transplantation; LVRS, lung volume reduction surgery. Work rate increments for cycle CPET were calculated using equations by Wassermann et al. [31]: $\dot{V}O_2$peak (estimated from literature review data) minus estimated unloaded $\dot{V}O_2$ divided by 92.5. Workrate increments could not be estimated for the following diagnoses and/or respiratory conditions: Irradiation of the lung; Primary ciliary dyskinesia; Tuberculosis and unclear respiratory symptoms.

During the test

- Blood pressure each 2 min
- Look at the ECG for ST segment change (elevation or depression)
- Report BP, HR, SpO_2 and Borg each 2 min
- Cycling speed between 60 to 70 rpm
- Assess the ”comfort” of the patient
  - Sign of suffering, sign of altered state of consciousness, keep eyes open

At the end of the test

- Report BP, HR, SPO_2
- Borg
- Report the reason to stop

Recovery phase

- Last 2 to 3 min. Cycling unloaded at low rpm (30/min)
- Can last longer depending of the patient
- Useful for the security and to assess the speed of recovery after the test

Normal values

TABLE 17. SUGGESTED NORMAL GUIDELINES FOR INTERPRETATION OF CARDIOPULMONARY EXERCISE TESTING RESULTS*

Variables	Criteria of Normality
$\dot{V}O_2$max or $\dot{V}O_2$peak	> 84% predicted
Anaerobic threshold	> 40% $\dot{V}O_2$max predicted; wide range of normal (40–80%)
Heart rate (HR)	HRmax > 90% age predicted
Heart rate reserve (HRR)	HRR < 15 beats/min
Blood pressure	< 220/90
O_2 pulse ($\dot{V}O_2$/HR)	> 80%
Ventilatory reserve (VR)	MVV − $\dot{V}$Emax: > 11 L or $\dot{V}$Emax/MVV × 100: < 85%. Wide normal range: 72 ± 15%
Respiratory frequency (f_R)	< 60 breaths/min
$\dot{V}_E/\dot{V}CO_2$ (at AT)	< 34
V_D/V_T	< 0.28; < 0.30 for age > 40 years
Pa_{O_2}	> 80 mm Hg
$P(A–a)O_2$	< 35 mm Hg

Adapted by permission from References 1, 3, 43, 235, 292, and 545.
* Maximum or peak cardiopulmonary responses except for anaerobic threshold and $\dot{V}_E/\dot{V}CO_2$ at AT.

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Criteria of maximal effort – ERS 2019

Variables	Cycling - treadmill
VO2 peak	Change in VO2 of < 2,1 mL/min/kg between consecutive stages (<150mL/min)
VEpeak/MVV %	≥ 85
Inspiratory capacity (IC)	Decrease in IC > 150 mL during exercise
RER (QR)	> 1,05
HR peak % pred ou bpm	≥ 100% predicted
VO2 peak % pred	≥ 100% predicted
Work predicted	≥ 100% predicted
Blood lactate	Post exercise blood lactate ≥ 8 mmol/L
Borg	7-10

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Criteria of maximal effort – ATS/ACCP 2003

Variables	Cycling - treadmill
Plateau VO2	Change in VO2 of < 2,1 mL/min/kg between consecutive stages
Predicted peak VO2	≥ 100% pred
Predicted maximal work rate	≥ 100% pred
Predicted maximal heart rate	≥ 100% pred
Predicted VE peak	≥ 85 % pred
RER	> 1,15
Borg	9-10/10

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TABLE 9. INDICATIONS FOR EXERCISE TERMINATION

Chest pain suggestive of ischemia
Ischemic ECG changes
Complex ectopy
Second or third degree heart block
Fall in systolic pressure > 20 mm Hg from the highest value during the test
Hypertension (> 250 mm Hg systolic; > 120 mm Hg diastolic)
Severe desaturation: $Sp_{O_2} \leq 80\%$ when accompanied by symptoms and signs of severe hypoxemia
Sudden pallor
Loss of coordination
Mental confusion
Dizziness or faintness
Signs of respiratory failure

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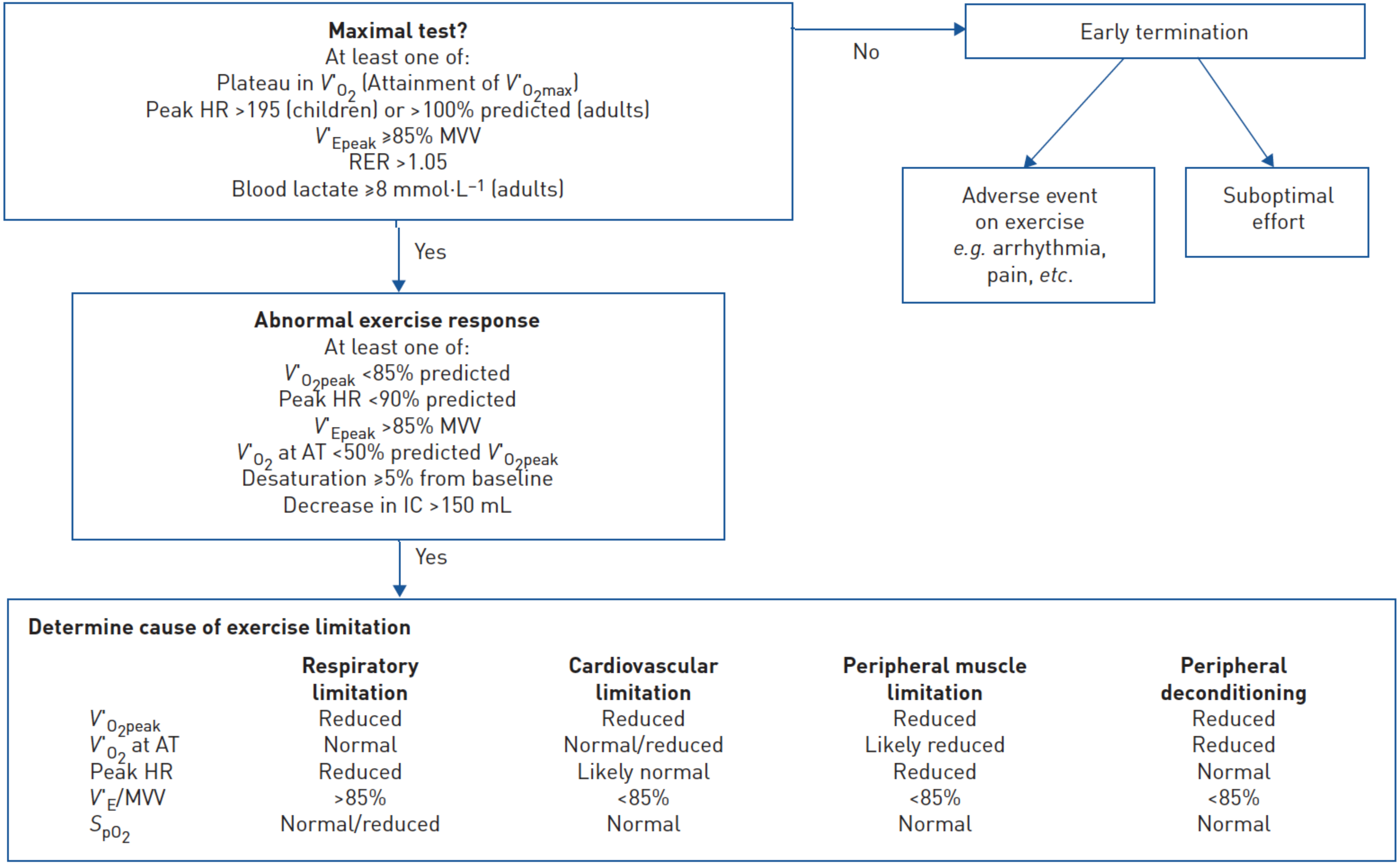
Reasons for reduced exercise tolerance

- Cardiovascular
- Ventilatory
- Gas exchange
- Musculoskeletal
- Deconditioning– obesity
- Sub-maximal effort


Maximal test?
At least one of:
Plateau in V'_{O_2} (Attainment of V'_{O_2max})
Peak HR >195 (children) or >100% predicted (adults)
V'_{Epeak} ≥85% MVV
RER >1.05
Blood lactate ≥8 mmol·L^{-1} (adults)
No
Early termination
Adverse event on exercise e.g. arrhythmia, pain, etc.
Suboptimal effort
Yes
Abnormal exercise response
At least one of:
V'_{O_2peak} <85% predicted
Peak HR <90% predicted
V'_{Epeak} >85% MVV
V'_{O_2} at AT <50% predicted V'_{O_2peak}
Desaturation ≥5% from baseline
Decrease in IC >150 mL
Yes
Determine cause of exercise limitation
Respiratory limitation
Cardiovascular limitation
Peripheral muscle limitation
Peripheral deconditioning
V'_{O_2peak}: Reduced; Reduced; Reduced; Reduced
V'_{O_2} at AT: Normal; Normal/reduced; Likely reduced; Reduced
Peak HR: Reduced; Likely normal; Reduced; Normal
V'_E/MVV: >85%; <85%; <85%; <85%
S_{pO_2}: Normal/reduced; Normal; Normal; Normal

Vo_2/W slope

- 8, 5 to 11 mL/min/W

- If too high= upper limb activity or bad calibration
- If too low = oxygen transport is affect
  - Heart, lung, circulation

Anaerobic threshold/ventilatory threshold

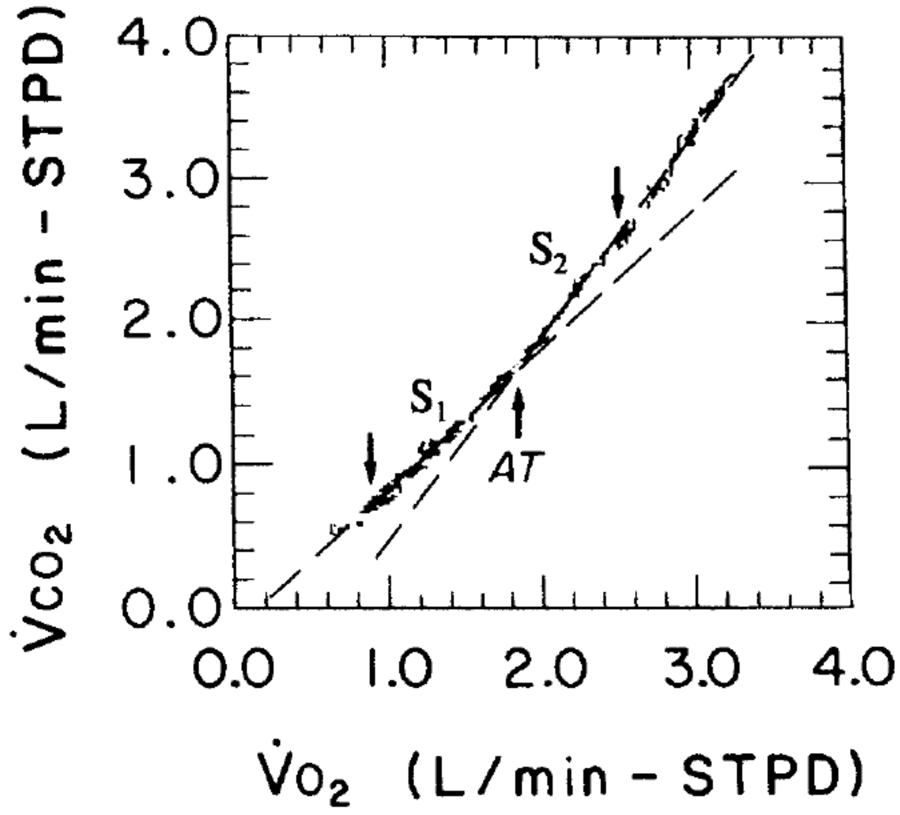
- The moment where the exercise start to be anaerobic
- Respiratory compensation for metabolic acidosis
- Effort is getting harder
- Why is it useful?
  - To help understand the cause of exercise limitation
  - To target the best level of training to increase physical capacity

How to determine it?

- Invasive method
  - Blood lactate
- Non-invasive method
  - V-slope
  - Ventilatory equivalent (VE/VO2 and VE/VCO2)
  - VE and PetCO2
  - RER

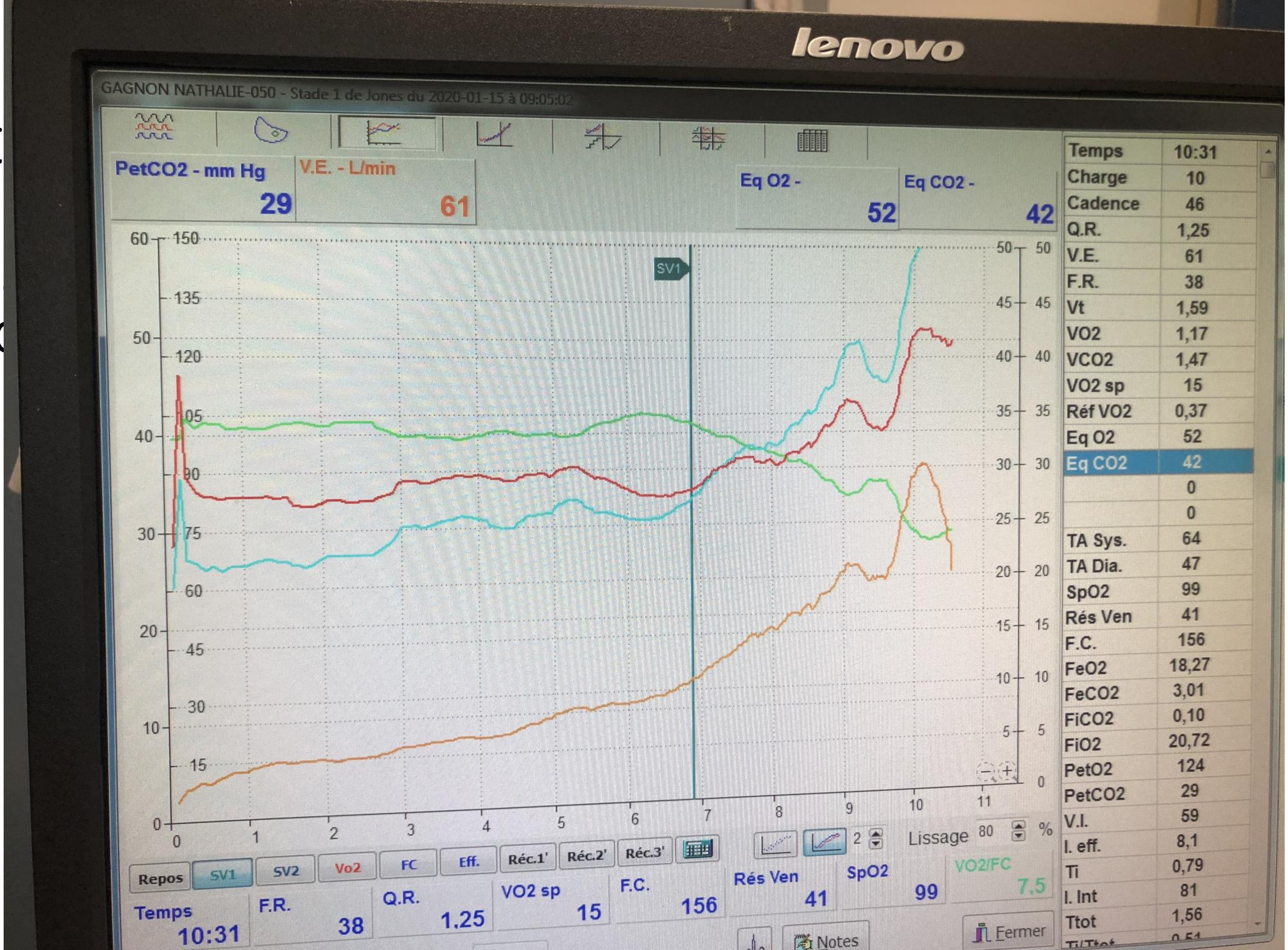
V-slope

- Inflection point in the VCO2 vs. VO2 curve



Vent

- Mom
  VE/VC



Ven

PetCO2 - mm Hg
41
V.E. - L/min
33
VO2 - L/min
1,20
VCO2 - L/min
1,16
SV1
Temps 06:50
Charge 90
Cadence 63
Q.R. 0,97
V.E. 33
F.R. 21
Vt 1,60
VO2 1,20
VCO2 1,16
VO2 sp 16
Réf VO2 1,17
Eq O2 27
Eq CO2 28
0
0
TA Sys. 109
TA Dia. 74
SpO2 97
Rés Ven 69
F.C. 114
FeO2 16,38
FeCO2 4,37
FiCO2 0,07
FiO2 20,81
PetO2 107
PetCO2 41
V.I. 31
I. eff. 0,3
Ti 1,21
I. Int 31
Ttot 2,95
Repos
SV1
SV2
Vo2
FC
Eff.
Réc.1'
Réc.2'
Réc.3'
Lissage 80 %
Temps 06:50
F.R. 21
Q.R. 0.97
VO2 sp 16
F.C. 114
Rés Ven 69
SpO2 97
VO2/FC 10.5
Vents
Pause
Notes
Fermer

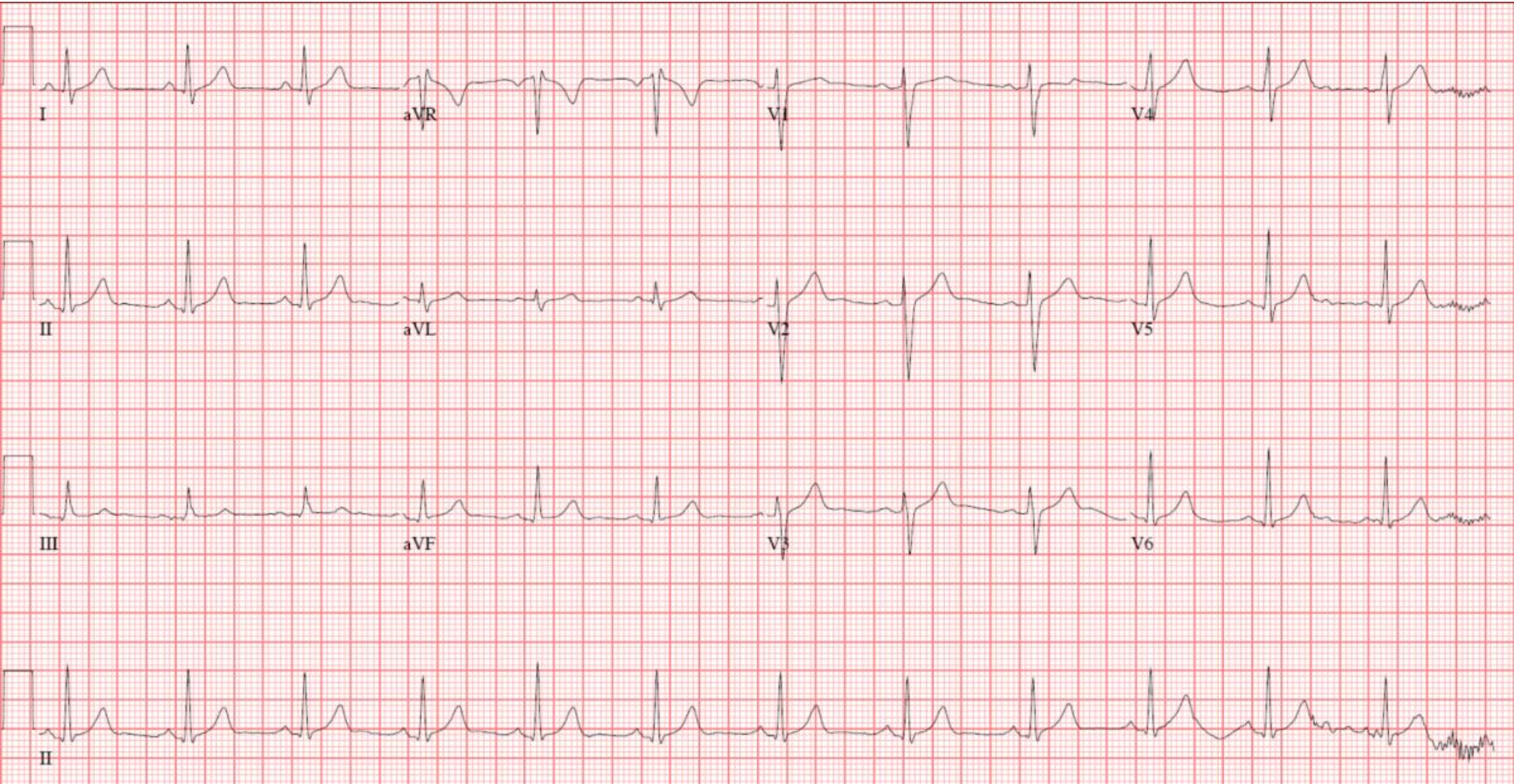
RER

- Arour


PetCO2 - mm Hg
41
V.E. - L/min
33
VO2 - L/min
1,20
VCO2 - L/min
1,16
SV1
Temps 06:50
Charge 90
Cadence 63
Q.R. 0,97
V.E. 33
F.R. 21
Vt 1,60
VO2 1,20
VCO2 1,16
VO2 sp 16
Réf VO2 1,17
Eq O2 27
Eq CO2 28
0
0
TA Sys. 109
TA Dia. 74
SpO2 97
Rés Ven 69
F.C. 114
FeO2 16,38
FeCO2 4,37
FiCO2 0,07
FiO2 20,81
PetO2 107
PetCO2 41
V.I. 31
I. eff. 0,3
Ti 1,21
I. Int 31
Ttot 2,95
Repos
SV1
SV2
Vo2
FC
Eff.
Réc.1'
Réc.2'
Réc.3'
Lissage 80 %
Temps 06:50
F.R. 21
Q.R. 0.97
VO2 sp 16
F.C. 114
Rés Ven 69
SpO2 97
VO2/FC 10.5
Vems
Pause
Notes
Fermer

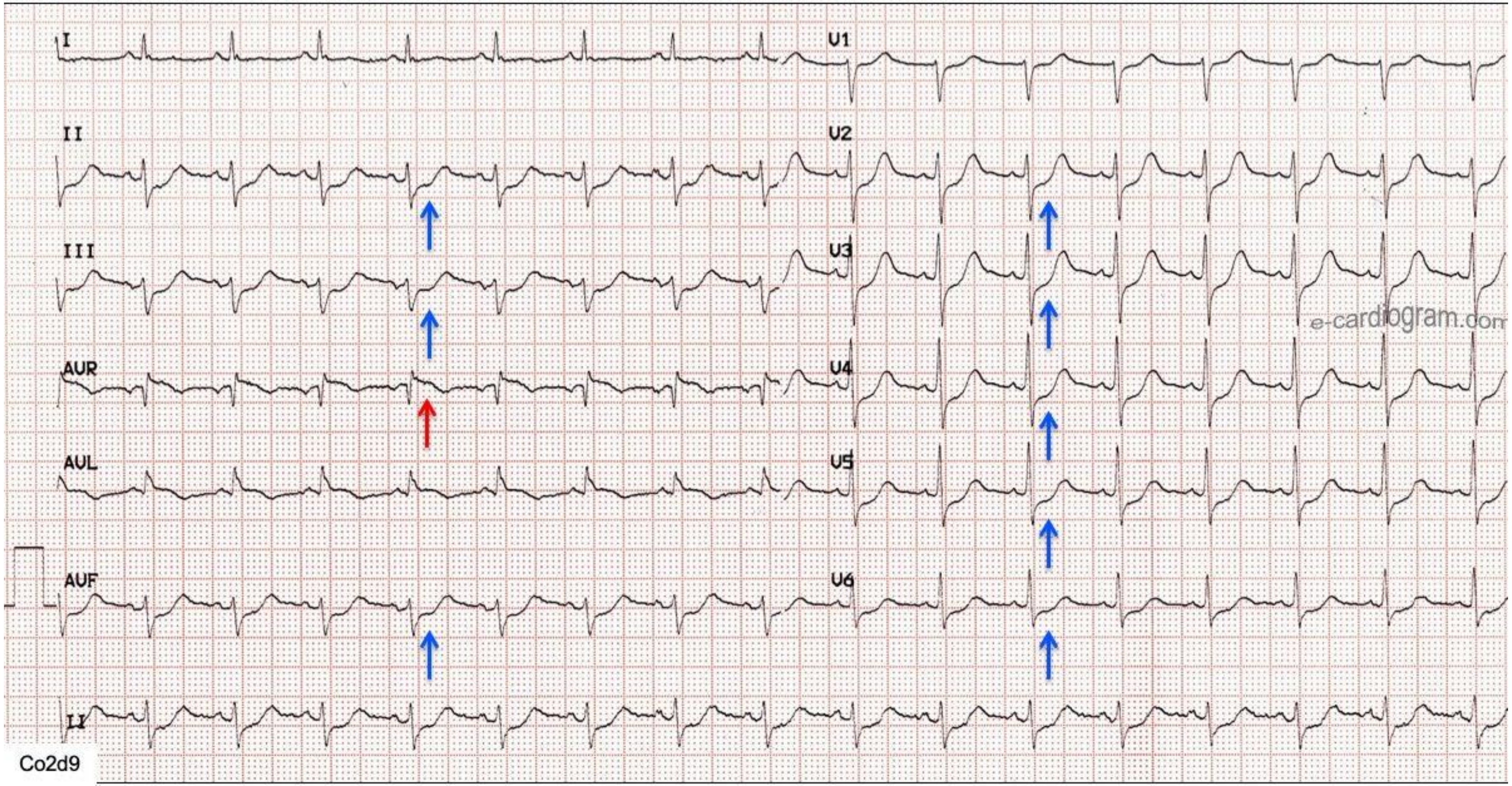
ECG - anomalies

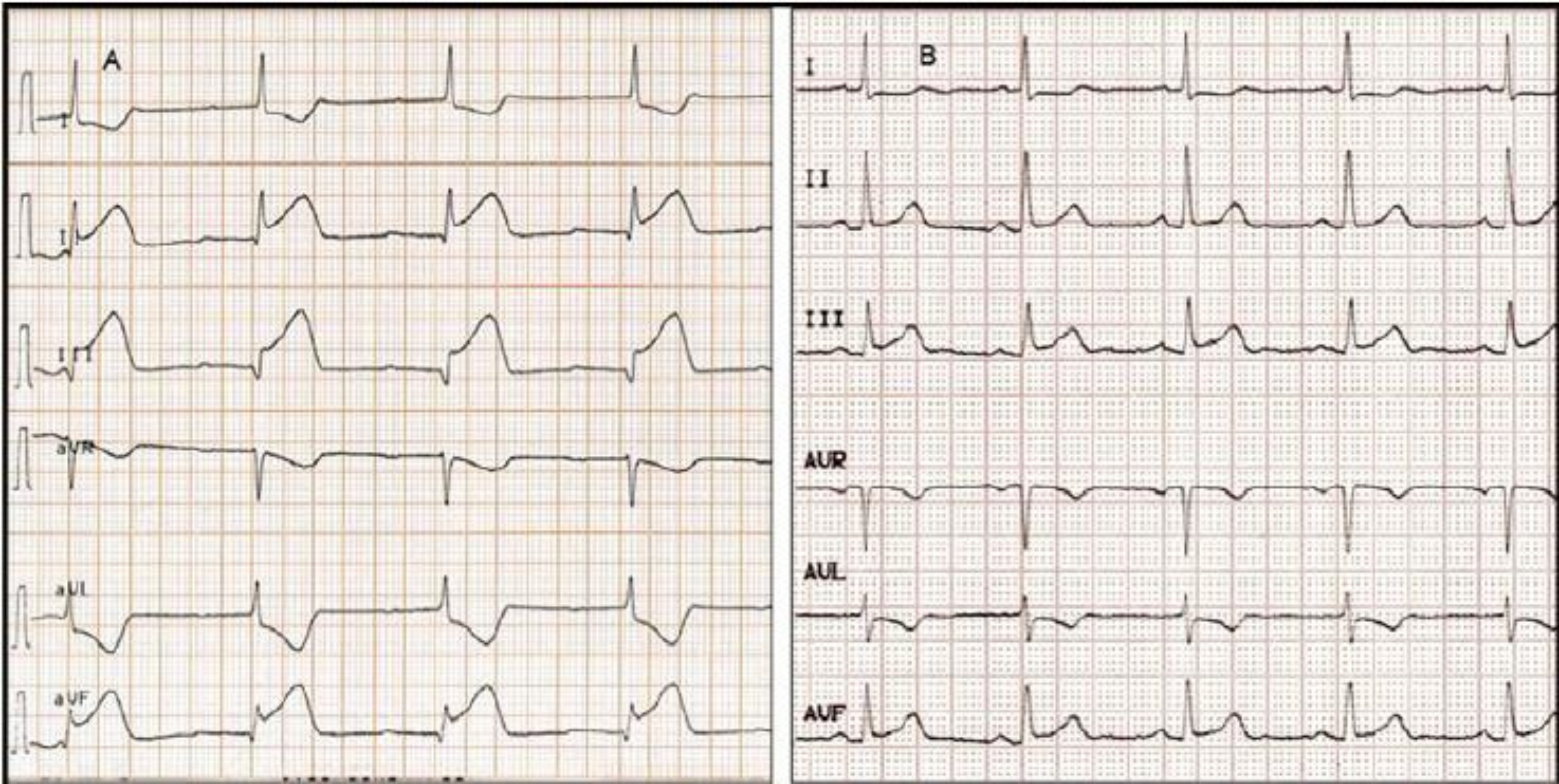
- Decrease in ST segment
  - During exercise or during recovery phase
  - 1,5 to 2 mm
- Increase in ST segment
- Arrythmia
- Important: the test should be stopped if chest pain, altered level of consciousness and dizziness

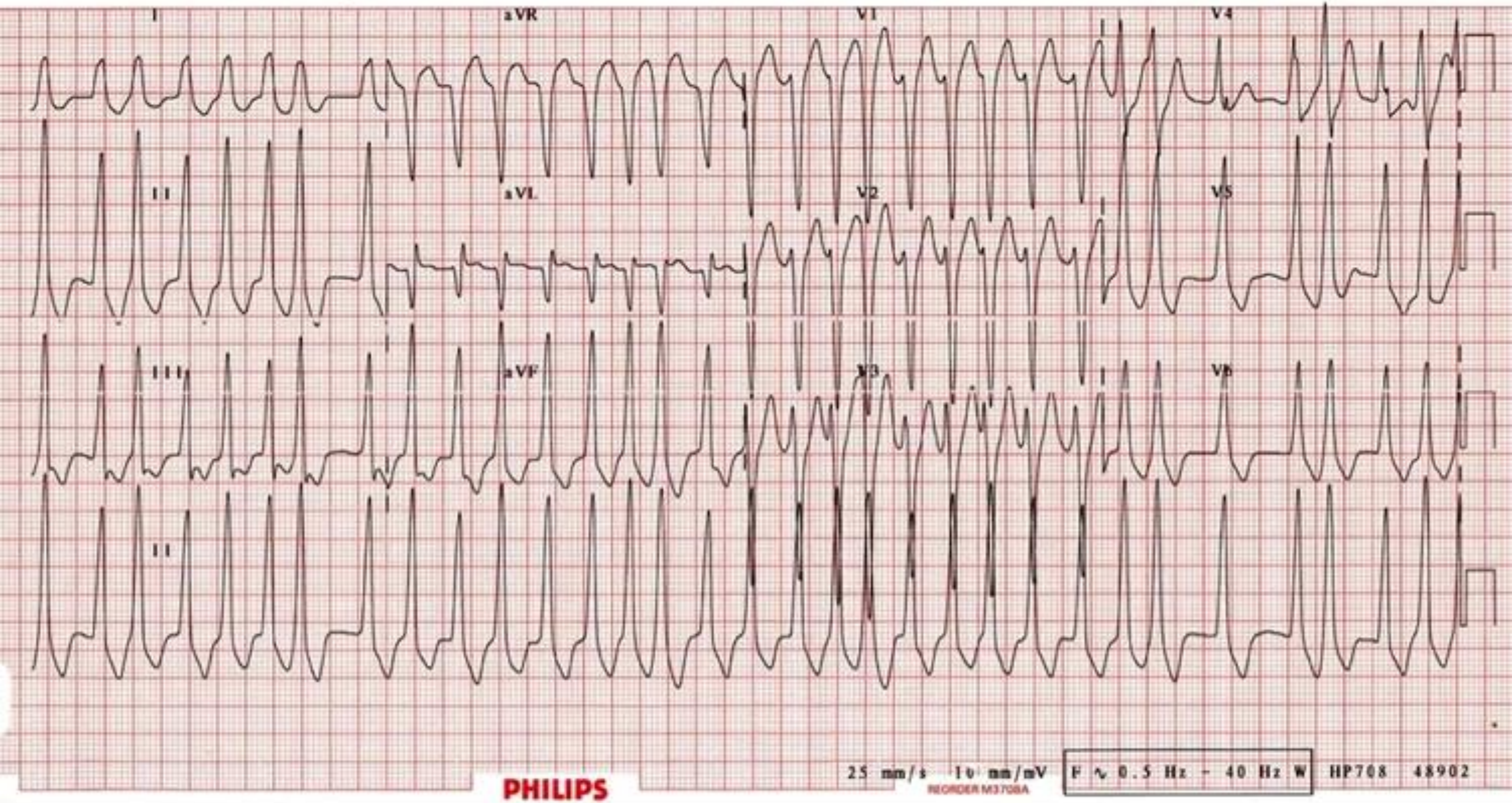

I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II

Sous-décalage de ST
SCA à haut risque

ST- dans 8 dérivations et ST+ en aVR
= lésions tritronculaires, IVA proximale ou tronc commun




A
I
II
III
aVR
aVL
aVF
B
I
II
III
AVR
AVL
AVF


I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
II
25 mm/s 10 mm/mV
F ~ 0.5 Hz - 40 Hz W
HP708 48902
PHILIPS
REORDER M3708A

Risk of CPET in general population

- Risk of death < 0,00002%

Risk of heart event with CPET in a known heart disease population

- 0,16%
  - Mostly related to VT (6/8 events in 5060 tests)
- No death

Circulation. 2012 Nov 20;126(21):2465-72. doi: 10.1161/CIRCULATIONAHA.112.110460. Epub 2012 Oct 22.

CPET interpretation

TABLE 16. INTEGRATIVE APPROACH TO THE INTERPRETATION OF CARDIOPULMONARY EXERCISE TESTING RESULTS

1. Determine reason(s) for CPET
2. Review pertinent clinical and laboratory information (clinical status)
3. Note overall quality of test, assessment of subject effort, and reasons for exercise cessation
4. Identify key variables: initially $\dot{V}O_2$, and then HR, $\dot{V}E$, Sa_{O_2}, and other measurements subsequently
5. Use tabular and graphic presentation of the data
6. Pay attention to trending phenomena: submaximal through maximal responses
7. Compare exercise responses with appropriate reference values
8. Evaluate exercise limitation: physiologic versus nonphysiologic
9. Establish patterns of exercise responses
10. Consider what conditions/clinical entities may be associated with these patterns
11. Correlate CPET results with clinical status
12. Generate CPET report

Definition of abbreviations: CPET = cardiopulmonary exercise testing; HR = heart rate; Sa_{O_2} = arterial oxygen saturation; $\dot{V}E$ = minute ventilation; $\dot{V}O_2$ = oxygen uptake.

Adapted by permission from Reference 1.

CPET report

- 4 sections
  - Patient information
  - Technical details
  - Exercise response
    - Aerobic capacity
    - Cardiovascular
    - Ventilatory
    - Gas exchange
    - Metabolic
  - Summary

Cardiopulmonary Exercise Test Summary Report

Hospital Name:	Department:
Patient's Surname:	Test Date:
Patient's Name:	Type of ergometer and metabolic cart:
DOB:	Reason for referral:
Consultant:	Clinical Diagnosis:
Indication(s) for conducting the test	

TECHNICAL

Protocol:
Describe exercise protocol employed, work increment as a function of time and total incremental exercise duration.

Technical Comments:
Review criteria outlined on Figure 3 to establish whether the test has led to the limit of tolerance. Report the source of equation used to express physiological variables as a fraction of predicted normal values.

Reason for termination of test:
Report the reason(s) indicated by the patient for terminating the test (breathlessness, leg discomfort or both). Indicate whether the patient complied well with the incremental effort or claimed discomfort with the exercise or breathing apparatus as a contributing factor to exercise limitation.

EXERCISE RESPONSE

Aerobic Capacity/Anaerobic Threshold*:
A peak VO_2 of …. $mL.min^{-1}.kg^{-1}$ (…% predicted normal) was achieved along with a peak workload of …. Watts (…% predicted normal) *or peak speed of … $km.h^{-1}$.* Anaerobic threshold (AT) occurred at …. $mL.min^{-1}.kg^{-1}$ (…% predicted VO_2 max. Corresponding values were …. METs at AT and …. METs at the limit of tolerance. Indicate whether VO_2/work rate slope (…. $mL.min^{-1}.Watt^{-1}$) was within the normal range.

Cardiovascular response:
Peak HR was …. $beats.min^{-1}$ (% predicted normal). Indicate any abnormalities detected by the ECG recordings and report systolic and diastolic BP at the limit of tolerance. Conclude if cardiovascular response was normal.

Ventilatory response:
Peak VE was …. $L.min^{-1}$ (…% MVV)**. Report the change from baseline in inspiratory capacity (delta IC = …. mL). Report shortness of breath score ………. Conclude whether exercise limitation was of ventilatory origin.

Gas exchange:
Report ventilatory equivalents for VO_2 and VCO_2 at AT and at peak exercise. Report resting and peak SpO_2. Report the VE/VCO_2 slope values. Conclude whether gas exchange response to exercise was normal.

Metabolic:
RER values were …. at rest, …. at AT and …. at the limit of tolerance.

SUMMARY

Conclusion: Comment on patient's effort and exercise capacity taking into consideration peak values for work rate, *speed*, VO2 and AT. Comment on potential ventilatory, cardiovascular or peripheral muscle limitation or simply poor effort.

Compare the results with previous tests on the same patient and indicate when the test should be repeated.

Sample of the **Cardio Pulmonary Exercise Test (CPET)**

Example of type of chart that will be used to provide tabular results:

Variable	Rest	Peak	% Predicted Max
Work (Watts)			
VO_2 (L/min)			
HR (b/min)			
O_2 pulse (ml/beat)			
VE (L/min)			
RR (b/min)			
VT (L)			
SpO_2 (%)			
$P_{ET}CO_2$ (mmHg)			
VD/VT			
SBP (mmHg)			
DBP (mmHg)			
Borg (dyspnea/leg)			

CPET: Graphic Plots to be displayed for interpretation:
9-panel graphic array as described by Wasserman (reference: Wasserman K. CHEST 1997; 112:1091-1101.) will be shown for CPET questions.

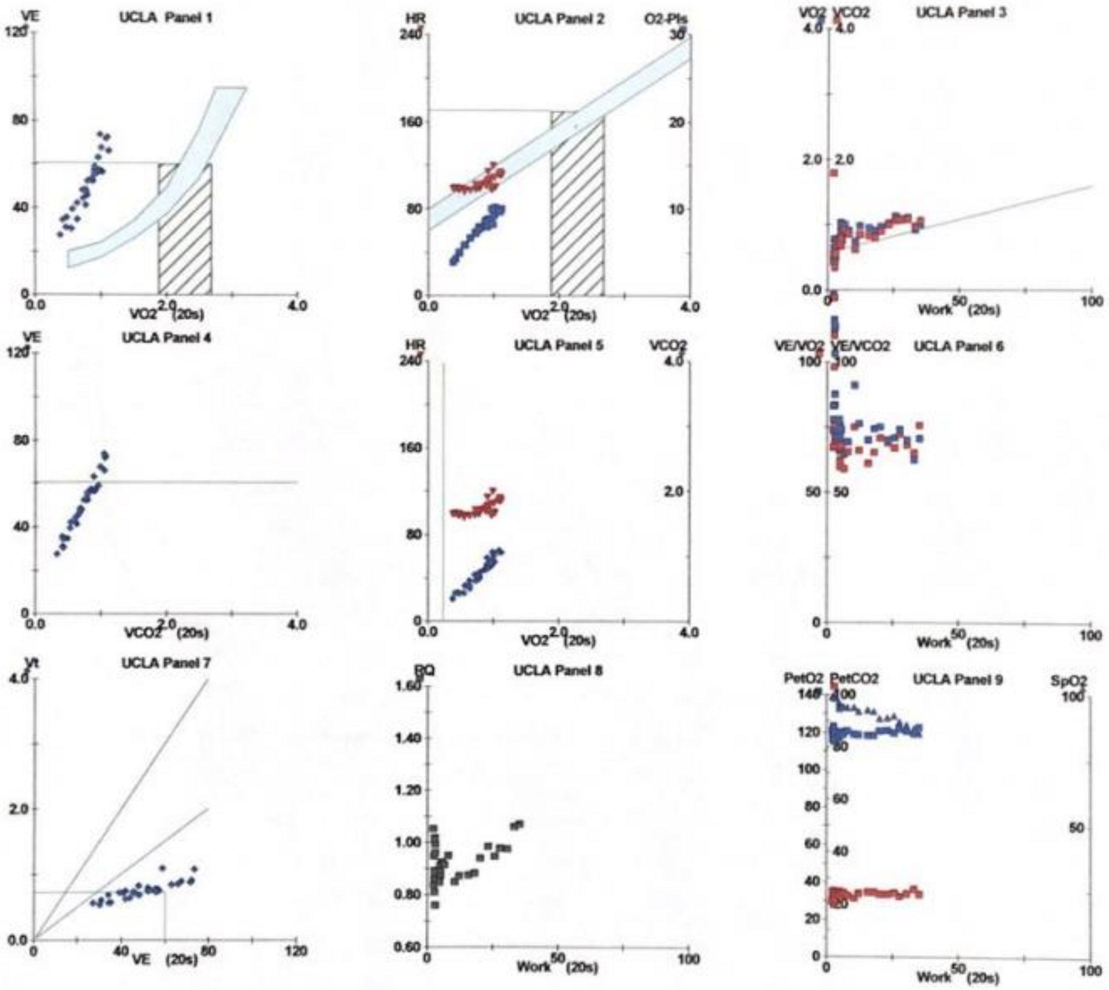
Graphic plots will include the following:

VE vs. W; HR and VO2/HR vs. W; VO2 and VCO2 vs. W; VE vs. VCO2; HR vs. VO2; VE/VO2 and VE/VCO2 vs. W; VT vs. VE; R vs. W; PO2 and PCO2 vs. W

CardioPulmonary Exercise Graphs: 9-Plot

Age: 60
Gender: Male

Height(cm): 174
Weight(kg): 71.0



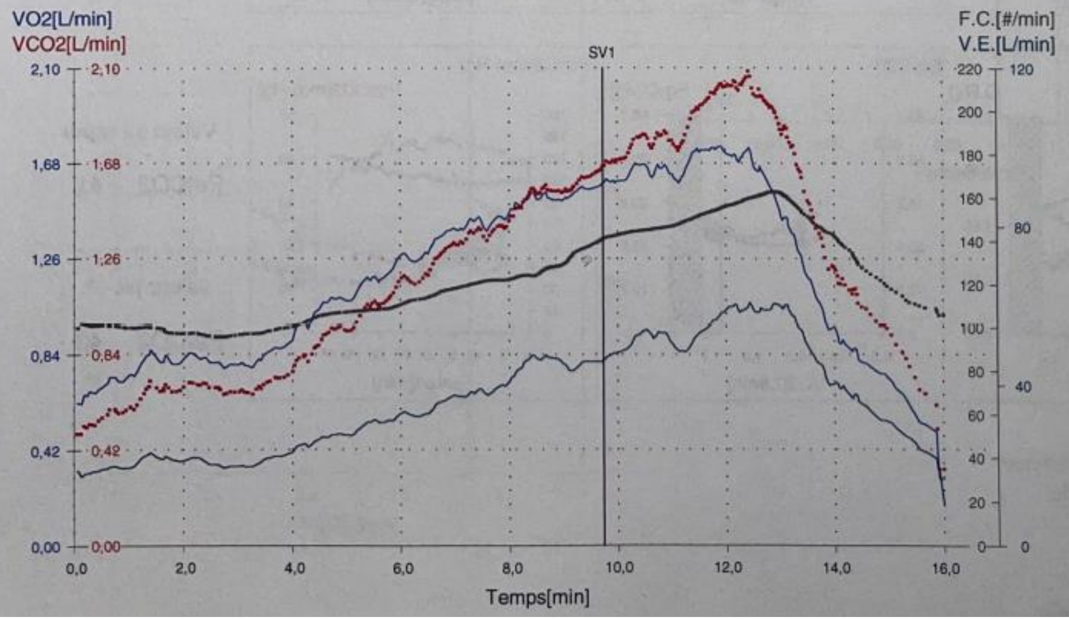
Case 1

- F 56 years old
- PMH
  - Asthma
  - No smoking
  - Work accident
    - Foot injury and shoulder injury
      - Away from regular physical activity for five years
      - Before, was able to do a lot of sports like hiking, biking at a good rythm
  - About 60 pounds of weigth gain
- Concern about effort dyspnea

Case 1

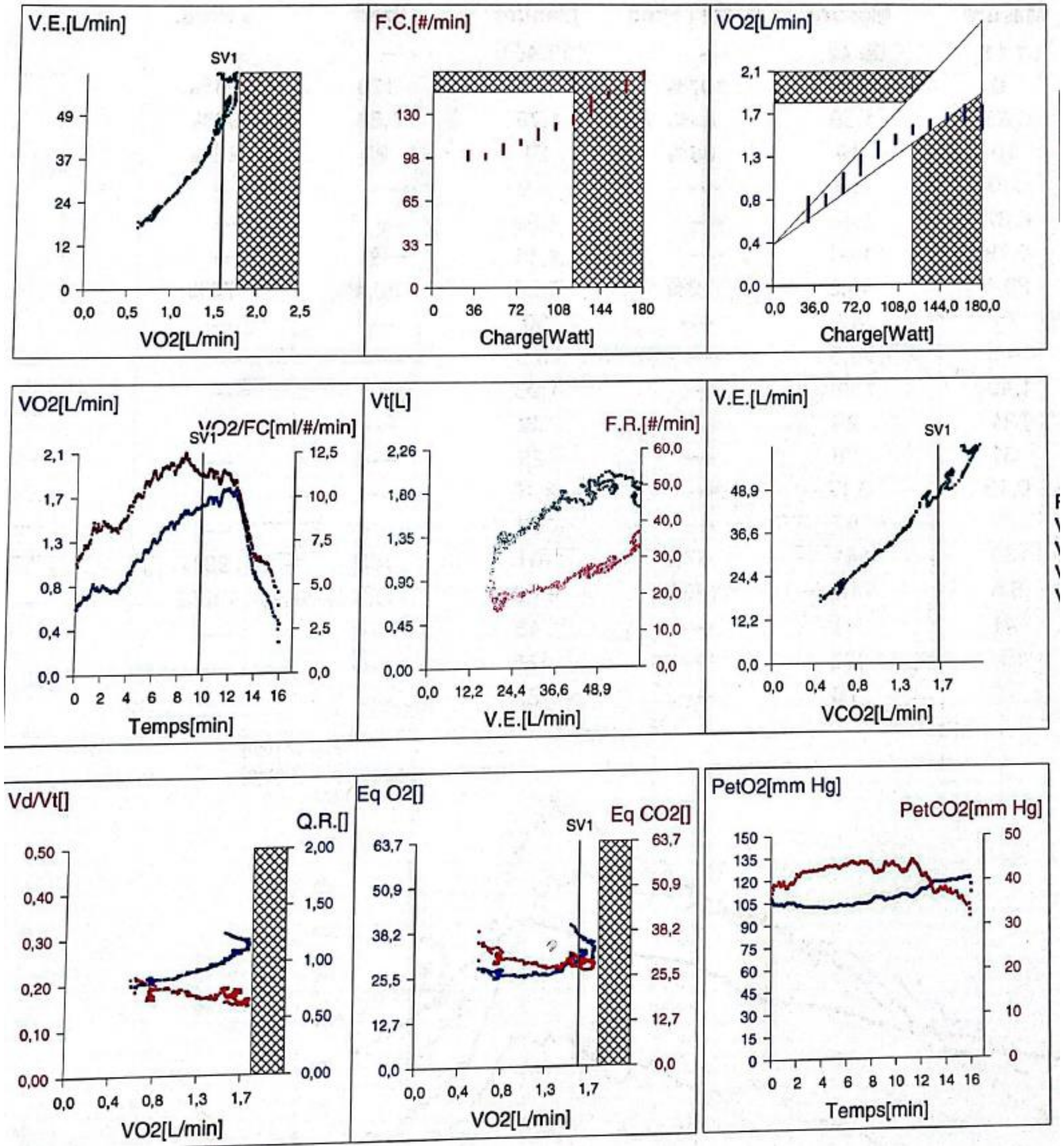
Reason for stopping
Borg dyspnea: 7/10
Legs:6/10

		Repos Mesuré	SV 1 Mesuré	SV 1 % Max Préd	Vo2 max Mesuré	Vo2 max Préd.	Vo2 max % Préd.
Temps	min	01:11	09:44	----	11:45	----	----
Charge	**Watt**	0	135	**107%**	165	126	131%
VO2	**L/min**	0,86	1,59	**85%**	1,75	1,88	93%
VO2 sp	**ml/kg**	10	19	**85%**	21	22	93%
Met		2,9	5,4	----	5,9	----	----
VCO2	**L/min**	0,67	1,66	----	1,99	----	----
Q.R.		0,78	1,04	----	1,14	----	----
V.E.	**L/min**	20,4	46,5	**58%**	56,6	80,4	70%
Rés Ven	**%**	75	42	----	30	----	----
F.R.	**#/min**	14,6	24,5	----	29,5	----	----
Vt	**L**	1,40	1,93	----	1,96	----	----
Eq O2		24	29	----	32	----	----
Eq CO2		31	28	----	29	----	----
Vd/Vt		0,18	0,17	----	0,16	----	----
SpO2	**%**	96	97	----	94	----	----
F.C.	**#/min**	100	141	87%	161	163	99%
VO2/FC	**ml/#/min**	8,6	11,3	135%	11,3	8,3	136%
PetCO2	**mm Hg**	41	44	----	43	----	----
TA Sys.	**mm Hg**	154	173	----	185	----	----
TA Dia.	**mm Hg**	70	78	----	83	----	----



Case 1

VO2/w = 9ml/min/kg



Case 1

- Maximal effort
- Normal aerobic capacity
- No limitation

- Normal study

Case 2

- M 51 years old
- PMH
  - Nothing
- History
  - Has a new girlfriend
  - Difficulty to follow her when hiking
  - Concern about effort dyspnea
  - Not doing regular physical activity

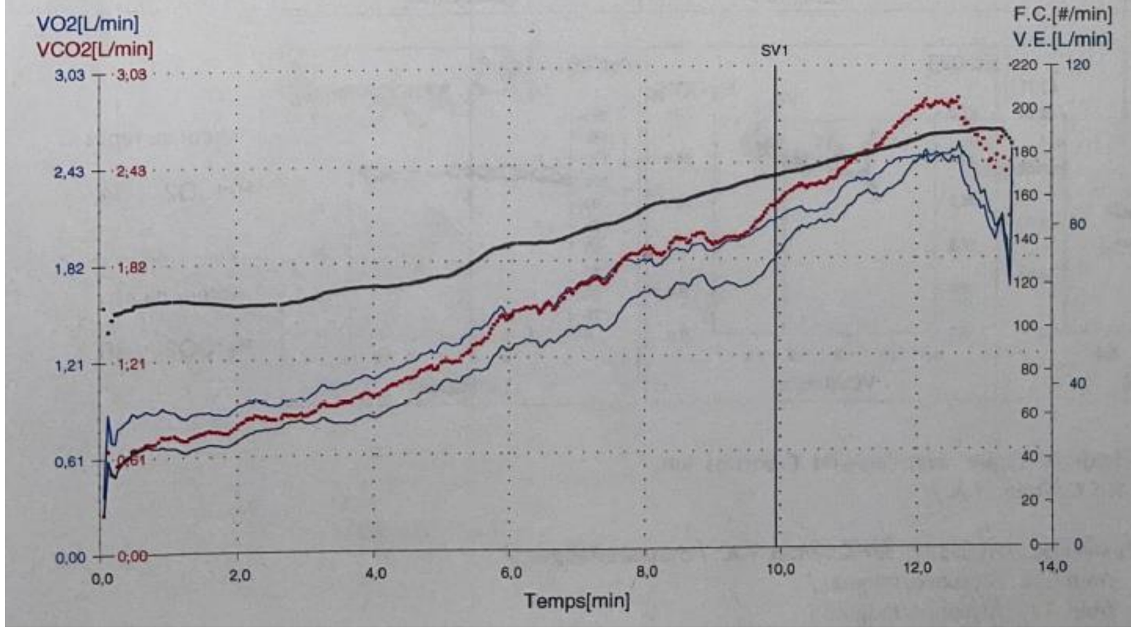
Case 2

H 51 ans
BMI 33,3

Reason for stopping
Borg dyspnea: 5/10
Legs 4/10

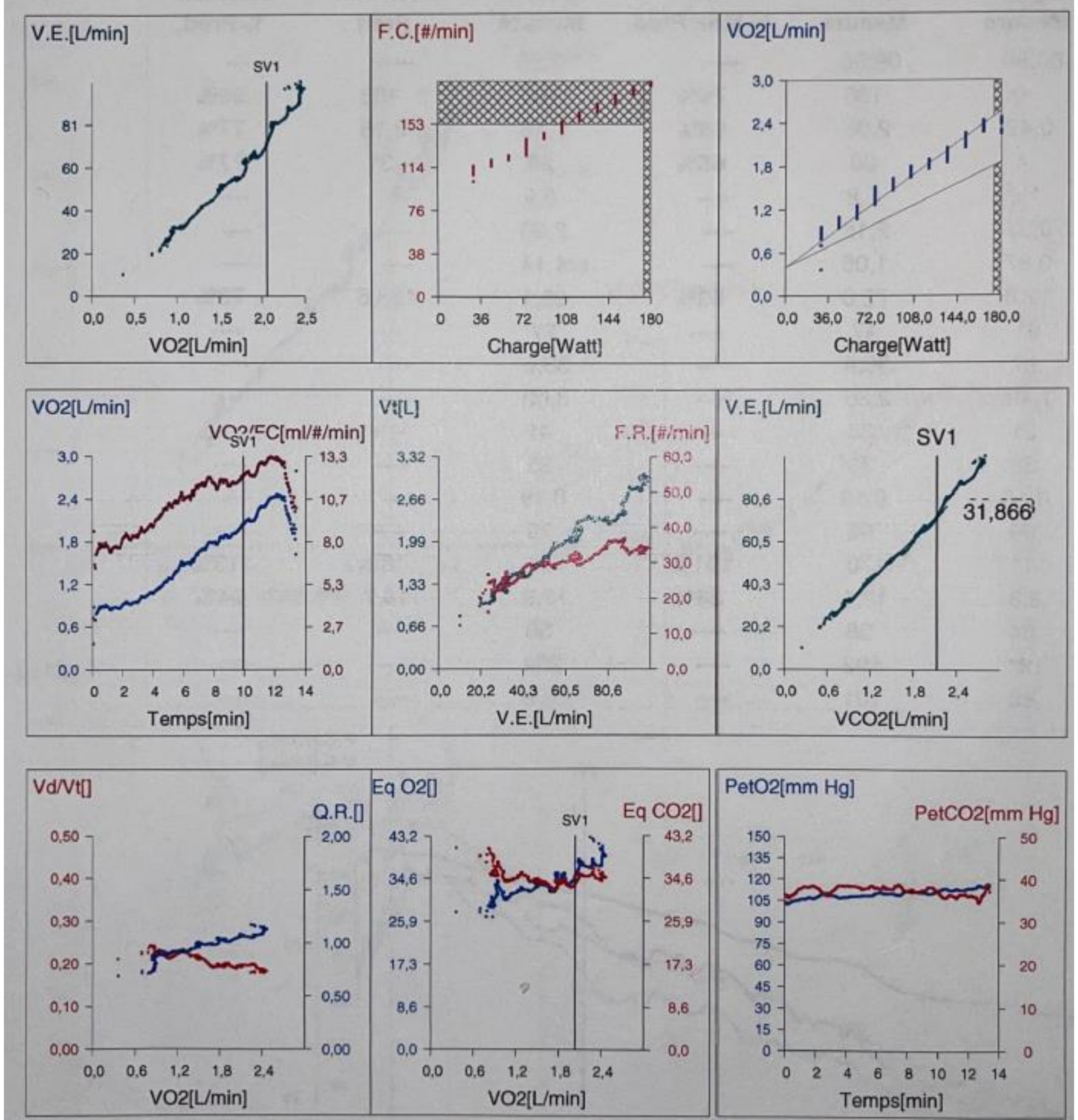
SpO2 not reliable at the end

		Repos Mesuré	SV 1 Mesuré	SV 1 % Max Préd	Vo2 max Mesuré	Vo2 max Préd.	Vo2 max % Préd.
Temps	min	00:58	09:56	----	12:36	----	----
Charge	Watt	0	135	74%	180	183	98%
VO2	L/min	0,42	2,06	65%	2,45	3,18	77%
VO2 sp	ml/kg	4	20	65%	24	31	77%
Met		1,2	5,8	----	6,9	----	----
VCO2	L/min	0,37	2,15	----	2,80	----	----
Q.R.		0,87	1,05	----	1,14	----	----
V.E.	L/min	12,8	72,0	53%	99,1	136,6	73%
Rés Ven	%	91	47	----	27	----	----
F.R.	#/min	8,7	30,9	----	33,6	----	----
Vt	L	1,48	2,35	----	3,00	----	----
Eq O2		31	35	----	41	----	----
Eq CO2		35	33	----	35	----	----
Vd/Vt		0,16	0,19	----	0,19	----	----
SpO2	%	96	96	----	79	----	----
F.C.	#/min	111	170	101%	191	169	113%
VO2/FC	ml/#/min	3,8	12,1	88%	12,9	13,7	94%
PetCO2	mm Hg	34	38	----	36	----	----
TA Sys.	mm Hg	131	192	----	204	----	----
TA Dia.	mm Hg	88	101	----	106	----	----



Case 2

VO2/W=
8,7
mL/min/kg



Case 2

- Maximal effort
- Decrease aerobic capacity
- No respiratory limitation
- No cardiac limitation

- Deconditioning

Case 3

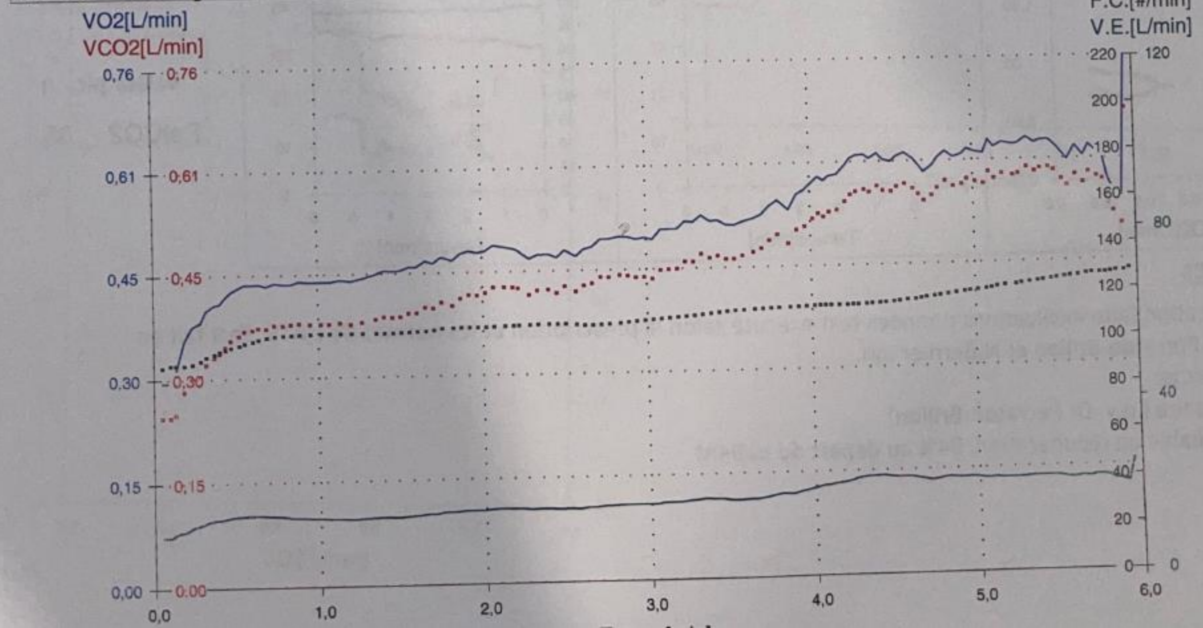
- M 64 years old
- PMH
  - Nothing
- History
  - Concern about breathlessness

Case 3

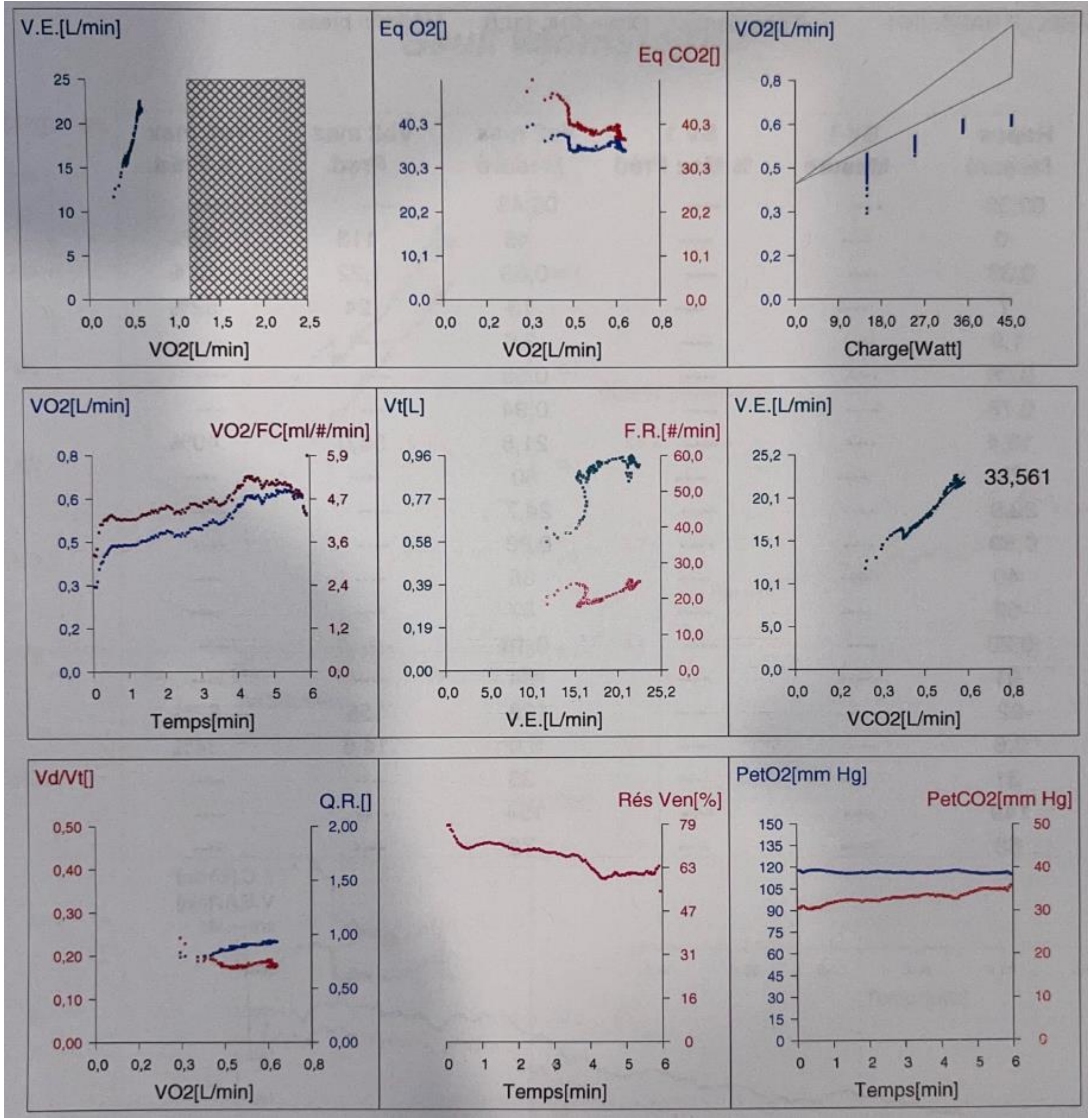
M 64 yo
BMI 20,7

EOT
dyspnea
5/10
Legs 5/10

		Repos Mesuré	SV 1 Mesuré	SV 1 % Max Préd	Vo2 max Mesuré	Vo2 max Préd.	Vo2 max % Préd.
Temps	min	02:30	----	----	05:43	----	----
Charge	Watt	0	----	----	45	113	40%
VO2	L/min	0,33	----	----	0,63	1,22	52%
VO2 sp	ml/kg	7	----	----	13	24	52%
Met		1,9	----	----	3,6	----	----
VCO2	L/min	0,26	----	----	0,59	----	----
Q.R.		0,78	----	----	0,94	----	----
V.E.	L/min	13,4	----	----	21,8	55,0	40%
Rés Ven	%	76	----	----	60	----	----
F.R.	#/min	22,9	----	----	24,7	----	----
Vt	L	0,59	----	----	0,88	----	----
Eq O2		40	----	----	35	----	----
Eq CO2		52	----	----	37	----	----
Vd/Vt		0,23	----	----	0,18	----	----
SpO2	%	91	----	----	84	----	----
F.C.	#/min	92	----	----	128	155	82%
VO2/FC	ml/#/min	3,6	----	----	5,0	14,6	34%
PetCO2	mm Hg	31	----	----	35	----	----
TA Sys.	mm Hg	149	----	----	154	----	----
TA Dia.	mm Hg	68	----	----	78	----	----



Case 3



V.E.[L/min]
VO2[L/min]
Eq O2[]
Eq CO2[]
VO2[L/min]
VO2[L/min]
Charge[Watt]
VO2[L/min]
VO2/FC[ml/#/min]
Temps[min]
Vt[L]
F.R.[#/min]
V.E.[L/min]
V.E.[L/min]
33,561
VCO2[L/min]
Vd/Vt[]
Q.R.[]
VO2[L/min]
Rés Ven[%]
Temps[min]
PetO2[mm Hg]
PetCO2[mm Hg]
Temps[min]

Case 3

- Sub-maximal

Case 4

- M 50 years old
- CAD, cardiac insufficiency EFLV 40%
- mMRC 2/4
- PFT N except DLCO 60%
- Taking bisoprolol

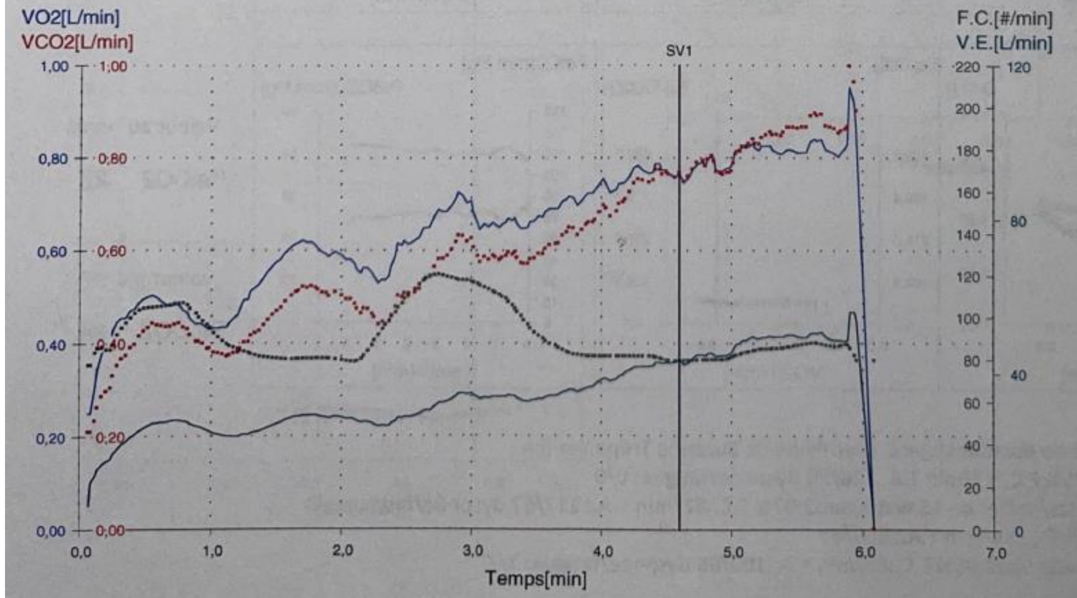
Case 4

M 50 ans
BMI 31,2
169 cm
89 kg

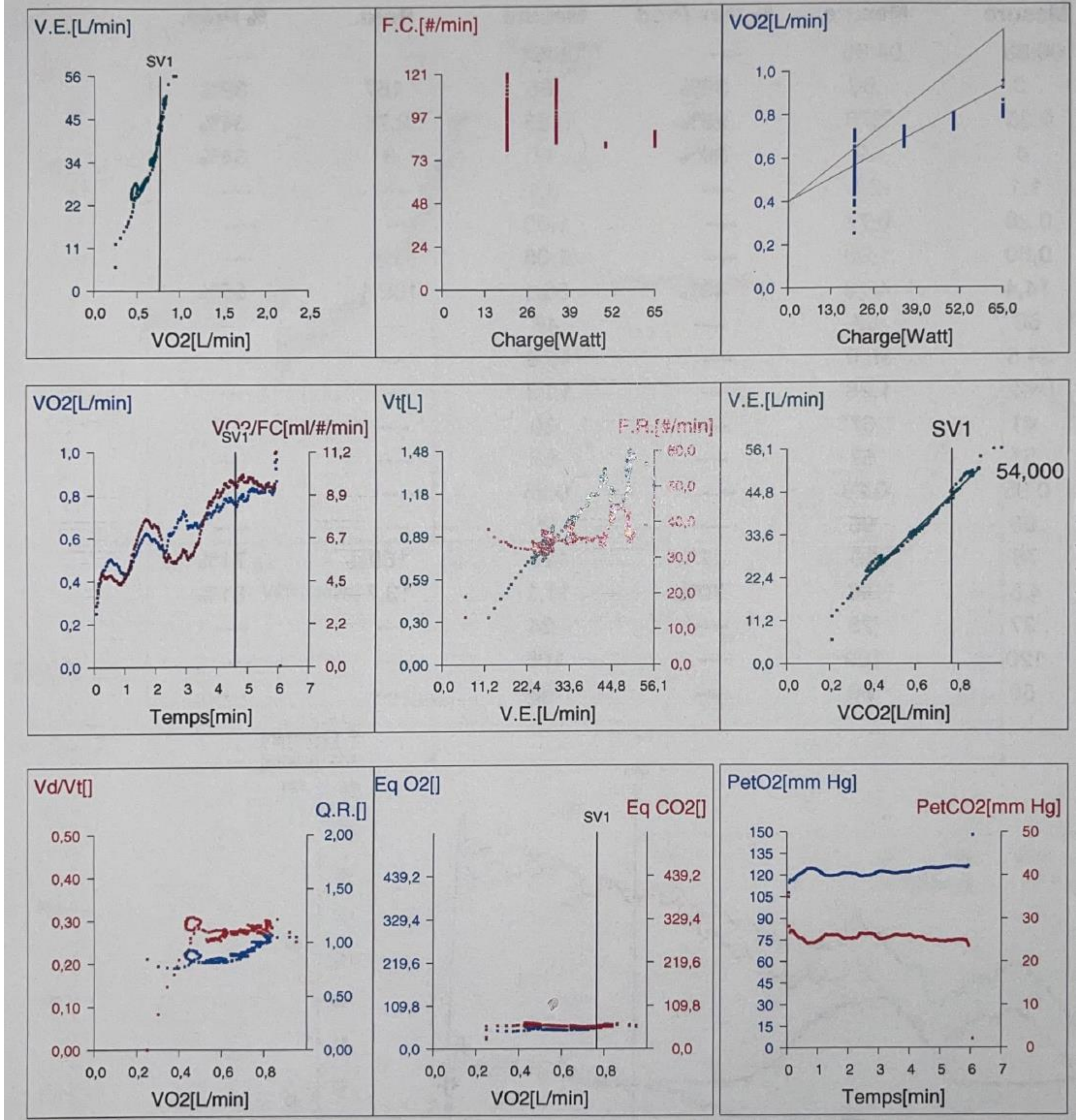
Reason for stopping

Borg dyspnea 9/10
Legs 9/10

		Repos Mesuré	SV 1 Mesuré	SV 1 % Max Préd	Vo2 max Mesuré	Vo2 max Préd.	Vo2 max % Préd.
Temps	min	00:53	04:36	----	05:54	----	----
Charge	**Watt**	0	50	**30%**	65	167	39%
VO2	**L/min**	0,35	0,76	**28%**	0,95	2,78	34%
VO2 sp	**ml/kg**	4	9	**28%**	11	31	34%
Met		1,1	2,5	----	3,1	----	----
VCO2	**L/min**	0,28	0,77	----	1,00	----	----
Q.R.		0,80	1,00	----	1,05	----	----
V.E.	**L/min**	14,4	43,6	**43%**	56,1	102,1	55%
Rés Ven	**%**	86	57	----	45	----	----
F.R.	**#/min**	34,5	36,0	----	45,9	----	----
Vt	**L**	0,42	1,28	----	1,23	----	----
Eq O2		41	57	----	59	----	----
Eq CO2		51	57	----	56	----	----
Vd/Vt		0,05	0,28	----	0,25	----	----
SpO2	**%**	95	95	----	95	----	----
F.C.	**#/min**	78	80	**47%**	120	169	71%
VO2/FC	**ml/#/min**	4,5	9,6	**70%**	11,1	13,7	81%
PetCO2	**mm Hg**	27	25	----	24	----	----
TA Sys.	**mm Hg**	120	109	----	105	----	----
TA Dia.	**mm Hg**	50	60	----	63	----	----



Case 4


V.E.[L/min]
SV1
VO2[L/min]
F.C.[#/min]
Charge[Watt]
VO2[L/min]
Charge[Watt]
VO2[L/min]
VO2/FC[ml/#/min]
SV1
Temps[min]
Vt[L]
F.R.[#/min]
V.E.[L/min]
V.E.[L/min]
SV1
54,000
VCO2[L/min]
Vd/Vt[]
Q.R.[]
VO2[L/min]
Eq O2[]
Eq CO2[]
SV1
VO2[L/min]
PetO2[mm Hg]
PetCO2[mm Hg]
Temps[min]

Case 4

- Maximal effort
- Decrease aerobic capacity
- Cardiac limitation
  - High ventilatory equivalent
  - Low AT
  - Chronotropic insufficiency

Case 5

- F 57 years old
- PMH
  - COPD FEV1 1,35L (40%)
  - No active smoking
  - mMRC 3/4

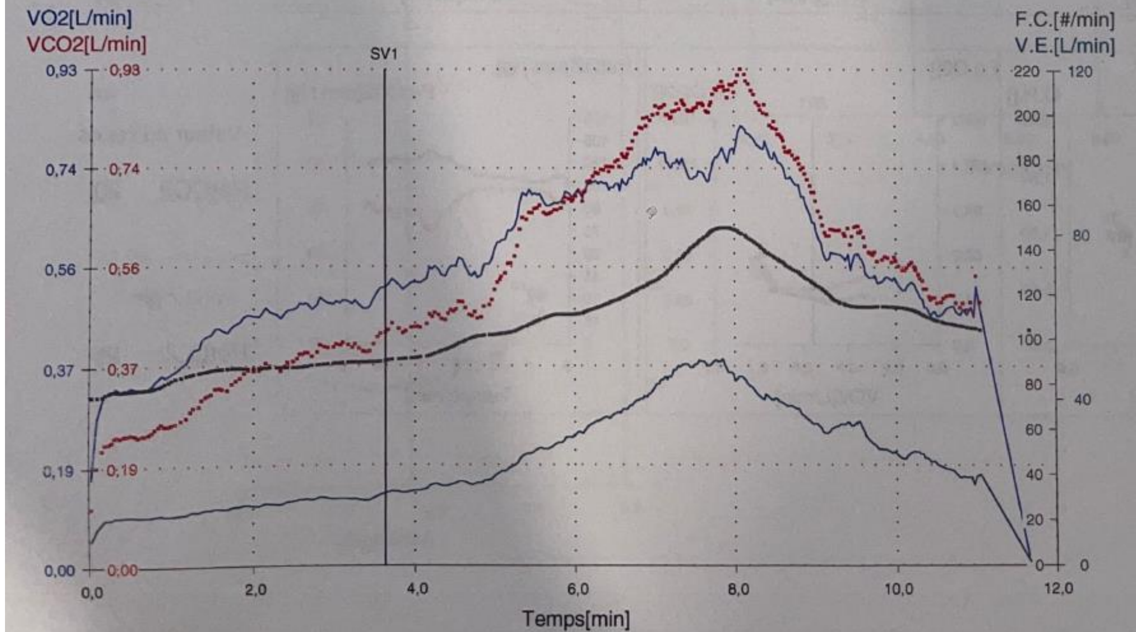
- CPET before pulmonary rehabilitation

Case 5

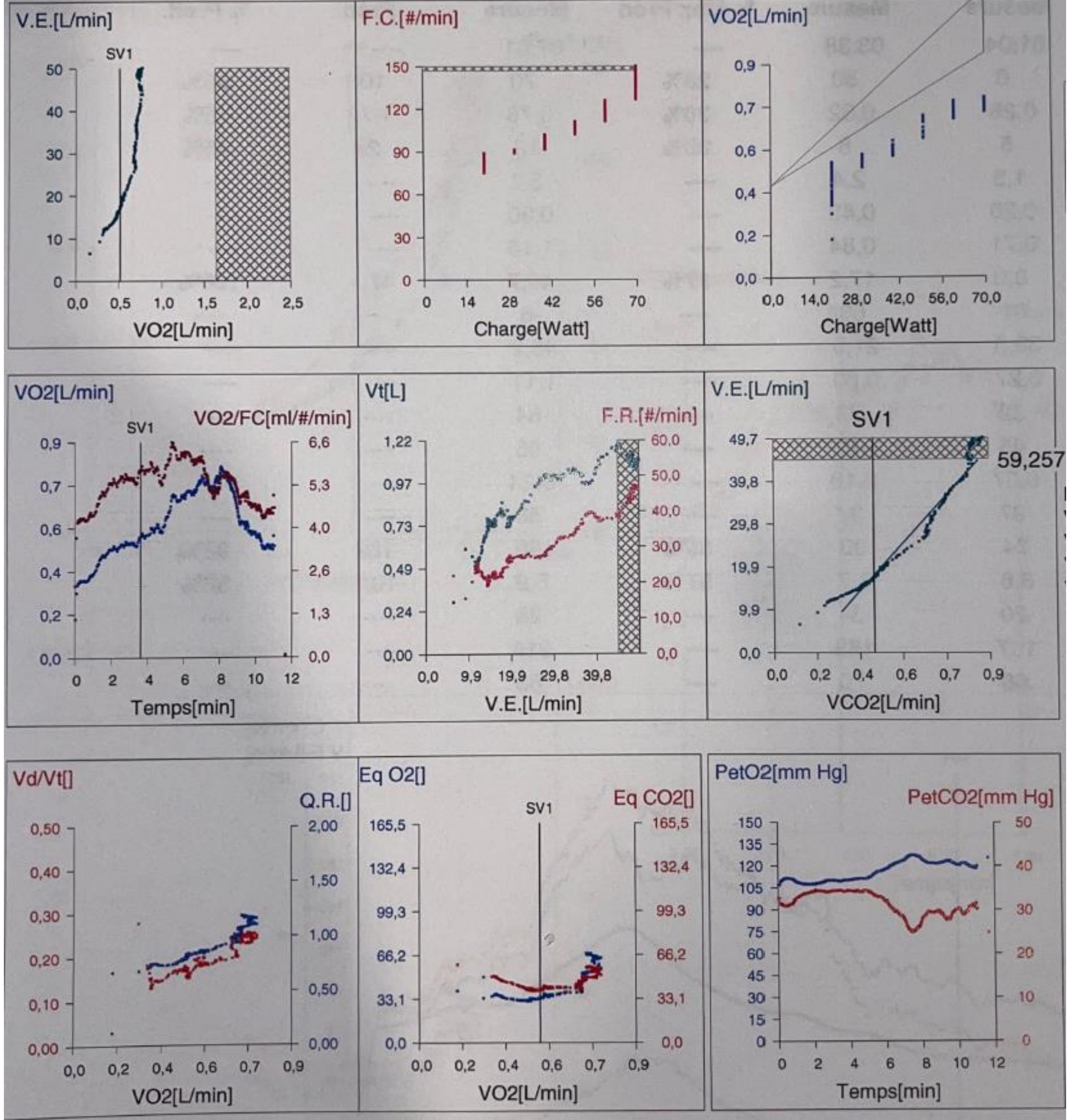
F 57 yo
BMI 31,2
169 cm
89 kg

EOT
dyspnea
9/10
Legs 8/10

		Repos Mesuré	SV 1 Mesuré	SV 1 % Max Préd	Vo2 max Mesuré	Vo2 max Préd.	Vo2 max % Préd.
Temps	min	01:04	03:38	----	07:51	----	----
Charge	**Watt**	0	30	**28%**	70	106	66%
VO2	**L/min**	0,28	0,52	**30%**	0,78	1,72	45%
VO2 sp	**ml/kg**	5	8	**30%**	13	28	45%
Met		1,3	2,4	----	3,7	----	----
VCO2	**L/min**	0,20	0,43	----	0,90	----	----
Q.R.		0,71	0,84	----	1,16	----	----
V.E.	**L/min**	9,0	17,2	**37%**	49,7	47,1	106%
Rés Ven	**%**	81	63	----	-6	----	----
F.R.	**#/min**	33,5	21,9	----	46,2	----	----
Vt	**L**	0,27	0,80	----	1,11	----	----
Eq O2		32	33	----	64	----	----
Eq CO2		45	40	----	55	----	----
Vd/Vt		0,07	0,18	----	0,24	----	----
SpO2	**%**	97	97	----	83	----	----
F.C.	**#/min**	74	90	**55%**	150	162	92%
VO2/FC	**ml/#/min**	3,8	5,7	**57%**	5,2	10,1	52%
PetCO2	**mm Hg**	20	34	----	26	----	----
TA Sys.	**mm Hg**	157	163	----	215	----	----
TA Dia.	**mm Hg**	68	70	----	83	----	----



VO2/W = 6,5 mL/min/W



Case 5

- Maximal effort
- Reduced aerobic capacity
- Respiratory limitation
  - No more ventilation reserve
  - Tidal volume drops at the end of the test (dynamic hyperinflation)
  - Exercise induced hypoxemia
  - High ventilatory equivalent

Key messages

- CPET is a very useful tool to understand mechanisms of exercise intolerance
- It’s a safe procedure
- For interpretation, don’t forget the steps
  - Is it maximal or not?
  - What is the aerobic capacity?
  - What is the mechanism of exercise intolerance?
    - Check the ventilatory, cardiovascular, metabolic and gas exchange response

Thank you!

- Questions?