Ergospirometri vid hjärtsvikt

Henrik Mosén
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- Vilka variabler är särskilt intressanta?
- Vad finns det för rekommendationer för hjärtsviktspatienter och när transplantation anses indicerat?
- Fallexempel

Variabler av särskilt intresse

Circulation
Volume 126, Issue 18, 30 October 2012; Pages 2261-2274
https://doi.org/10.1161/CIR.0b013e31826fb946

EACPR/AHA SCIENTIFIC STATEMENT

Clinical Recommendations for Cardiopulmonary Exercise Testing Data Assessment in Specific Patient Populations

Marco Guazzi, Volker Adams, Viviane Conraads, Martin Halle, Alessandro Mezzani, Luc Vanhees, Ross Arena, Gerald F. Fletcher, Daniel E. Forman, Dalane W. Kitzman, Carl J. Lavie, and Jonathan Myers

Primary CPX variables

VE/V_{CO_2} slope	Peak V_{O_2} [a]	EOV	$P_{ET}CO_2$
Ventilatory class I VE/V_{CO_2} slope <30.0	Weber class A Peak V_{O_2} >20.0 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$	Not present	Resting $P_{ET}CO_2$ ≥33.0 mmHg 4,40 kPa 3–8 mmHg increase during ET 0,40-1,07 kPa
Ventilatory class II VE/V_{CO_2} slope 30.0–35.9	Weber class B Peak V_{O_2} = 16.0–20.0 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$		
Ventilatory class III VE/V_{CO_2} slope 36.0–44.9	Weber class C Peak V_{O_2} = 10.0–15.9 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$	Present	Resting $P_{ET}CO_2$ <33.0 mmHg 4,40 kPa <3 mmHg increase during exercise 0,40-1,07 kPa
Ventilatory class IV VE/V_{CO_2} slope ≥45.0	Weber class D Peak V_{O_2} <10.0 mL $O_2 \cdot kg^{-1} \cdot min^{-1}$		

Standard ET variables

Haemodynamics	ECG	HRR
Rise in systolic BP during ET	No sustained arrhythmias, ectopic foci, and/or ST segment changes during ET and/or in recovery	>12 beats at 1 min recovery
Flat systolic BP response during exercise	Altered rhythm, ectopic foci, and or ST segment changes during ET and/or in recovery: did not lead to test termination	≤12 beats at 1 min recovery
Drop in systolic BP during ET	Altered rhythm, ectopic foci, and or ST segment changes during ET and/or in recovery: led to test termination	

Patient reason for test termination

Lower extremity muscle fatigue	Angina	Dyspnoea

Interpretation

- All variables in green: excellent prognosis in next 1–4 years (≥90% event free)
  - Maintain medical management and retest in 4 years.
- Greater number of CPX and standard ET variables in red/yellow/orange indicative of progressively worse prognosis.
  - All CPX variables in red: risk for major adverse event extremely high in next 1–4 years (>50%).
- Greater number of CPX and standard ET variables in red/yellow/orange indicative of increasing HF disease severity.
  - All CPX variables in red: expect significantly diminished cardiac output, elevated neurohormones, higher potential for secondary PH.
- Greater number of CPX and standard ET variables in red/yellow/orange warrants strong consideration of more aggressive medical management and surgical options.

VE/V_{CO_2}, minute ventilation/carbon dioxide production; V_{O_2}, oxygen consumption; EOV, exercise oscillatory ventilation; $P_{ET}CO_2$, partial pressure of end-tidal carbon dioxide; BP, blood pressure; CPX, cardiopulmonary exercise test; ECG, electrocardiogram; ET, exercise test; HRR, heart rate recovery; RER, respiratory exchange ratio.

[a]Peak V_{O_2} valid if peak RER is at least 1.00 or test terminated secondary to abnormal haemodynamic or ECG exercise response.

Fokusera således på

- VO_2peak
- VE/VCO_2-slope
- Oscillerande andning under arbete (EOV)
- Endtidal CO_2-dynamik

- BT-reaktion
- HRR (heart rate recovery)
- Uttalade EKG-förändringar

ESC European Society of Cardiology
European Heart Journal (2018) **39**, 1144–1161
doi:10.1093/eurheartj/ehw180

SPECIAL ARTICLE
EACPR/AHA scientific statement

2016 focused update: clinical recommendations for cardiopulmonary exercise testing data assessment in specific patient populations

Marco Guazzi*, Ross Arena†, Martin Halle*, Massimo F. Piepoli*, Jonathan Myers, and Carl J. Lavie

Online publish-ahead-of-print 2 May 2016

In the past several decades, cardiopulmonary exercise testing (CPX) has seen an exponential increase in its evidence base. The growing volume of evidence in support of CPX has precipitated the release of numerous scientific statements by societies and associations. In 2012, the European Association for Cardiovascular Prevention & Rehabilitation and the American Heart Association developed a joint document with the primary intent of redefining CPX analysis and reporting in a way that would streamline test interpretation and increase clinical application. Specifically, the 2012 joint scientific statement on CPX conceptualized an easy-to-use, clinically meaningful analysis based on evidence-vetted variables in color-coded algorithms; single-page algorithms were successfully developed for each proposed test indication. Because of an abundance of new CPX research in recent years and a reassessment of the current algorithms in light of the body of evidence, a focused update to the 2012 scientific statement is now warranted. The purposes of this update are to confirm algorithms included in the initial scientific statement not requiring revision, to propose revisions to algorithms included in the initial scientific statement, to propose new algorithms based on emerging scientific evidence, to further clarify the application of oxygen consumption at ventilatory threshold, to describe CPX variables with an emerging scientific evidence base, to describe the synergistic value of combining CPX with other assessments, to discuss personnel considerations for CPX laboratories, and to provide recommendations for future CPX research.

Keywords AHA Scientific Statements • diagnosis • exercise test • physical exertion • prognosis

Diskuterar bl a ”exercise ventilatory power” [SBPpeak/(VE/VCO2-slope)] som potentiellt index för att identifiera dålig prognos vid hjärtsvikt.

Circulation
Volume 145, Issue 18, 3 May 2022; Pages e895-e1032
https://doi.org/10.1161/CIR.0000000000001063

AHA/ACC/HFSA CLINICAL PRACTICE GUIDELINE

2022 AHA/ACC/HFSA Guideline for the Management of Heart Failure: A Report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines

4.7. Exercise and Functional Capacity Testing

Recommendations for Exercise and Functional Capacity Testing

COR	LOE	Recommendations
1	C-LD	1. In patients with HF, assessment and documentation of NYHA functional classification are recommended to determine eligibility for treatments.[1–3]
1	C-LD	2. In selected ambulatory patients with HF, cardiopulmonary exercise testing (CPET) is recommended to determine appropriateness of advanced treatments (eg, LVAD, heart transplant).[4–8]
2a	C-LD	3. In ambulatory patients with HF, performing a CPET or 6-minute walk test is reasonable to assess functional capacity.[4,5,9–16]
2a	C-LD	4. In ambulatory patients with unexplained dyspnea, CPET is reasonable to evaluate the cause of dyspnea.[17,18]

- 6MWT fungerar bäst hos patienter som går < 490 m
- 300 m är en användbar cutoff

ESC European Society of Cardiology

European Heart Journal (2021) **42**, 3599–3726
doi:10.1093/eurheartj/ehab368

ESC GUIDELINES

2021 ESC Guidelines for the diagnosis and treatment of acute and chronic heart failure

Developed by the Task Force for the diagnosis and treatment of acute and chronic heart failure of the European Society of Cardiology (ESC)

With the special contribution of the Heart Failure Association (HFA) of the ESC

Authors/Task Force Members: Theresa A. McDonagh* (Chairperson) (United Kingdom), Marco Metra * (Chairperson) (Italy), Marianna Adamo (Task Force Coordinator) (Italy), Roy S. Gardner (Task Force Coordinator) (United Kingdom), Andreas Baumbach (United Kingdom), Michael Böhm (Germany), Haran Burri (Switzerland), Javed Butler (United States of America), Jelena Čelutkienė (Lithuania), Ovidiu Chioncel (Romania), John G.F. Cleland (United Kingdom), Andrew J.S. Coats (United Kingdom), Maria G. Crespo-Leiro (Spain), Dimitrios Farmakis (Greece), Martine Gilard (France), Stephane Heymans

Cardiopulmonary exercise testing		
Cardiopulmonary exercise testing is recommended as a part of the evaluation for heart transplantation and/or MCS.[94–96]	I	C
Cardiopulmonary exercise testing should be considered to optimize prescription of exercise training.[94–96]	IIa	C
Cardiopulmonary exercise testing should be considered to identify the cause of unexplained dyspnoea and/or exercise intolerance.[94–96]	IIa	C

När är det aktuellt att hjärttransplantera?

ISHLT:s guidelines

GUIDELINE

International Society for Heart and Lung Transplantation Guidelines for the Evaluation and Care of Cardiac Transplant Candidates—2024

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Endorsed by the Pediatric Heart Transplant Society.

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Table 18 Summary of Heart Transplant Evaluation

Test (COR)	Baseline	While listed	Comments
Assessment of HF severity			
CPET (Class 1, Baseline; Class 2b Waitlist)	x	x	Table 4 Should not be used as the sole determinant of need/ listing status for HT

Table 4 Summary of CPET Parameters Supporting Transplant Listing in Different Populations

Patient population	Parameter supporting transplant listing
On beta-blocker[63–67]	Lower peak VO_2 cutoff is supportive of transplant listing, generally ≤12 ml/kg/min
Off beta-blocker[67,68]	Higher peak VO_2 may be considered supportive of transplant listing, generally ≤14 ml/kg/min
Patients with obesity (BMI ≥ 30 kg/m^2)[69]	Peak VO_2 adjusted for lean body mass ≤19 ml/kg/min
All, especially if submaximal CPET[70–75]	VE/VCO_2 slope >35
Women or patients ≤50 or ≥70 years[76–78]	Peak VO_2 ≤ 50% predicted

Abbreviations: BMI, body mass index; CPET, cardiopulmonary exercise test; VE/VCO_2, the minute ventilation/carbon dioxide production. Maximal CPET: respiratory exchange ratio (RER) > 1.05 and reaching anaerobic threshold.[79]

2. TASK FORCE I: EVALUATION FOR HEART TRANSPLANT CANDIDACY

2.1. Listing Criteria for Heart Transplantation

2.1.1. Indications for Heart Transplantation

Recommendations for Indications for Heart Transplantation		
COR	**LOE**	**RECOMMENDATIONS**
1	**B-NR**	1. In patients with HF, when consistent with the patient's goals of care, the presence of clinical indicators of advanced HF (AvdHF) should trigger evaluation for AdvHF therapies, including HT.
1	**B-NR**	2. In ambulatory adult HF patients referred for transplant evaluation (and pediatric patients when age-appropriate), CPET should routinely be performed to quantify exertional intolerance, inform HF prognosis, and guide transplant listing.
1	**C-LD**	3. In adult HF patients evaluated for transplantation, right heart catheterization (RHC) should be performed prior to listing to assess for potentially prohibitive PH and for cardiogenic shock requiring inotropic support and/or temporary MCS.
2b	**C-EO**	4. In pediatric HT candidates, RHC may be performed prior to listing.
2a	**C-LD**	5. In adult HT candidates, HF prognosis scores can be considered in the context of other data collected during transplant evaluation to guide listing decisions.

Recommendation-Specific Supportive Text

Parameters derived during CPET are strongly prognostic in ambulatory HF patients being considered for HT. In HFrEF, Guazzi et al showed that the prognostic value of maximal oxygen consumption (peak VO_2) and the minute ventilation/carbon dioxide production (VE/VCO_2) slope are comparable for both men and women, with a greater discriminative power of the VE/VCO_2 slope over peak VO_2 in female patients,[38] which has been confirmed recently.[39] A summary of CPET parameters supporting transplant listing in different populations is shown in Table 4. In ambulatory patients, the results of CPET should be evaluated in the context of other data collected during transplant evaluation rather than used as the sole criterion for listing. In patients limited enough to require urgent or semiurgent inpatient evaluation, there is no clear role for CPET except in select cases where sufficient clinical improvement occurs and allows hospital discharge to be considered. The use of CPET is challenging in pediatric HF patients due to wide variations in protocols and patients' ages, sizes, and muscle mass.[40] In addition, patients with single-ventricle physiology have poor exercise performance with peak VO_2 often less than 65% predicted. Thus, a peak VO_2 less than 50% predicted is often considered supportive of transplant listing in this population.[41]

- CPET har värde hos uppegående patienter/polikliniska patienter
- Ska dock användas som del i värdering, inte ensamt
- CPET har inget klar roll hos patienter som är sjuka nog att vara nära att vara, eller är inneliggande

Sammanfattningsvis
ISHLT:s guidelines

- **VO_2peak < 14** ml/(min*kg) (RER > 1,05) [utan betablockad]
- **VO_2peak < 12** ml/(min*kg) (RER > 1,05) [med betablockad]
- Särskilt om RER < 1,05 ➔ **VE/VCO_2-slope > 35**
- VE/VCO_2-slope också bättre att använda hos kvinnor än män
- **VO_2peak % av förväntat < 50 %** om < 50 år, > 70 år, eller kvinna
- Om överviktig (BMI > 30) ➔ **VO_2peak justerad för lean body mass < 19 ml/(min*kg)**
- Hos barn och patienter med enkammarfysiologi används ofta **50 % av förväntad VO_2peak**

Fallexempel

39-årig man. Inkommit med biventrikulär svikt, särskilt dålig högerkammarfunktion. Dyspnoisk vid några meters gång, svullna ben och svullen buk. Lite pleuravätska på lungröntgen.

Gör ergospirometri som del av transplantationsutredning.

Protokoll: 5/3. Tid i arbete: cirka 12 min 15 sek.
Patienten har ingen kalciumflödeshämmare och har bibehållen betablockad.

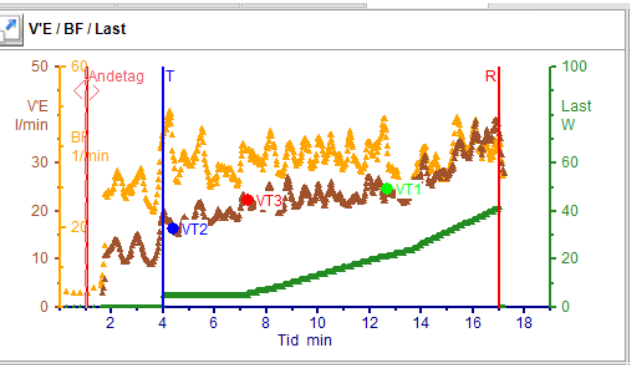
RESULTAT:
(av Swedac ackrediterad verksamhet enligt ISO/IEC 17025, provning, ackr.nr. 1309)

Arbete: Slutbelastning: 42W. Arbetsförmåga: 26 % av förväntad (Brudin et al 2014). Vilopuls: 113 slag/min. Max.puls under arbete: 135 slag/min (75 % av beräknad max.puls) (bibehållen betablockad). Puls 1 minut efter arbete: 132 slag/min. Blodtryck: Liggande i vila: 70 / 50 mmHg. Sittande på cykel: 60 / - mmHg. På 11 W: 75/- mmHg. På 42 W: 60/- mmHg. 1 min efter arbete: 50/ mmHg. 6 min efter arbete: 60/ mmHg.

Symptom: Allmänt "utmattad". Avbryts pga blodtrycksfall. cirkumoral blekhet efter avslutat arbete

Pulsoximetri, SpO2 (ej ackrediterad metod): I vila före arbete: 91%. På 42 W belastning: 78%. 6 min efter arbete: 87%.

EKG-reaktion: Sinustakykardi i vila. Låg slutpuls då arbetet avbryts pga sjunkande blodtryck och sänkt allmäntillstånd. Utbredda ST-förändringar i vila. Svårvärderad ST-reaktion på grund av viloförändringar.värderad ST-reaktion.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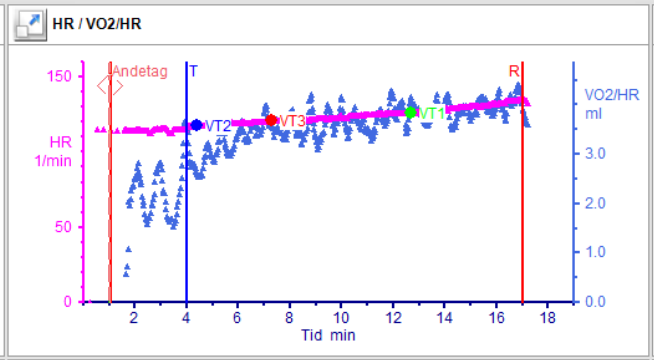
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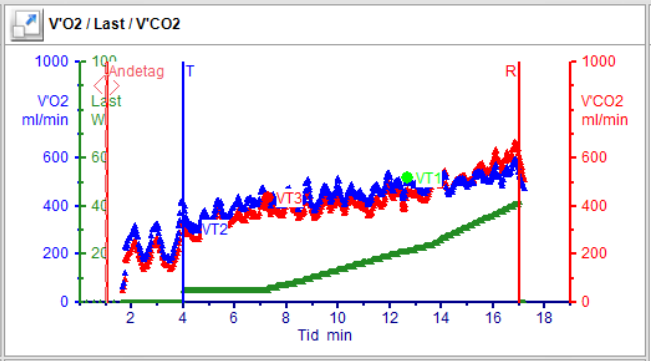
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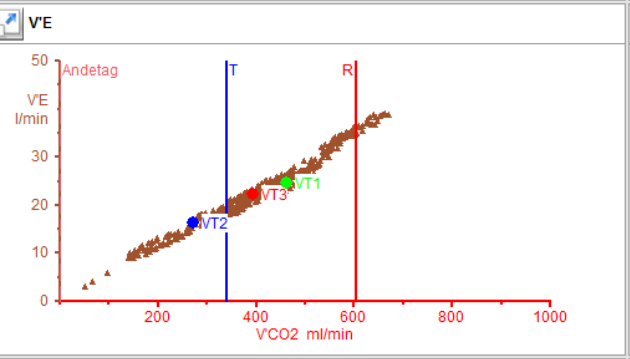
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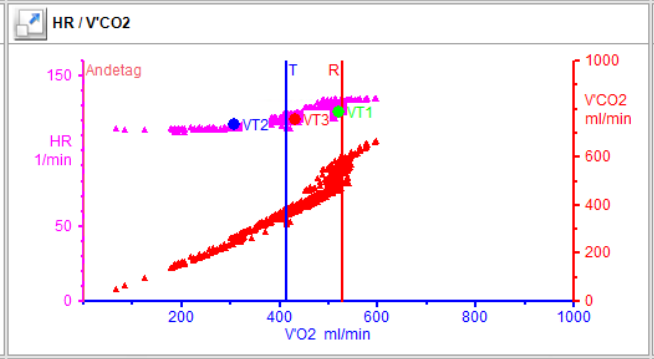
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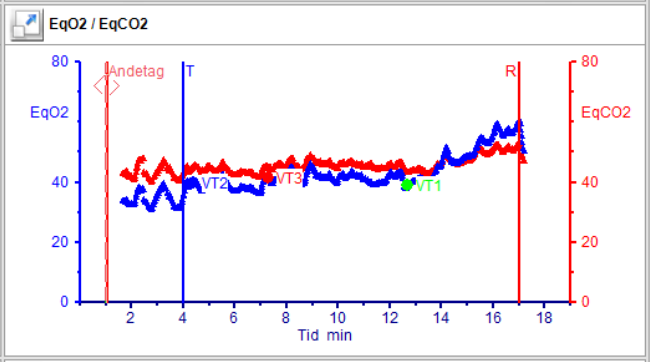
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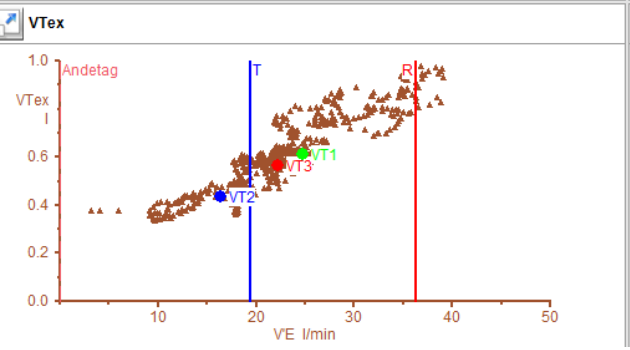
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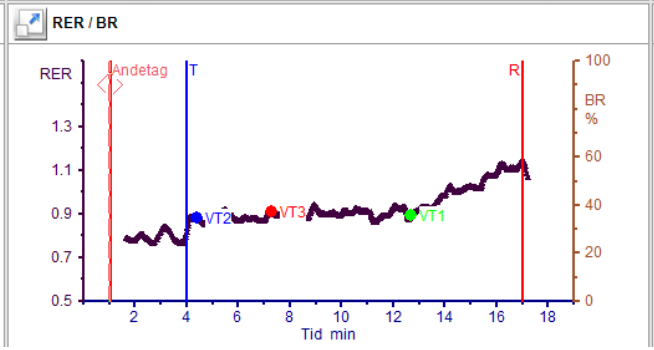
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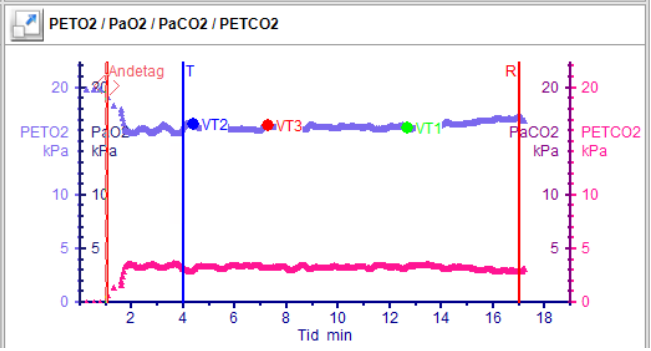
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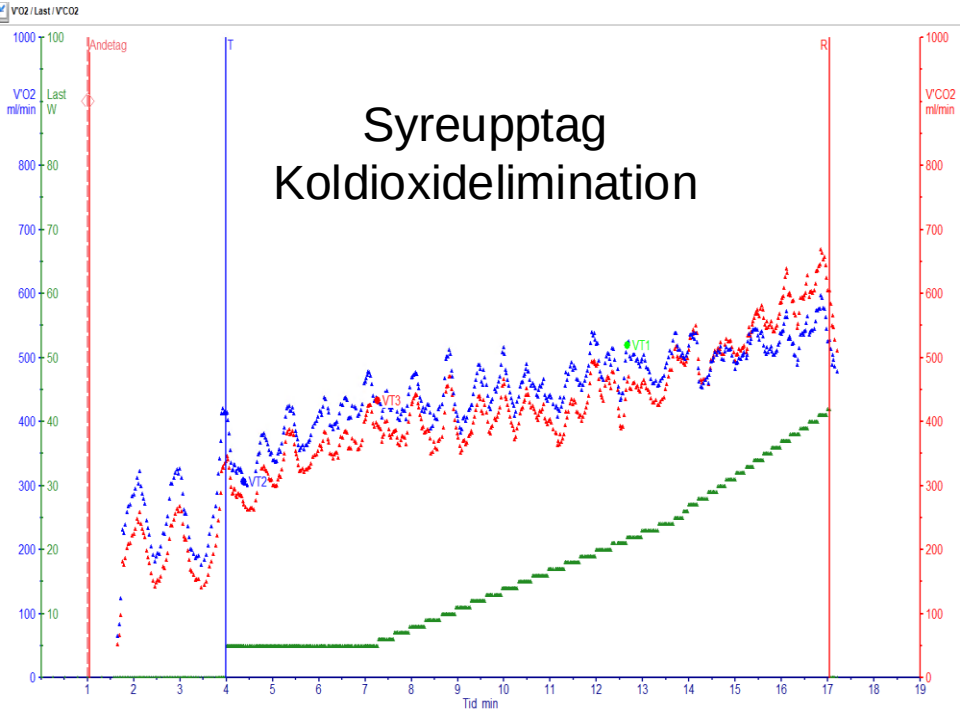

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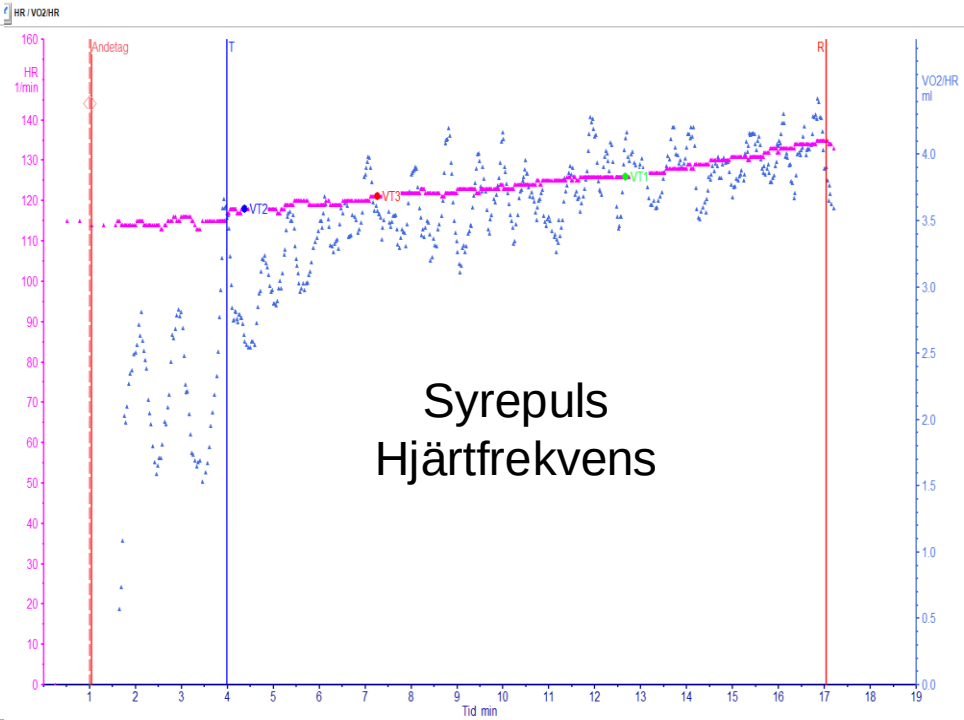
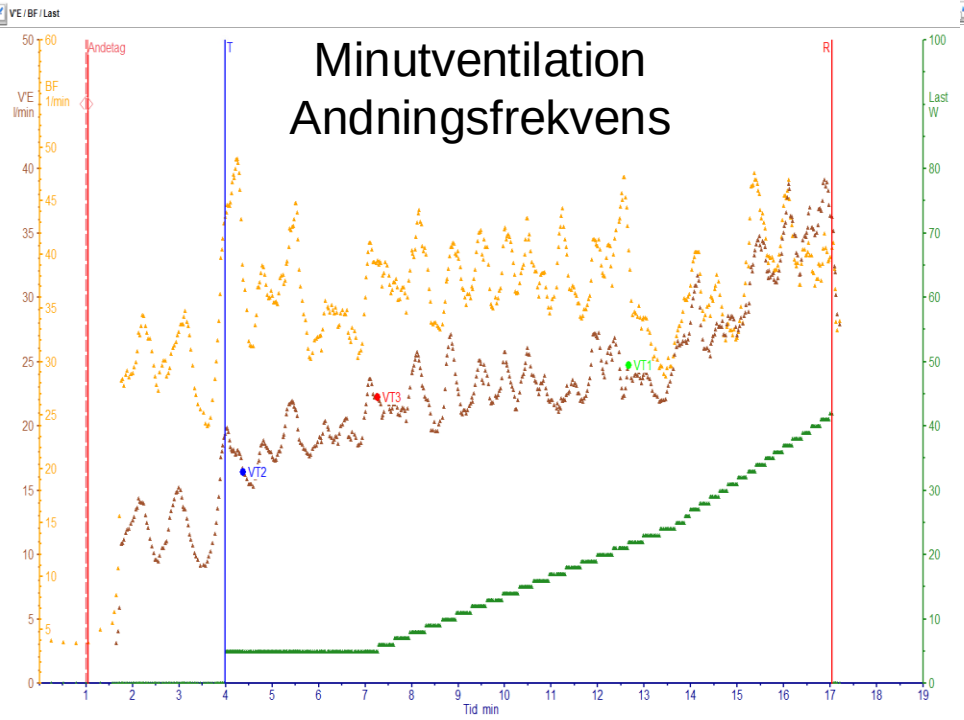
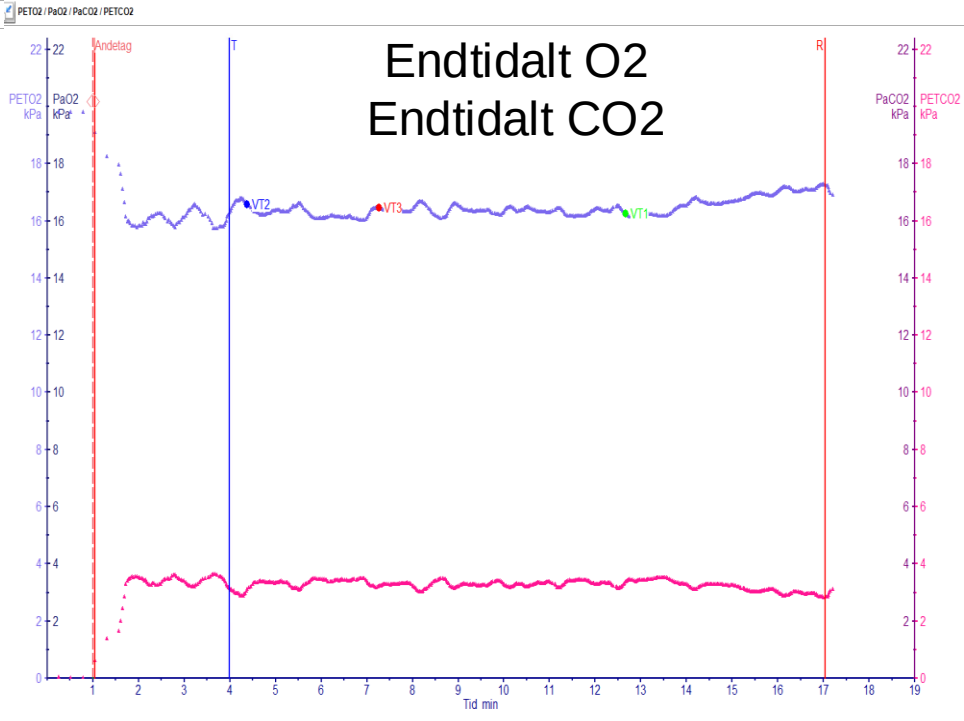


Syrepuls
Hjärtfrekvens



Minutventilation
Andningsfrekvens



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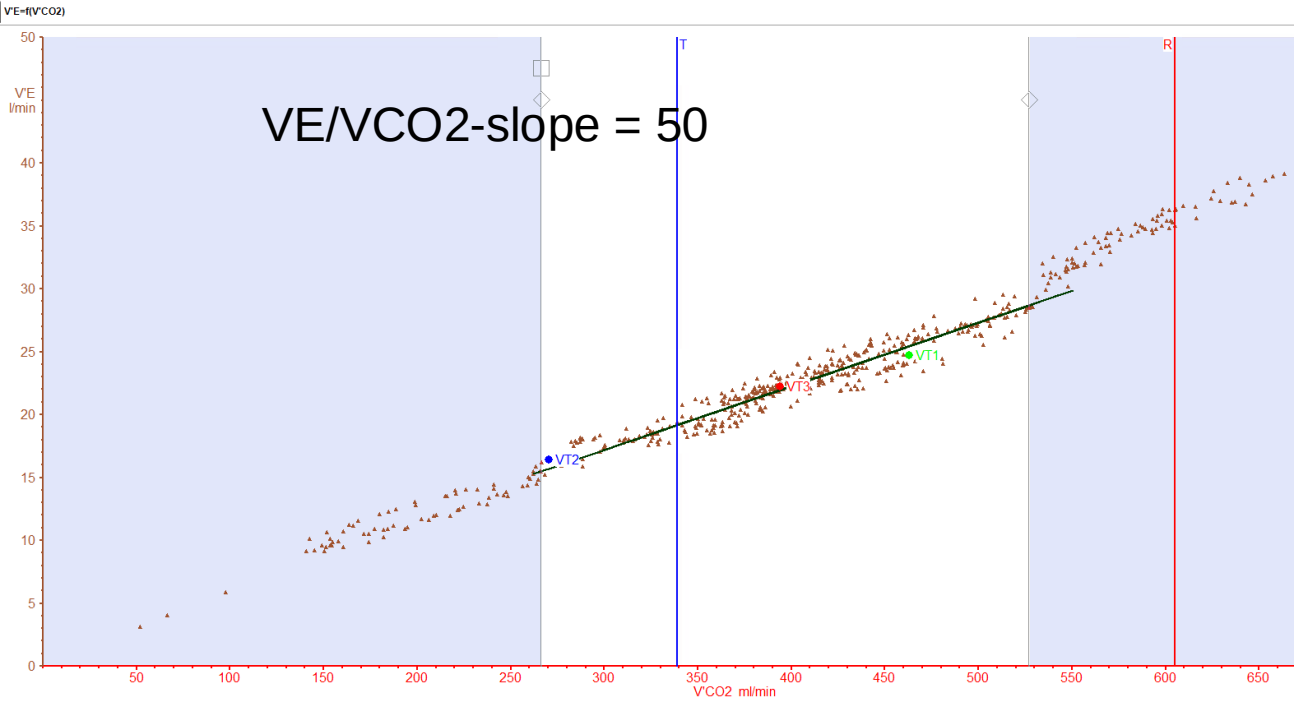
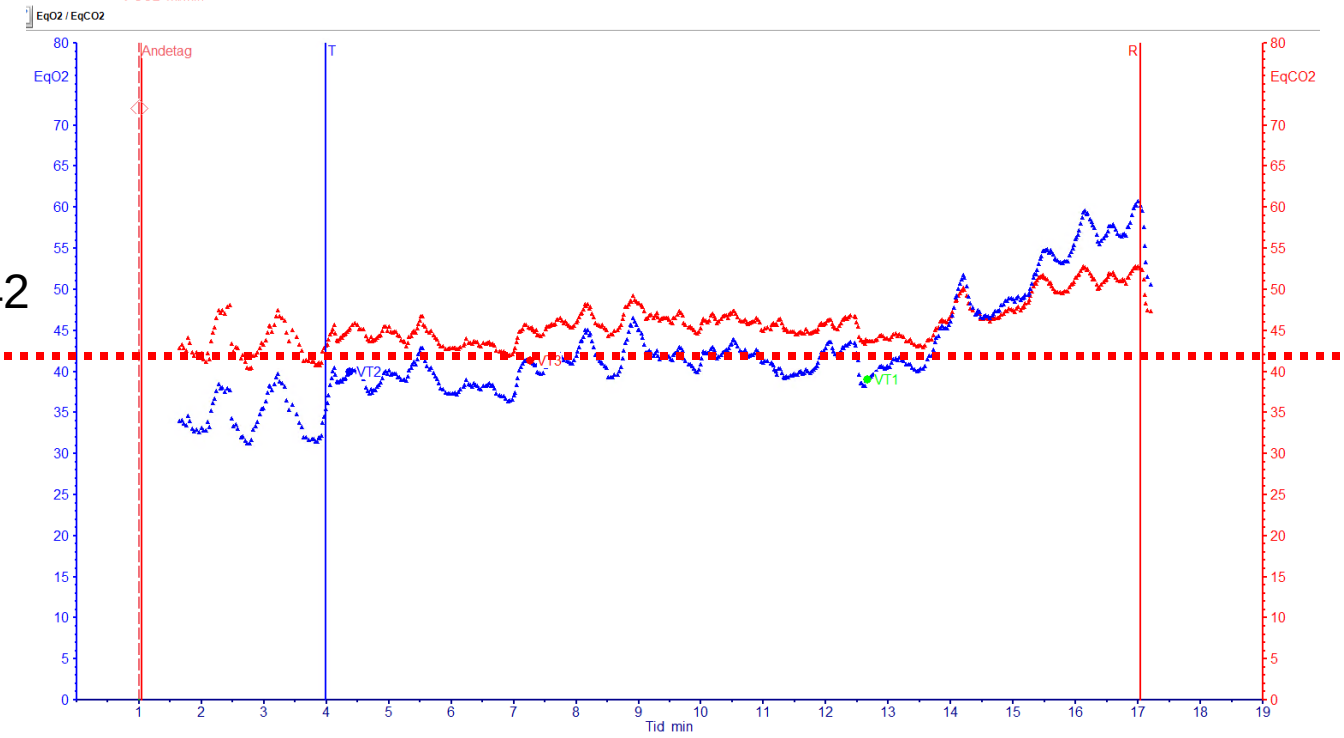


VE/VCO2-slope = 50

EqCO2 nadir = c:a 42



VO2peak (ml/min):	570 (23 % av förväntat)
VO2peak (ml/(min*kg)):	6,9
VO2 vid AT (ml/(min*kg):	6,0 (39 % av förväntat)
VO2 vid AT i % av förväntad VO2peak:	19 (normalt >40 %)
Syrepuls peakvärde (ml/slag):	4.2 (25 % av förväntat)
VE/VCO2-slope:	50 (217 % av förväntat)
VE/VCO2 vid AT:	44 (179 % av förväntat)
PETCO2 i vila (kPa):	3,42 (normalt c:a 4,8-5,6)
PETCO2 max under arbete (kPa):	3,33
Ökning PETCO2 vila ==> max under arb:	-0,1 (normalt 0,4-1,1)
RER i vila/i början av steady state:	0,78 (normalt c:a 0,75-0,85)
RER vid maxbelastning:	1,11 (normalt >1,10)
Andningsreserv (%):	59 (normalt c:a 15-40 %)

	VE/VCO_2-slope		**VO_2peak** (ml/(min*kg))		**Oscillerande ventilation**	**Endtidal CO_2-dynamik**		
Grön	Slope <30,0		Peak > 20,0			>0,4 kPa ökning under arbete		**Grön**
Gul	Slope 30,0-35,9		Peak 16,0-20,0					
Orange	Slope 36,0-44,9		Peak 10,0-15,9		Ja	< 0,4kPa ökning under arbete	-0,1	**Röd**
Röd	Slope ≥ 45,0	50,0	Peak < 10,0	6,9				

BEDÖMNING:

Mycket låg prestationsförmåga, VO2peak cirka 7 ml/(min*kg). Subjektivt främst begränsad av "utmattning". Patologisk blodtrycksreaktion med successiv blodtrycksnedgång från 75 mmHg som högst till 60 mmHg då arbetet avbryts. Kraftigt förhöjd VE/VCO2-slope, c:a 50. Oscillerande andning under arbete (EOV). Patologisk endtidal CO2-dynamik under arbete. Desaturation från 91% i vila till 78 % vid maxbelastning. Ingen bröstsmärta. Patienten bedöms vara maximalt belastad. Svårvärderad ST-reaktion.

Sammanfattningsvis fynd som vid grav hjärtsvikt med dålig prognos.