

RESPONSABILE SCIENTIFICO:  
*Dr Sergio Harari*

SABATO,  
24 NOVEMBRE 2018

*Milano*  
HOTEL LA GARE

MALATTIE  
RESPIRATORIE:  
DAI SINTOMI  
ALLA DIAGNOSI

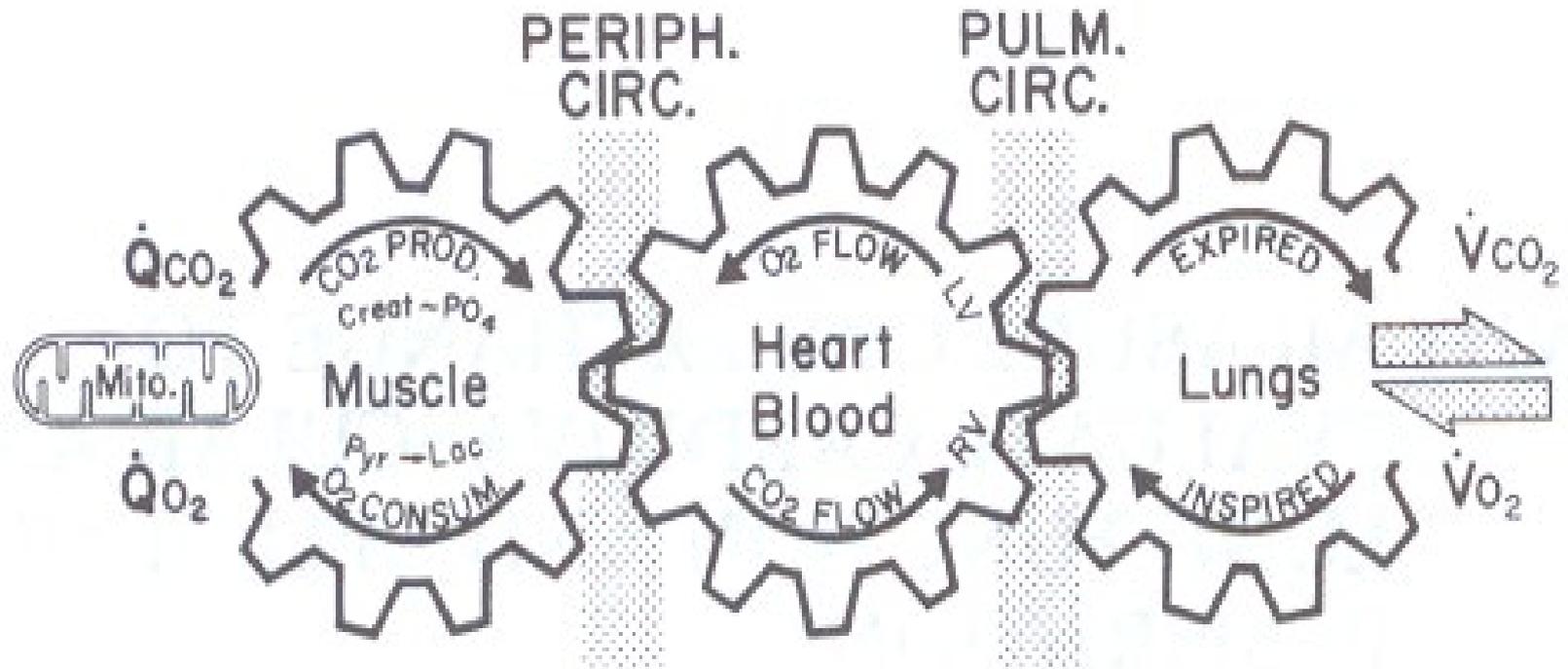
QUANDO IL CUORE  
FA  
DA PRIMADONNA

**Dott.ssa Gaia Cattadori**  
UO Cardiologia Riabilitativa  
H San Giuseppe  
IRCCS - Multimedica  
MILANO

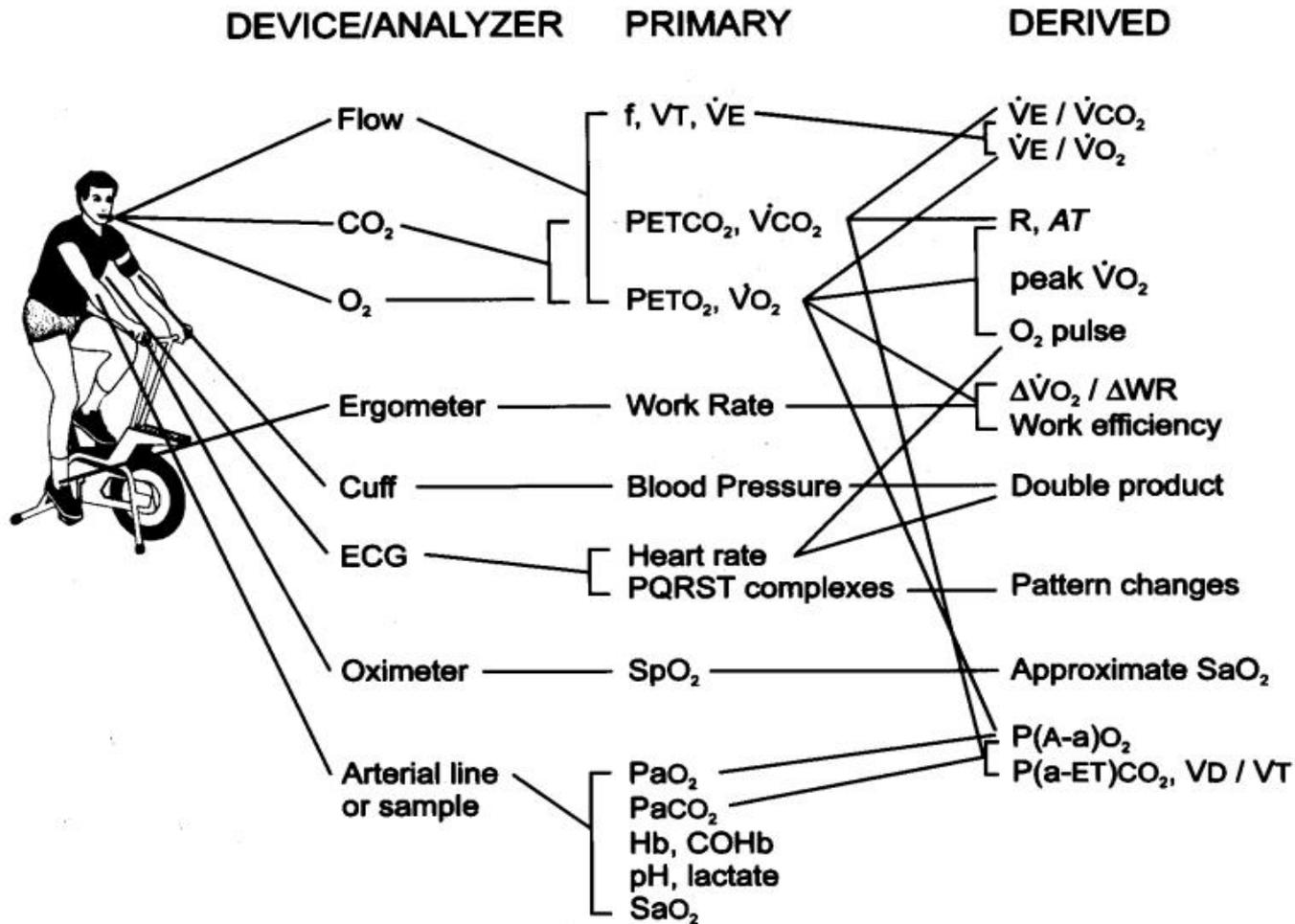
MUSCLE  
ACTIVITY

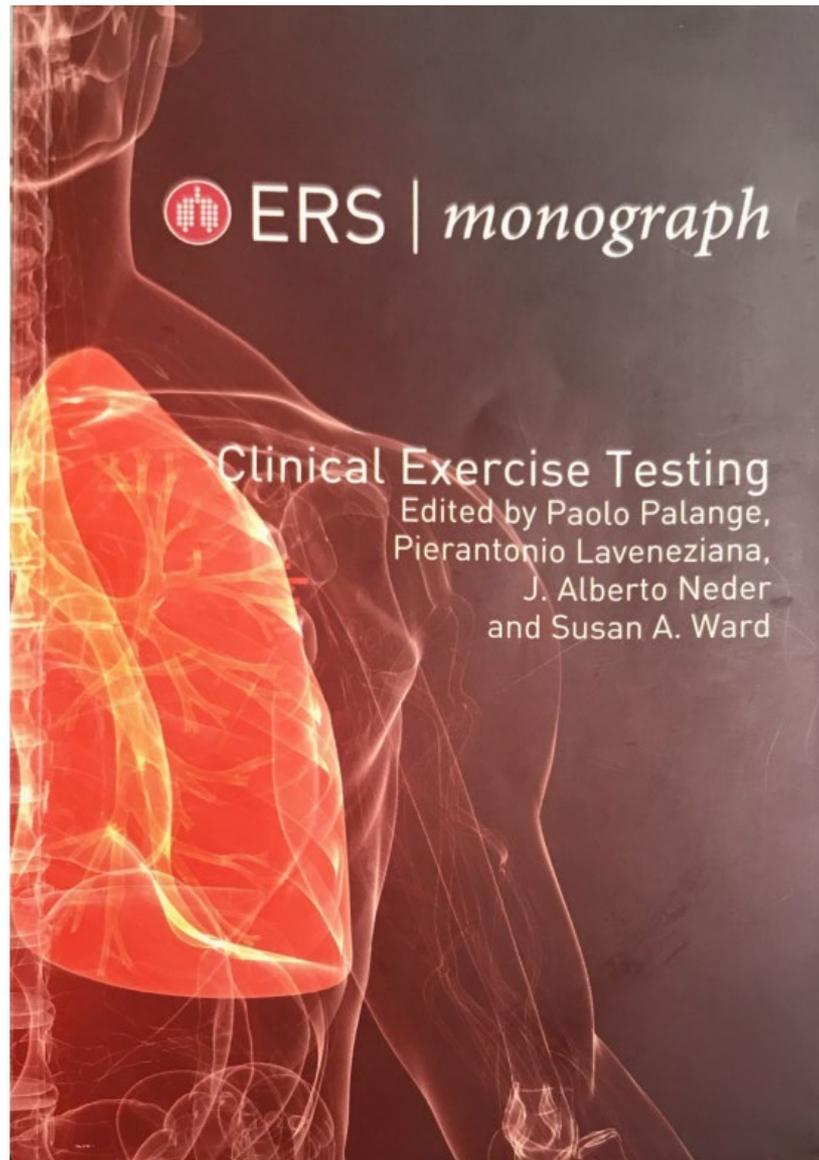
$O_2$  &  $CO_2$   
TRANSPORT

VENTILATION  
( $\dot{V}_A + \dot{V}_D = \dot{V}_E$ )



# Test da sforzo cardiopolmonare





# INDICAZIONI CPX

- Cardiologia

- cardiopatia ischemica (diagnosi e prognosi)
- scompenso cardiaco (limitazione funzionale, indicazione al trapianto cardiaco)
- problemi aritmici da sforzo
- malattie congenite

- Pneumologia

- danno respiratorio (diagnosi e quantificazione)
- asma da sforzo (diagnosi)
- ipertensione polmonare (diagnosi precoce)
- necessità di ossigeno-terapia

- Efficacia della terapia (sia in C che in P)

- Programma riabilitativo (sia in C che in P)

- **D.D. dispnea**

- Medicina sportiva (massimo carico di lavoro, efficacia training,...)

- Valutazione preoperatoria (resezione polmonare, trapianto cuore-polmone)

- Definizione invalidità

# CONTROINDICAZIONI CPX

- **Cuore**: scompenso cardiaco non stabilizzato, IMA in atto o recente, angina instabile, aritmie severe, trombo intraventricolare o tromboflebite, episodio embolico recente, sincope, endocardite, pericardite, miocardite, stenosi aortica severa sintomatica
- Sospetta **dissezione aortica o di aneurisma**
- **Polmone**: asma, scompenso respiratorio,  $\text{SatO}_2 < 85\%$  a riposo
- **Febbre**
- **Disturbi metabolici o elettrolitici severi**
- **Problematiche mentali** (assenza di collaborazione)

# COMPLICANZE DURANTE SFORZO

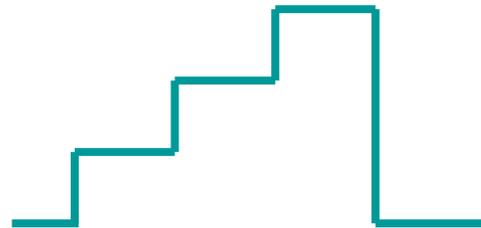
- ▶ Ipotensione
- ▶ Scompenso cardiaco congestizio
- ▶ Infarto miocardico acuto
- ▶ Aritmie cardiache severe
- ▶ Arresto cardiaco
  
- Eventi di pertinenza del sistema nervoso centrale (sincope, stroke,.....)
  
- Trauma fisico accidentale
  
- Morte (2-5:100.000)

# PROTOCOLLI CPX

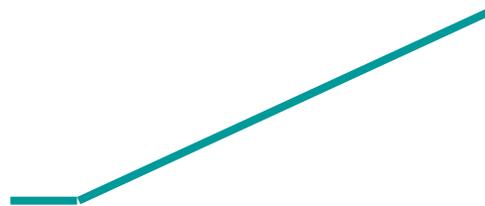
CARICO COSTANTE



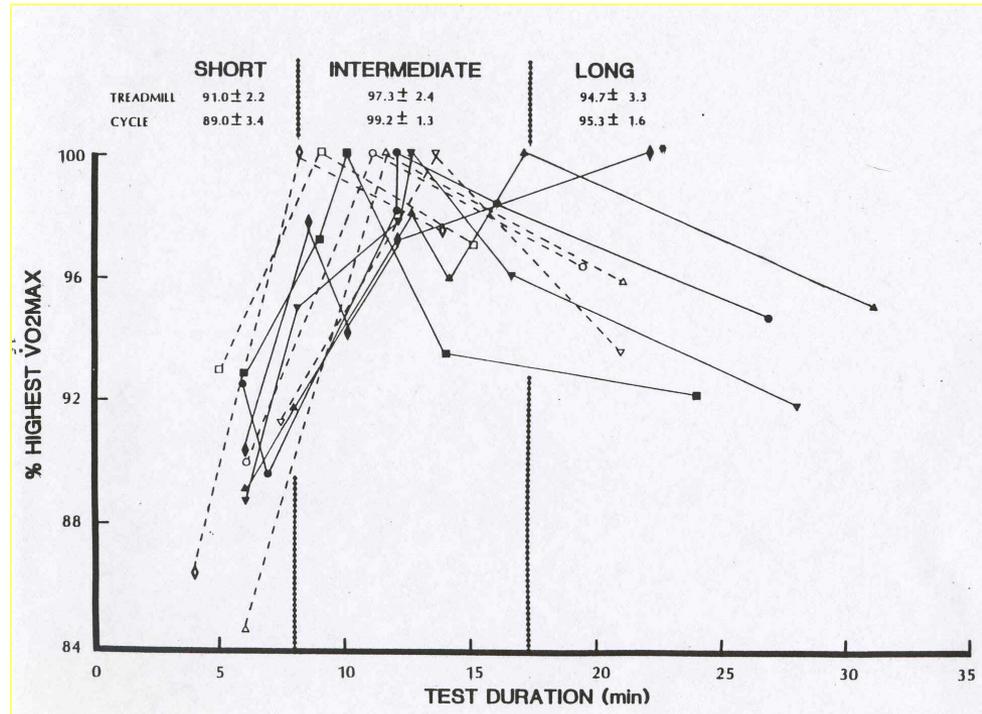
CARICO CRESCENTE  
("multistage" o ogni 2-3')



CARICO CRESCENTE  
(a rampa o ogni minuto)



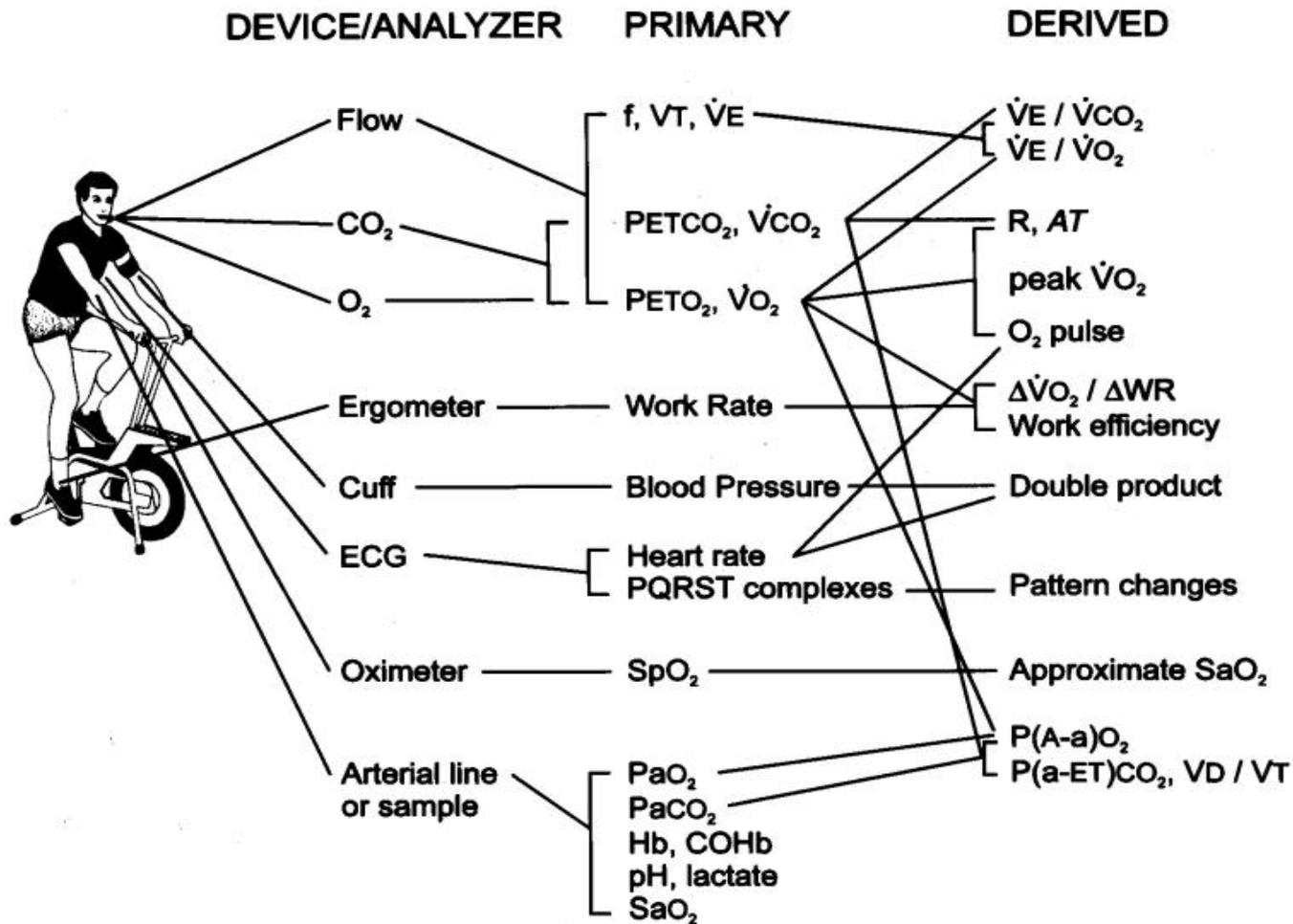
# DURATA DEL CPX



- $\text{VO}_2\text{ max}$  dipende dalla durata del test
- Per ottenere il maggior  $\text{VO}_2\text{ max}$  bisogna selezionare un incremento di carico tale da portare il soggetto a compiere un test massimale in

**$10 \pm 2$  minuti**

# Test da sforzo cardiopolmonare





Referti : prova da sforzo CardioPolmonare

	Misurati	Teorici	% Teorici
Spirometria	FVC (L)	5.48	
	FEV1 (L)	4.61	
	MVV(L)		

Dati a riposo    HR 104 1/min    SBP mmHg    DBP mmHg

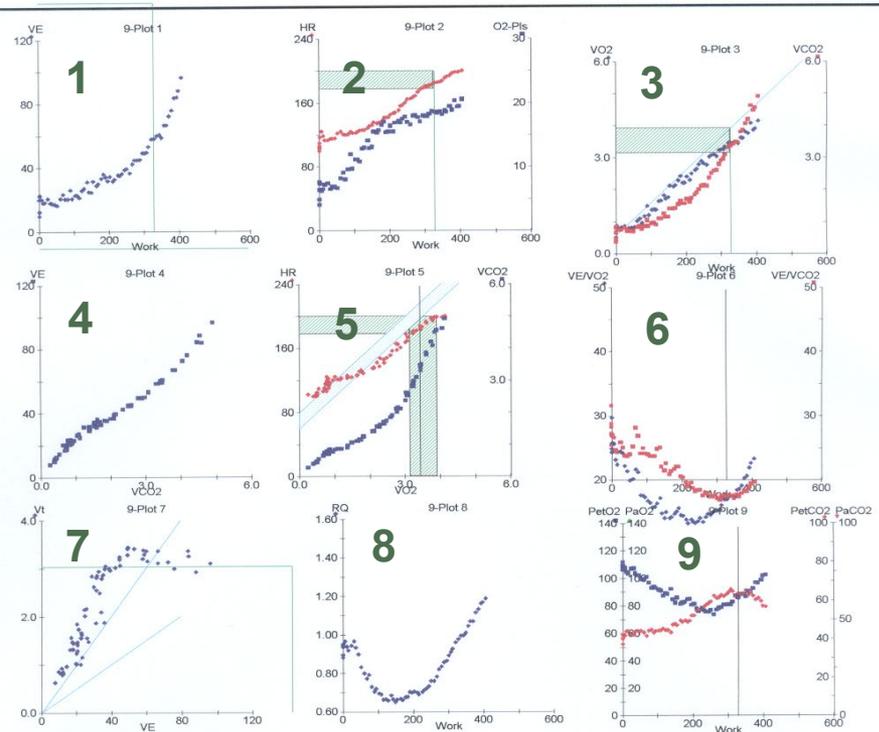
	Teorici	Misurati	% Teorici
<b>Risposta Cardiovascolare</b>			
VO2 Max (l/min)	3.560	4.007	113
Soglia Anaerobica (l/min)	1.42	3.462	243
AT (% Max VO2 Teorico)	> 40%	97	
Carico Lavoro Max (Watts)	329	402	122
VO2/WR Slope	10.3		
Polso O2 (ml/b)	18.2	19.9	109
Frequenza Cardiaca Max	190	201	106
Pressione Sistolica Max	198		
Pressione Diastolica Max			
<b>Risposta Ventilatoria</b>			
VE Max	144.0	98.6	68
Riserva Respiratoria (%)		30	
Frequenza Respiratoria	< 50		
<b>Scambi Gassosi</b>			
End Tidal CO2 (PetCO2)		57.4	
End Tidal O2 (PetO2)		102.9	
VE/VO2 @ AT	25-27	17	65
VEN/CO2 @ AT	28-30	17	60
VD/VT Rest (Est.)	0.30	0.15	50
VD/VT Max (Est.)	<0.20	0.09	49
Quoziente respiratorio (RQ) Max		1.17	
SpO2 (O2 Sat-Pulse Ox) Riposo			
SpO2 (O2 Sat-Pulse Ox) al Max			

Tarature

Flow Cal:	Pred Volume: 3.00		Expire Avg: 2.98		Inspire Avg: 2.96	
Gas Cal:	Cal 1 O2	Cal 1 CO2	Cal 2 O2	Cal 2 CO2	Ambient O2	Ambient CO2
Measured	16.10	3.97	26.11	0.00	20.90	0.08
Predicted	16.09	3.97	26.10	0.00		
Transit	0.08		0.101			
Response	0.512		0.406			

Il Medico:

Grafici della prova da sforzo CardioPolmonare



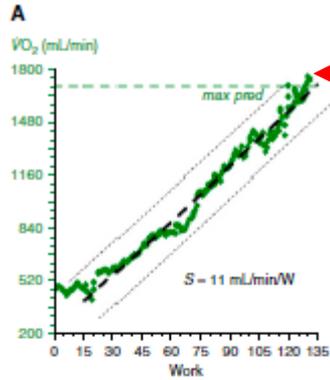
Parametro	Teorico	Misurato	% Teorico	Grafico N.
Max VO2(L/min)	3.560	4.007	113	1,3
Max Carico (Work) (W)	329	402	122	3
Max HR (BPM)	190	201	106	2
Max Polso O2 (ml/b)	18.2	19.9	109	5
VO2/WR (ml/watt)	10.3			3
HR/VO2 (beats/ml)	3.5	4	112	2
AT(L/min)	1.42	3.462	243	1,5,6,9
Max VE(L/min)	144.0	98.6	68	1,7
Riserva Respiratoria (%)				1,7
Quoziente Respiratorio (RQ)		1.17		8

Osservazione e Confronto

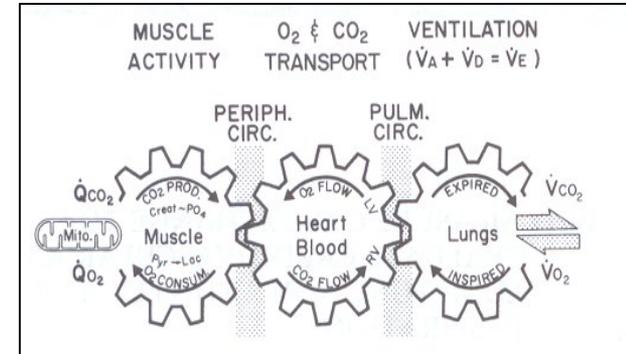
Analisi e identificazione

# Test da sforzo cardiopolmonare

NORMALE

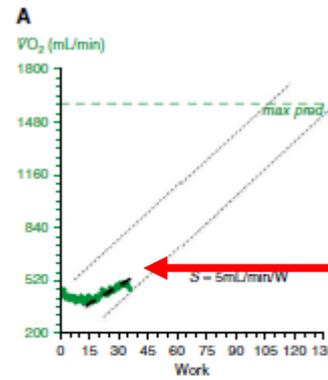
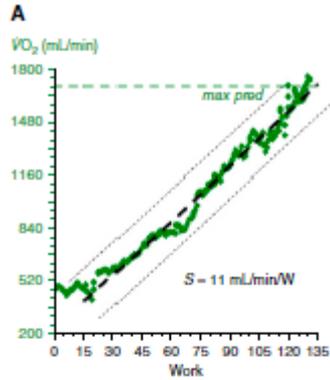


peakVO<sub>2</sub>



# Test da sforzo cardiopolmonare

PATOLOGICO

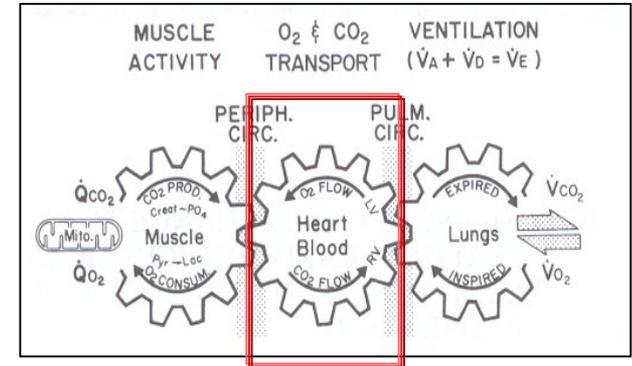
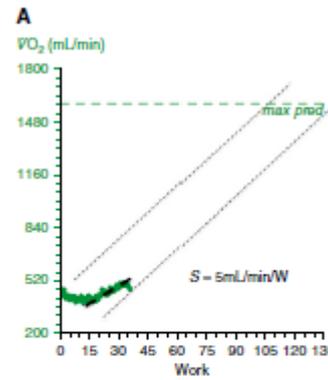
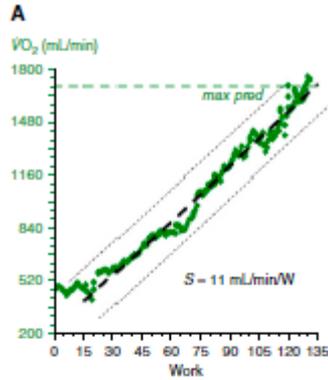


peakVO<sub>2</sub>

DISPNEA

# Test da sforzo cardiopolmonare: peakVO<sub>2</sub>

PATOLOGICO



DISPNEA

# VO<sub>2</sub>

## Classificazione di Weber

<b>Class</b>	<b>Severity</b>	<b>VO<sub>2</sub> max</b> <i>(ml/kg/min)</i>
<b>A</b>	<b>None to mild</b>	<b>&gt; 20</b>
<b>B</b>	<b>Mild to moderate</b>	<b>16-20</b>
<b>C</b>	<b>Moderate to severe</b>	<b>10-16</b>
<b>D</b>	<b>Severe</b>	<b>&lt; 10</b>

**VO<sub>2</sub>**

## Value of Peak Exercise Oxygen Consumption for Optimal Timing of Cardiac Transplantation in Ambulatory Patients With Heart Failure

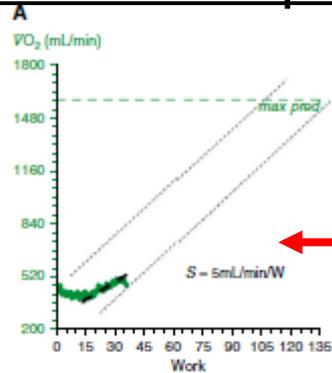
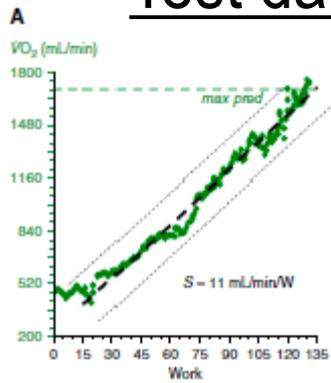
Donna M. Mancini, MD; Howard Eisen, MD; William Kussmaul, MD; Rebekah Mull, RN;  
L. Henry Edmunds Jr., MD; and John R. Wilson, MD

**Background.** Optimal timing of cardiac transplantation in ambulatory patients with severe left ventricular dysfunction is often difficult. To determine whether measurement of peak oxygen consumption ( $\dot{V}O_2$ ) during maximal exercise testing can be used to identify patients in whom transplantation can be safely deferred, we prospectively performed exercise testing on all ambulatory patients referred for transplant between October 1986 and December 1989.

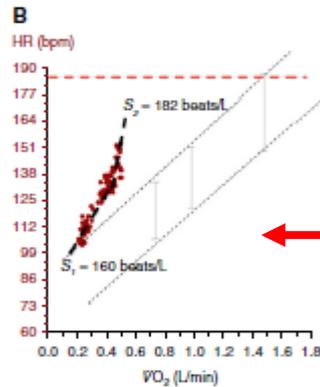
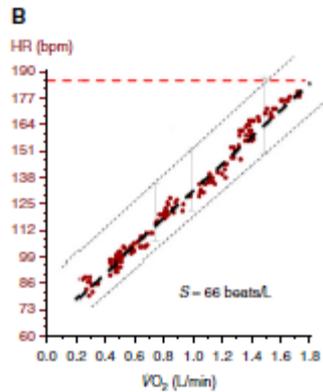
**Methods and Results.** Patients were assigned into one of three groups on the basis of exercise data: Group 1 ( $n=35$ ) comprised patients accepted for transplant ( $\dot{V}O_2 \leq 14$  ml/kg/min); group 2 ( $n=52$ ) comprised patients considered too well for transplant ( $\dot{V}O_2 > 14$  ml/kg/min); and group 3 ( $n=27$ ) comprised patients with low  $\dot{V}O_2$  rejected for transplant due to noncardiac problems. All three groups were comparable in New York Heart Association functional class, ejection fraction, and cardiac index ( $p=NS$ ). Pulmonary capillary wedge pressure was significantly lower in group 2 than in either group 1 or 3 ( $p < 0.05$ ), although there was wide overlap. Patients with preserved exercise capacity (group 2) had cumulative 1- and 2-year survival rates of 94% and 84%, which are equal to survival levels after transplantation. In contrast, patients rejected for transplant (group 3) had survival rates of only 47% at 1 year and 32% at 2 years, whereas patients in group 1 had a survival rate of 70% at 1 year (both  $p < 0.005$  versus group 3). Death in group 2 were sudden. By univariate and multivariate analysis,  $\dot{V}O_2 < 14$  ml/kg/min was a predictor of survival, with only pulmonary capillary wedge pressure providing additional prognostic information.

**Conclusions.** These data suggest that cardiac transplantation can be safely deferred in ambulatory patients with severe left ventricular dysfunction and peak exercise  $\dot{V}O_2$  of more than 14 ml/min/kg. (*Circulation* 1991;83:778-786)

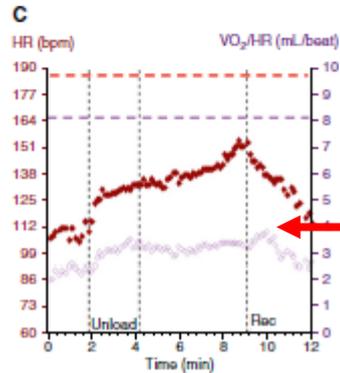
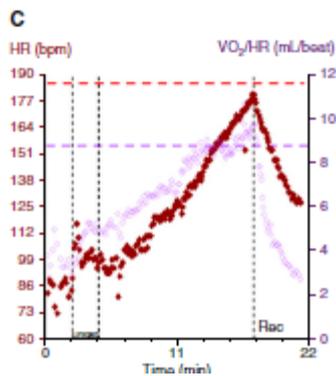
# Test da sforzo cardiopolmonare



← peak $\text{VO}_2$



← HR

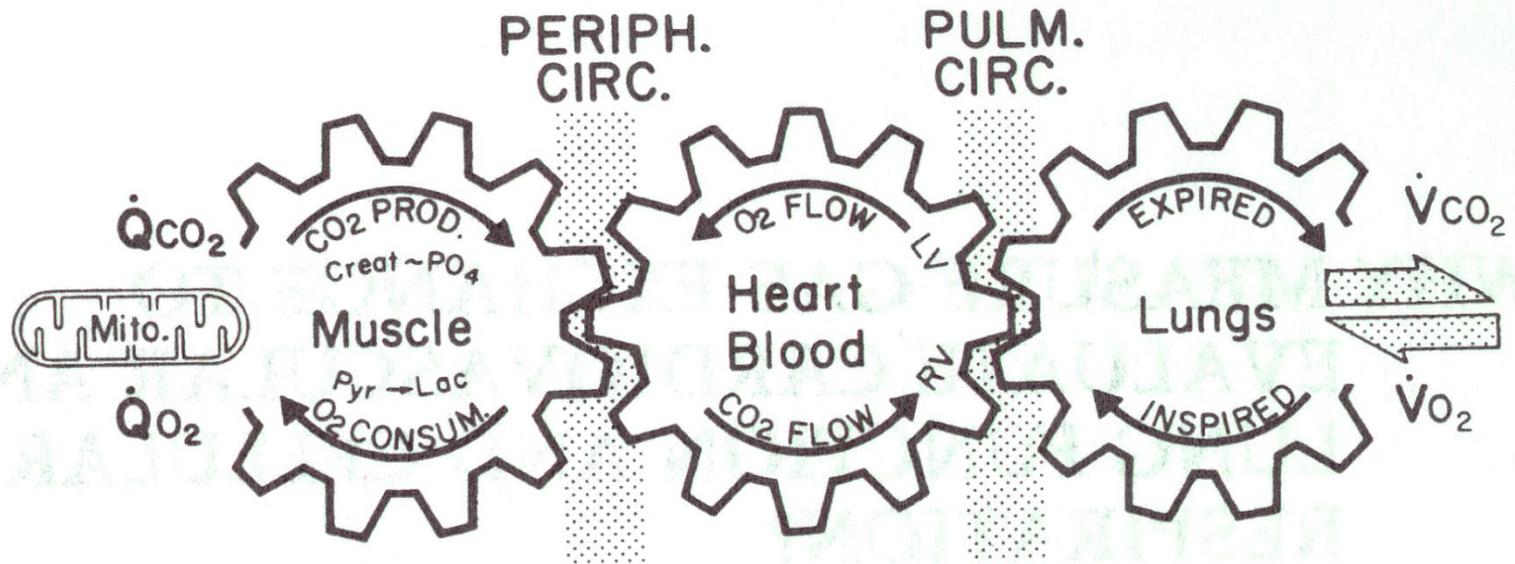


← polso $\text{O}_2$

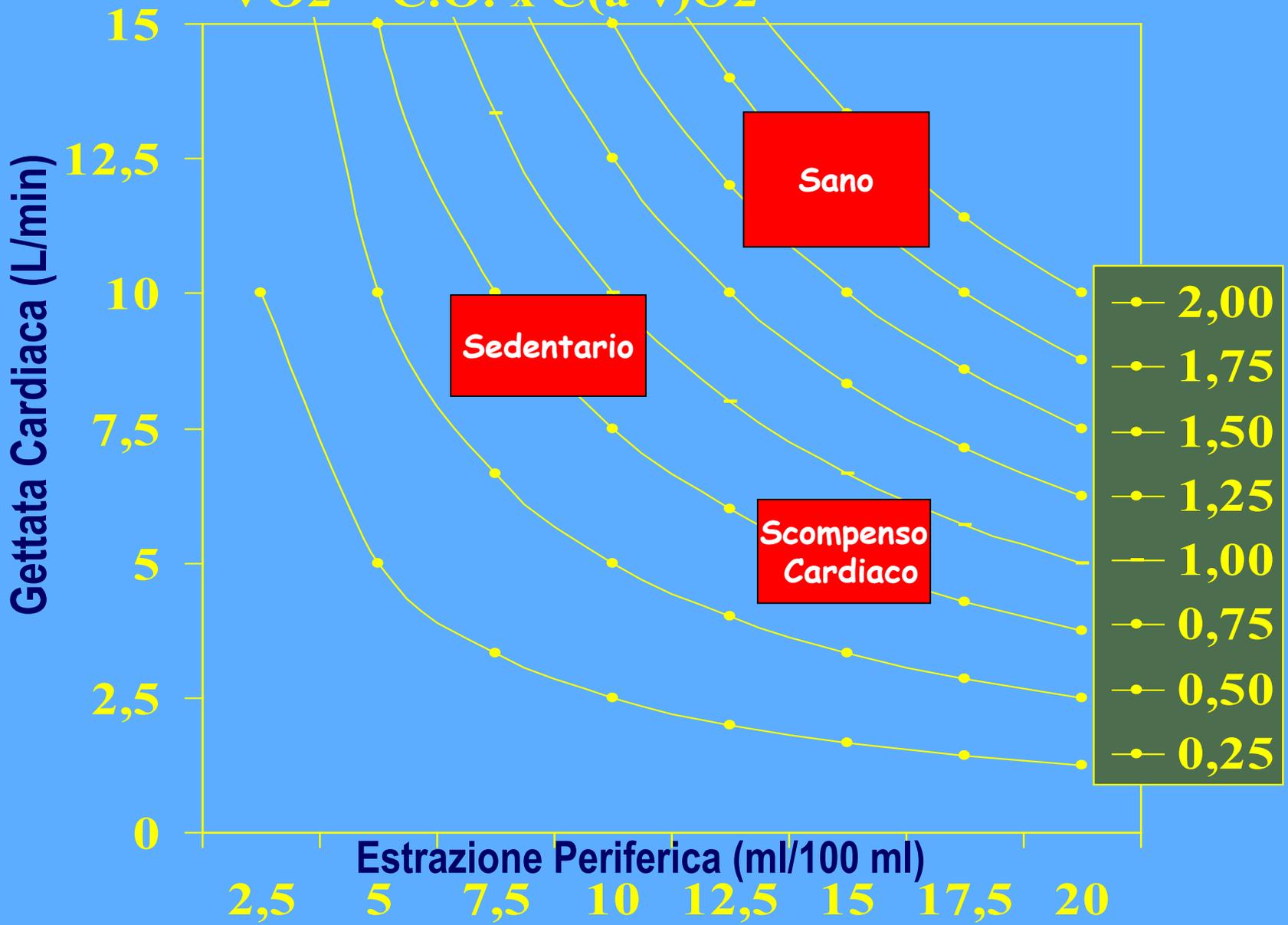
$\dot{V}O_2$

=

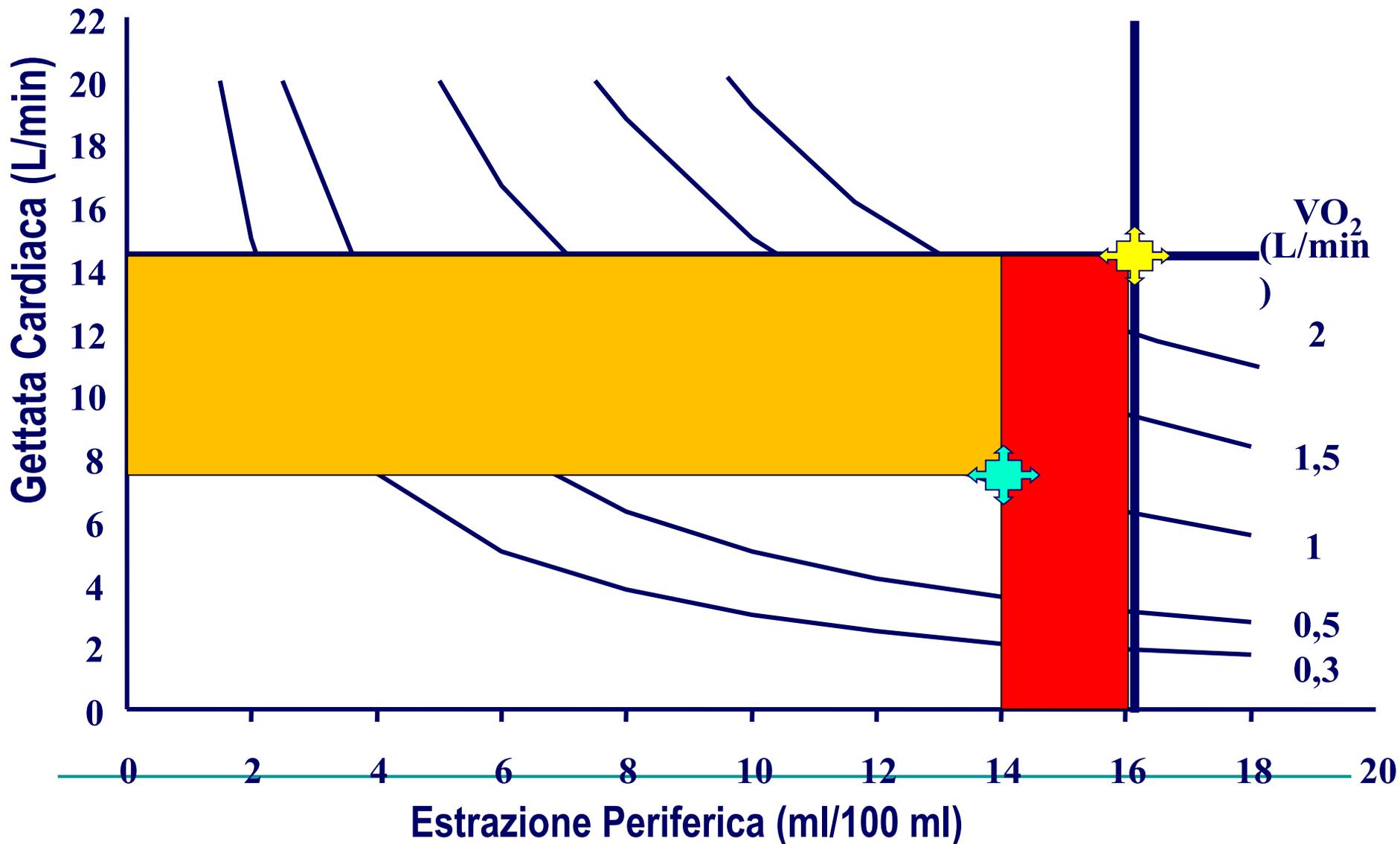
Estrazione Periferica  $O_2$  x Gettata Cardiaca



$$VO_2 = C.O. \times C(a-v)O_2$$

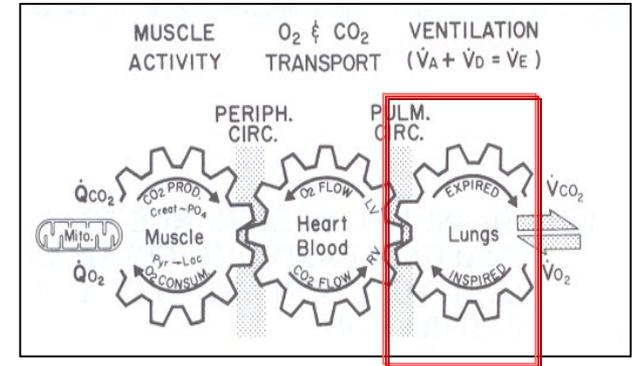
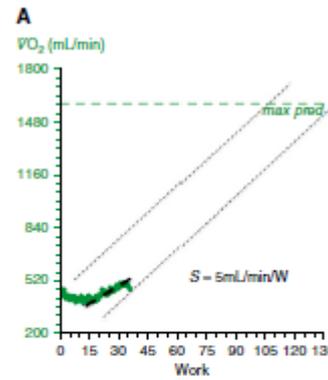
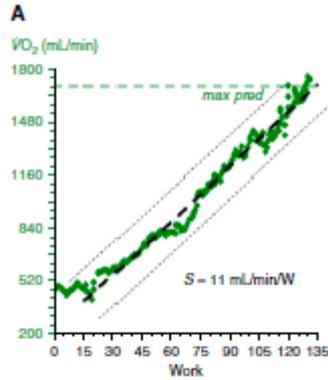


VO2 Pred = 2120    VO2 Measured 1080 (51%pred)



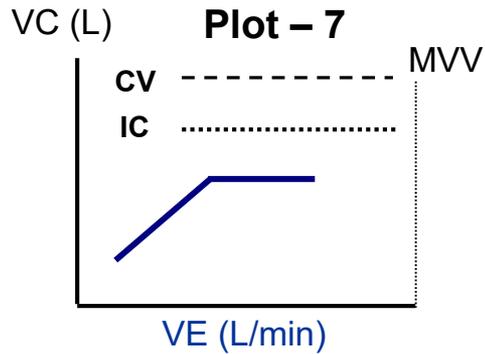
# Test da sforzo cardiopolmonare: peakVO<sub>2</sub>

PATOLOGICO

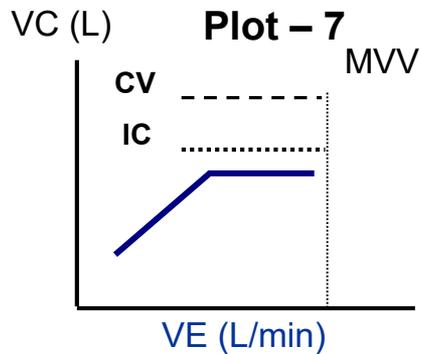


DISPNEA

# Pattern ventilatorio da sforzo



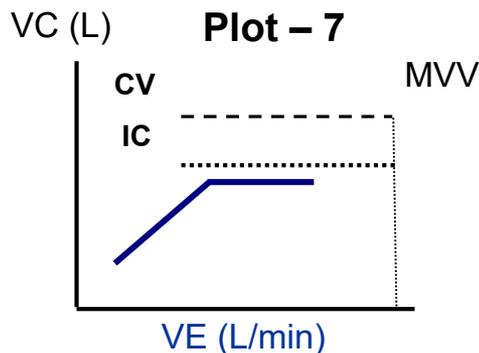
Normale



## Pneumopatia Ostruttiva *(erosione della riserva respiratoria)*

Nelle sindromi polmonari ostruttive la ventilazione all'apice dell'esercizio si avvicina alla MVV. In tal modo la riserva respiratoria ( $BR = MVV - VE$ ) risulta essere approssimativamente uguale a zero.

**BR al picco Normale >20%**



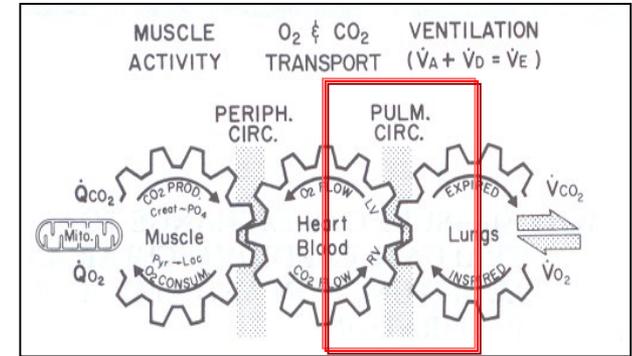
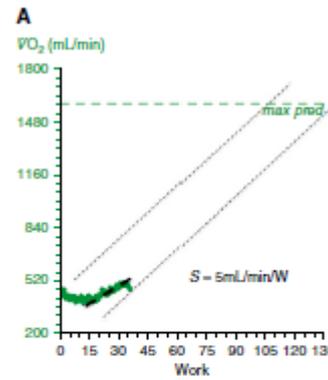
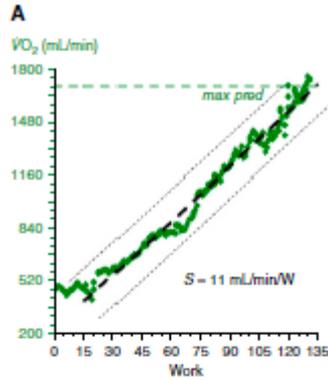
## Pneumopatia Restrittiva

*(raggiungimento precoce della capacità inspiratoria e aumento cospicuo della frequenza respiratoria)*

Nel caso di sindrome polmonare restrittiva il Volume Corrente può avvicinarsi alla capacità inspiratoria a bassi carichi di lavoro e la frequenza ventilatoria può alla fine aumentare oltre ai 50 o 60.

# Test da sforzo cardiopolmonare: peakVO<sub>2</sub>

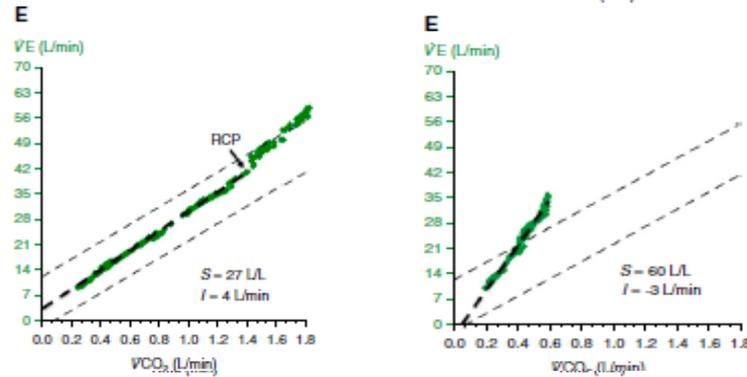
PATOLOGICO



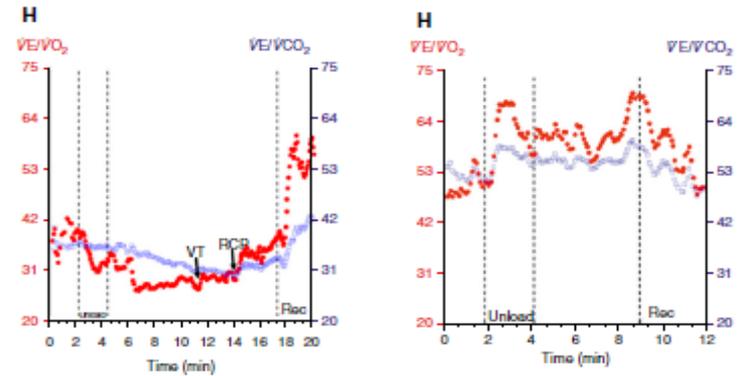
DISPNEA

# Test da sforzo cardiopolmonare: ventilazione

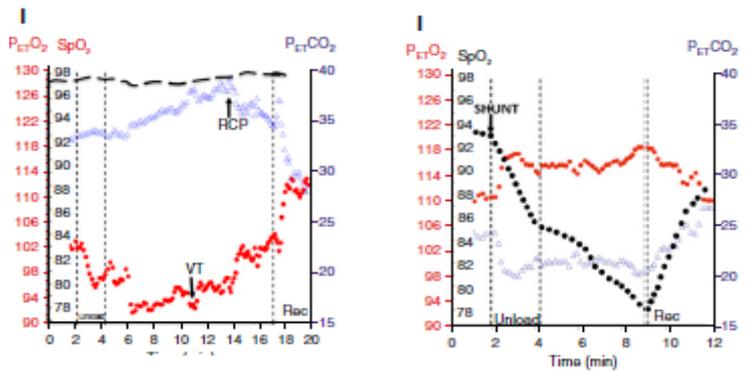
PAH



← slope VE/VCO<sub>2</sub>



$$VE = \frac{VCO_2 \times 863}{[PaCO_2 \times (1 - VD/VT)]}$$



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## Anamnesi

*Paziente di 67 anni, ricoverato per la comparsa da alcuni mesi di dispnea da sforzo.*

*Paziente affetto da cardiopatia ischemica con anamnesi positiva per IMA anteriore e successiva PTCA + stent su IVA prossimale.*

*Recente test da sforzo in terapia risultato non indicativo di ridotta riserva coronarica.*

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Protocollo:

Misurati

Teorici

% Teorici

Spirometria FVC (L)  
FEV1 (L)  
MVV(L)

Dati a riposo

HR 86 1/min

SBP mmHg

DBP mmHg

	Teorici	Misurati	% Teorici
<b>Risposta Cardiovascolare</b>			
VO2 Max (l/min)	2.056	1.881	92
VO2/Kg Max (ml/kg/min)		21.6	
Soglia Anaerobica (l/min)	0.82	0.833	101
AT (% Max VO2 Teorico)	> 40%	40	
Carico Lavoro Max (Watts)	160	100	63
VO2/WR Slope	10.3	10.3	
Polso O2 (ml/b)	14.8	15.7	106
Frequenza Cardiaca Max	152	120	79
Pressione Sistolica Max	167		
Pressione Diastolica Max			

Risposta Ventilatoria

	Teorici	Misurati	% Teorici
VE Max	28.8	103.5	360
Riserva Respiratoria (%)			
Frequenza Respiratoria	< 50	34	

Scambi Gassosi

VE/VO2 Slope		53.4	
End Tidal CO2 (PetCO2)		21.4	
End Tidal O2 (PetO2)		127.2	
VE/VO2 @ AT	25-27	27	104
VE/VO2 @ AT	28-30	40	138
VD/VT Rest (Est.)	0.30	0.24	81
VD/VT Max (Est)	<0.20	0.11	64

SpO2 (O2 Sat-Pulse Ox) Riposo  
SpO2 (O2 Sat-Pulse Ox) al Max

95

Tarature

Flow Cal:	Pred Volume: 3.00		Expire Avg: 3.02		Inspire Avg: 2.98	
Gas Cal:	Cal 1 O2	Cal 1 CO2	Cal 2 O2	Cal 2 CO2	Ambient O2	Ambient CO2
Measured	15.88	4.01	26.13	0.00	21.69	0.08
Predicted	15.88	4.01	26.06	0.00		
Transit	0.08		0.113			
Response	0.516		0.420			

Il Medico:

# VE/VCO<sub>2</sub> Slope

ISTITUTO DI CARDIOLOGIA  
CENTRO CARDIOLOGICO  
Unità Scopenso  
Tel. 02-580021 Via Parea,4 -Milano-

Pre

Plot View ---

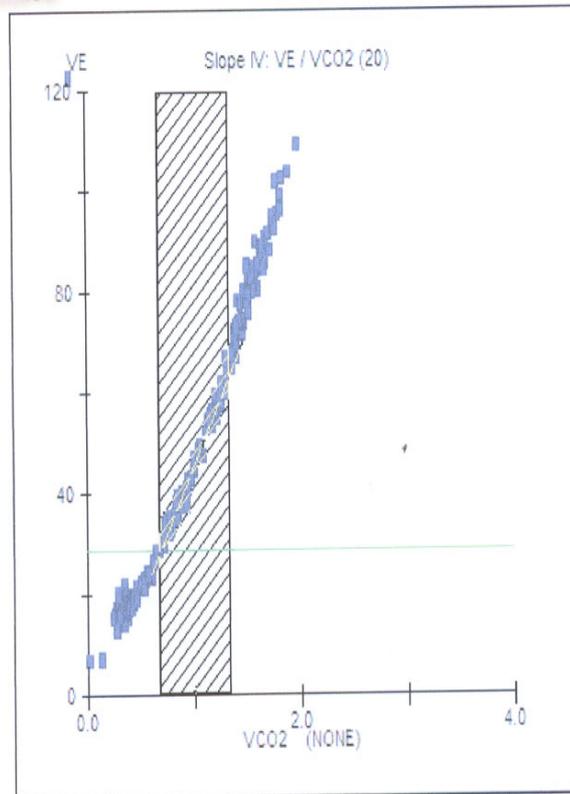
## Graph

- Vt e RQ vs time
- VO<sub>2</sub> W
- Slope I: VO<sub>2</sub>/Work
- Slope II: HR/VO<sub>2</sub> (20)
- Slope III: VE / VO<sub>2</sub> (20)
- Slope IV: VE / VCO<sub>2</sub> (20)

Slope: 53.4127

Intercept: -8.2248

X =  Y =



---

## Ecocardiogramma

### **Tricuspide**

Vel. max (m/s): 4

Grad. max (mmHg): 64

Stima Pressione

AD (mmHg): 6

Calcolo Pressione

Sistolica VD (mmHg): 70

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Axial  
Ex: 4292

A 156

\*\*\*\*

Centro Cardiologico Monzino  
M 53 00047567  
DoB: Mar 06 1957  
Ex: Nov 22 2010

Se: 4  
I: 161.5  
Im: 92  
DFOV 31.2cm  
STND/M No Filter

500ms

R

1  
5  
6

L

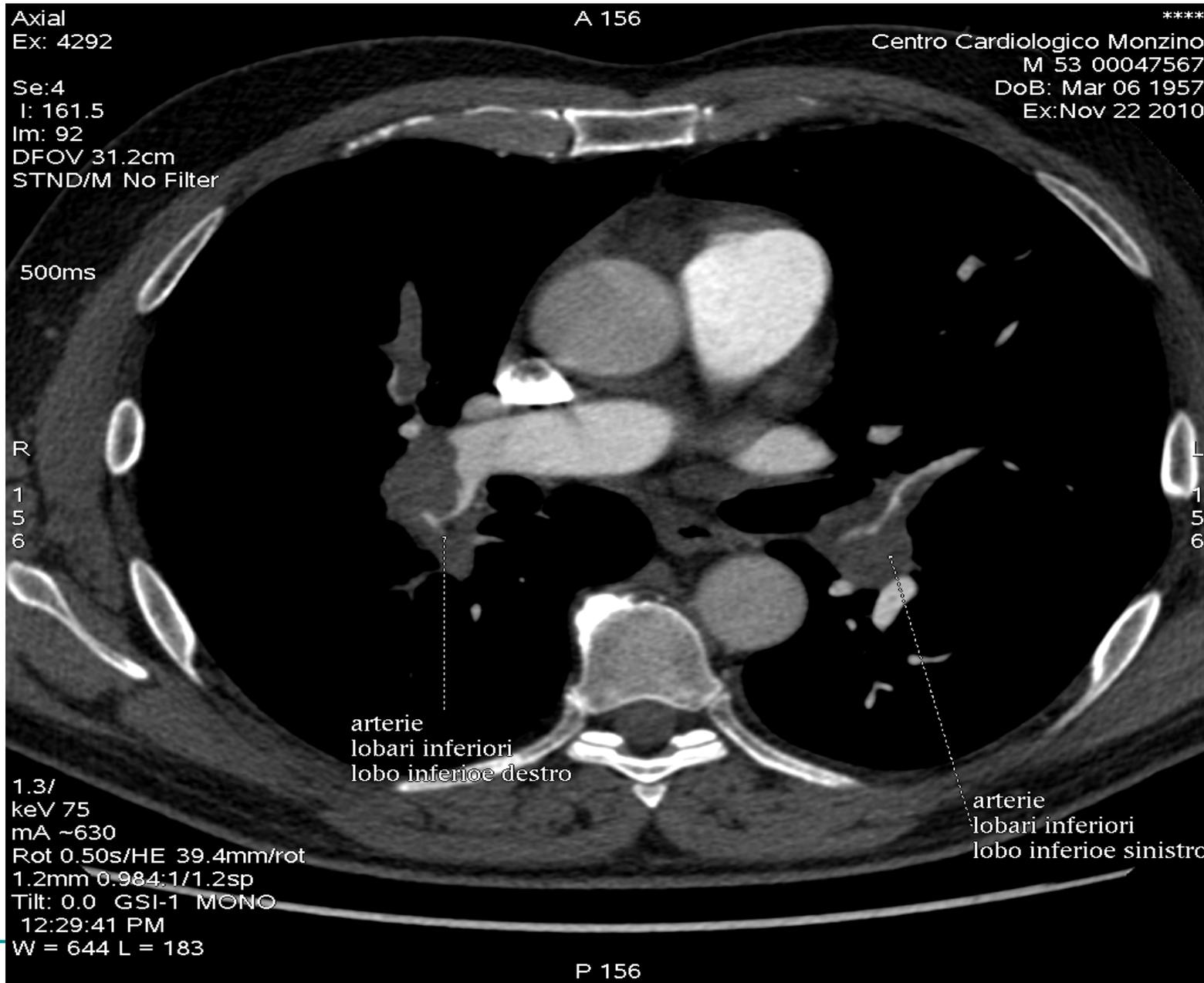
1  
5  
6

arterie  
lobari inferiori  
lobo inferiore destro

arterie  
lobari inferiori  
lobo inferiore sinistro

1.3/  
keV 75  
mA ~630  
Rot 0.50s/HE 39.4mm/rot  
1.2mm 0.984:1/1.2sp  
Tilt: 0.0 GSI-1 MONO  
12:29:41 PM  
W = 644 L = 183

P 156



# Post Terapia



ISTITUTO DI CARDIOLOGIA  
CENTRO CARDIOLOGICO  
Unità Scompenso  
Tel. 02-580021 Via Parea,4 -Milano-

Referti : prova da sforzo CardioPolmonare  
Protocollo: RAMPA 15

Nome: LANTERO, ALBERTO  
Id: ESTERNO  
Data: 29/11/06  
Età: 69  
Altezza: 172    Peso: 89.0

	Misurati	Teorici	% Teorici			
<b>Spirometria</b>						
FVC (L)		3.77				
FEV1 (L)		2.90				
MVV(L)						
<b>Dati a riposo</b>						
HR	88 1/min	SBP	170 mmHg			
		DBP	110 mmHg			
<b>Risposta Cardiovascolare</b>						
	Teorici	Misurati	% Teorici			
VO2 Max (l/min)	1.992	1.700	85			
VO2/Kg Max (ml/kg/min)		19.1				
Soglia Anaerobica (l/min)	0.80	1.075	135			
AT (% Max VO2 Teorico)	> 40%	54				
Carico Lavoro Max (Watts)	157	144	92			
VO2/WR Slope	10.3	9.8	95			
Polso O2 (ml/b)	14.8	13.0	88			
Frequenza Cardiaca Max	151	131	87			
Pressione Sistolica Max	166	220	132			
Pressione Diastolica Max		140				
<b>Risposta Ventilatoria</b>						
VE Max	101.4	63.1	62			
Riserva Respiratoria (%)		38				
Frequenza Respiratoria	< 50	24				
<b>Scambi Gassosi</b>						
VE/VCO2 Slope		31.2				
End Tidal CO2 (PetCO2)		33.4				
End Tidal O2 (PetO2)		112.9				
VE/VO2 @ AT	25-27	27	102			
VE/VCO2 @ AT	28-30	32	111			
VD/VT Rest (Est.)	0.30	0.30	101			
VD/VT Max (Est)	<0.20	0.15	81			
Quoziente respiratorio (RQ) Max		1.06				
SpO2 (O2 Sat-Pulse Ox) Riposo		98				
SpO2 (O2 Sat-Pulse Ox) al Max	95	98				
<b>Tarature</b>						
Flow Cal:	Pred Volume: 3.00		Expire Avg: 2.98	Inspire Avg: 2.95		
Gas Cal:	Cal 1 O2	Cal 1 CO2	Cal 2 O2	Cal 2 CO2	Ambient O2	Ambient CO2
Measured	15.93	3.98	25.99	0.00	20.91	0.06
Predicted	15.95	3.98	26.01	0.00		
Transit	0.06		0.122			
Response	0.538		0.434			

Il Medico:

# Post Terapia

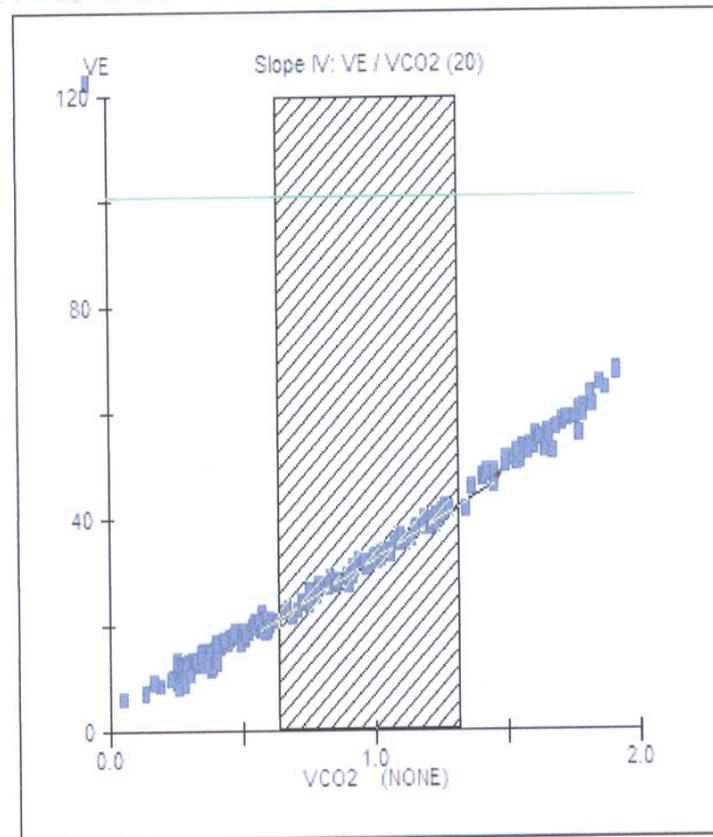
Plot View ---

- Graph
- Vt e RQ vs time
  - VO2 W
  - Slope I: VO2/Work
  - Slope II: HR/VO2 (20)
  - Slope III: VE / VO2 (20)
  - Slope IV: VE / VCO2 (20)

Slope: 31.2191

Intercept: 1.4763

X =  Y =



## Ecocardiogramma

### Tricuspide

Vel.:max (m/s): 2,3

Grad. max (mmHg): 21

Stima Pressione

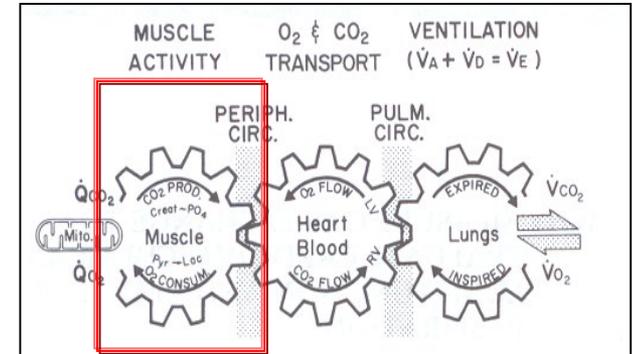
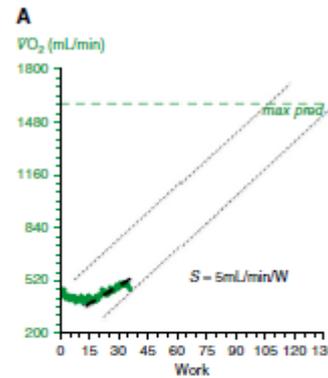
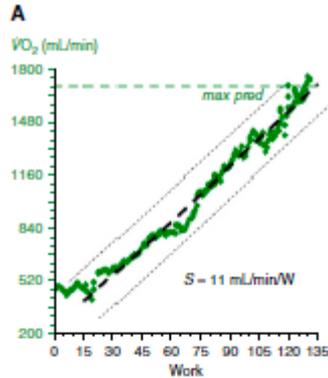
AD (mmHg): 6

Calcolo Pressione

Sistolica VD (mmHg): 27

# Test da sforzo cardiopolmonare: $\text{peakVO}_2$

PATOLOGICO



DISPNEA / AFFATICABILITA'

SECOND EDITION

# HEART DISEASE

*A Textbook of Cardiovascular Medicine*

Edited by

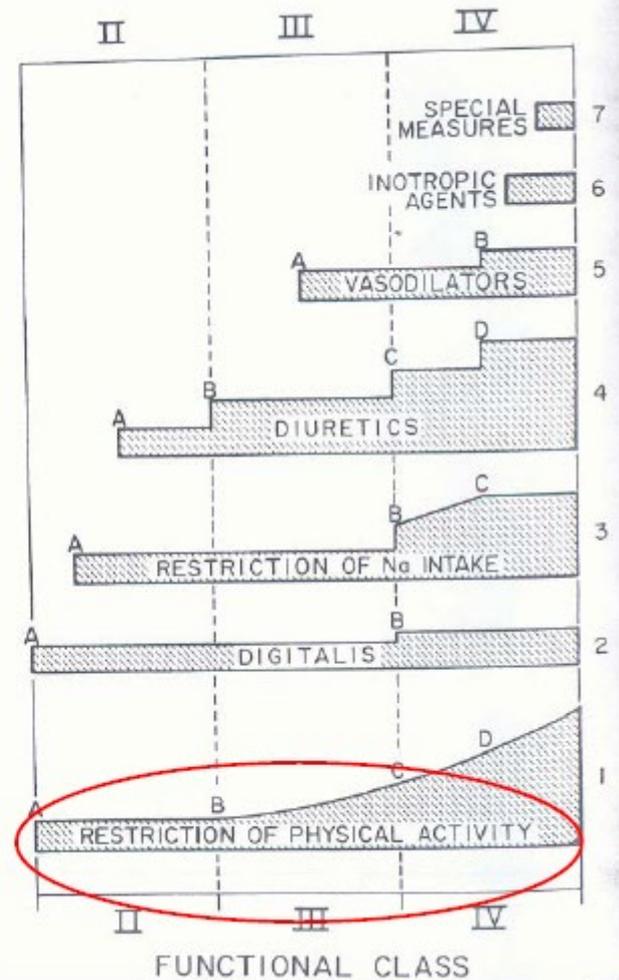
EUGENE BRAUNWALD, M.D.

Hersey Professor of the Theory and Practice of Physic,  
Herman Ludwig Blumgart Professor of Medicine, Harvard Medical School,  
Chairman, Department of Medicine,  
Brigham and Women's and Beth Israel Hospitals, Boston

1984

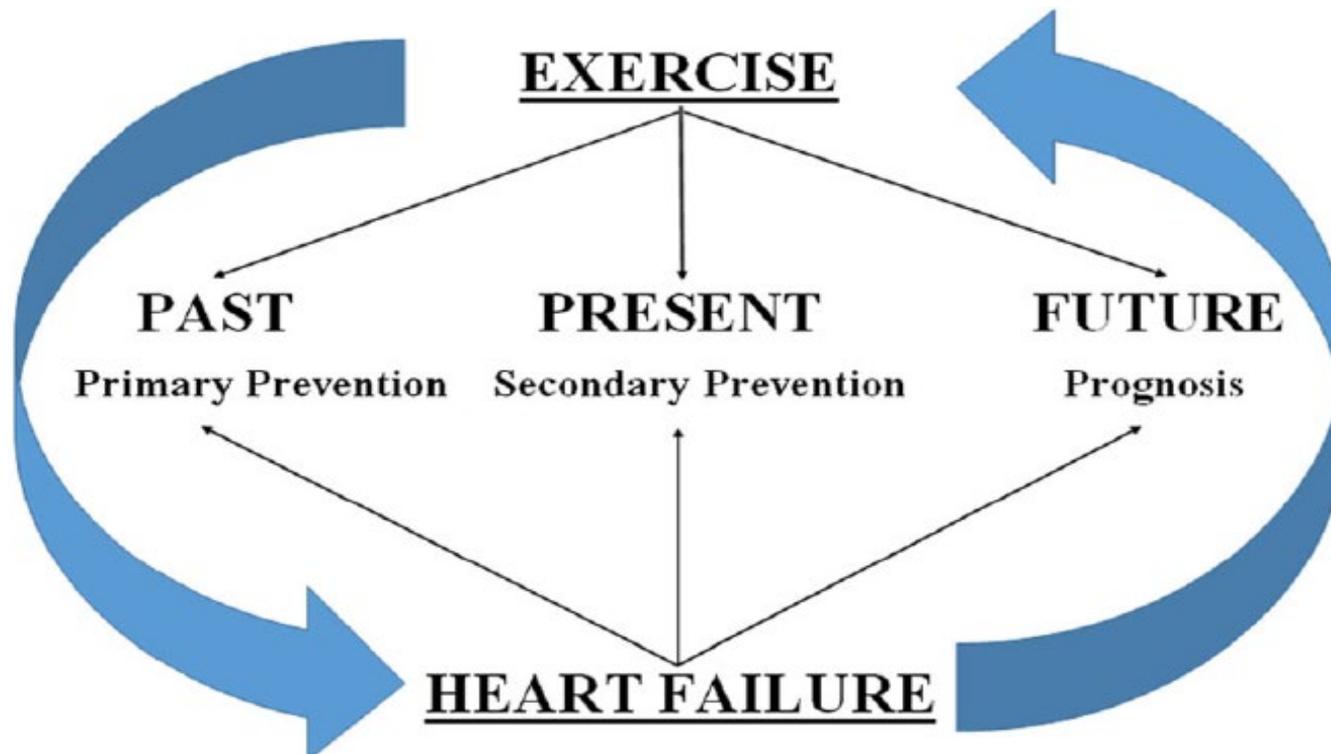
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## Exercise and heart failure: an update

Gaia Cattadori<sup>1\*</sup>, Chiara Segurini<sup>1</sup>, Anna Picozzi<sup>1</sup>, Luigi Padeletti<sup>1,2</sup> and Claudio Anzà<sup>1</sup>



# Exercise and the right ventricle: a potential Achilles' heel

**Andre La Gerche<sup>1,2,3\*</sup>, Dhrubo J. Rakhit<sup>1,4</sup>, and Guido Claessen<sup>2</sup>**

<sup>1</sup>Sports Cardiology and Cardiac Magnetic Resonance Imaging Lab, Baker Heart and Diabetes Institute, 75 Commercial Road, Melbourne, Victoria 3004, Australia; <sup>2</sup>Department of Cardiovascular Sciences, KU Leuven, Leuven, Belgium; <sup>3</sup>Cardiology Department, St Vincent's Hospital, Melbourne, Australia; and <sup>4</sup>Cardiovascular Imaging Department, Southampton University Hospital, Southampton, UK

Received 24 April 2017; revised 17 July 2017; editorial decision 19 July 2017; accepted 8 August 2017; online publish-ahead-of-print 14 August 2017



CrossMark



Canadian Journal of Cardiology 31 (2015) 502–508

## Review

# Is Exercise Good for the Right Ventricle? Concepts for Health and Disease

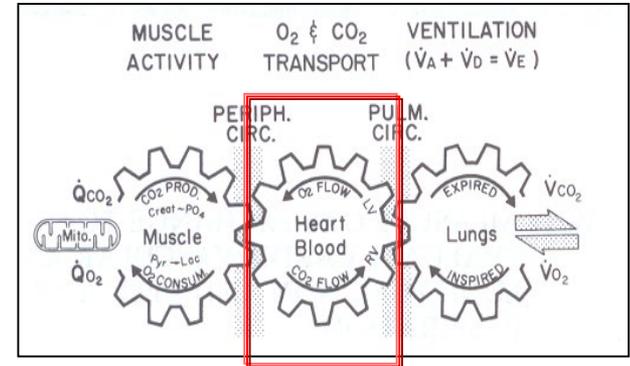
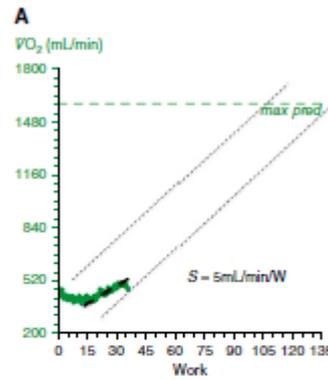
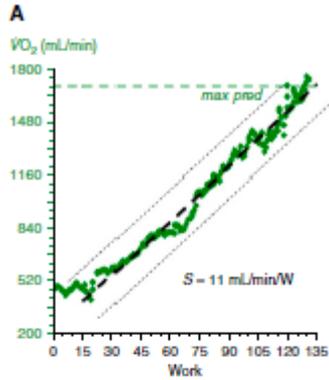
André La Gerche, MD, PhD,<sup>a,b</sup> and Guido Claessen, MD<sup>b</sup>

<sup>a</sup>Baker IDI Heart and Diabetes Institute, Melbourne, Australia

<sup>b</sup>Department of Cardiovascular Medicine, University of Leuven, Leuven, Belgium

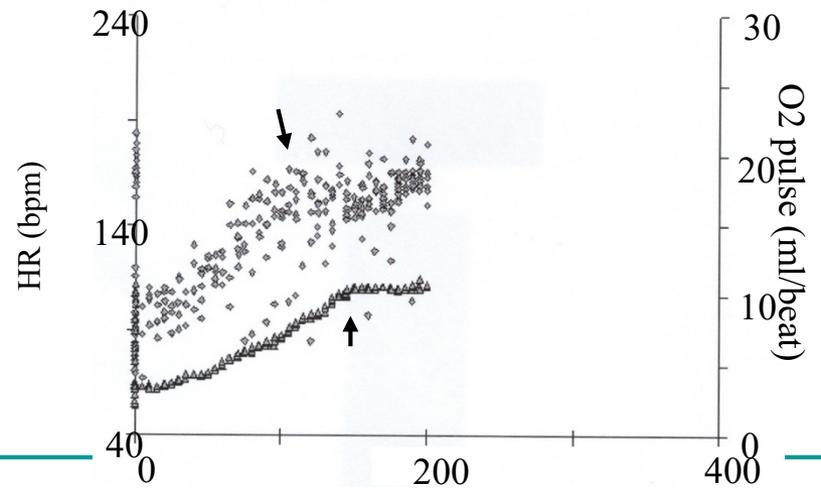
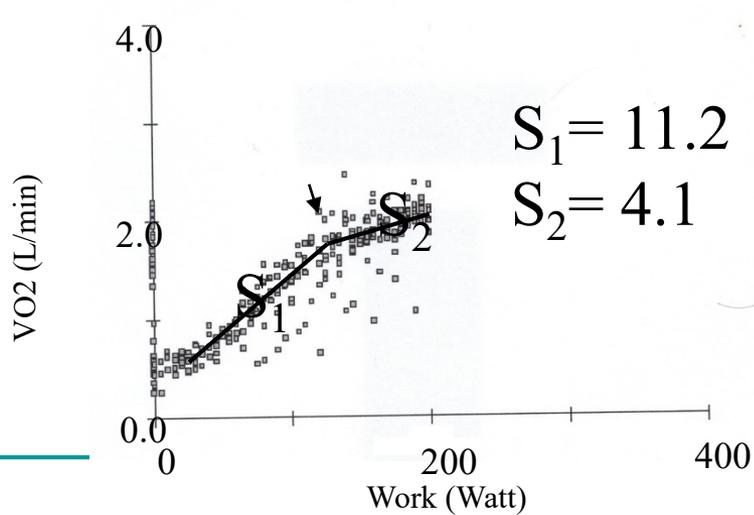
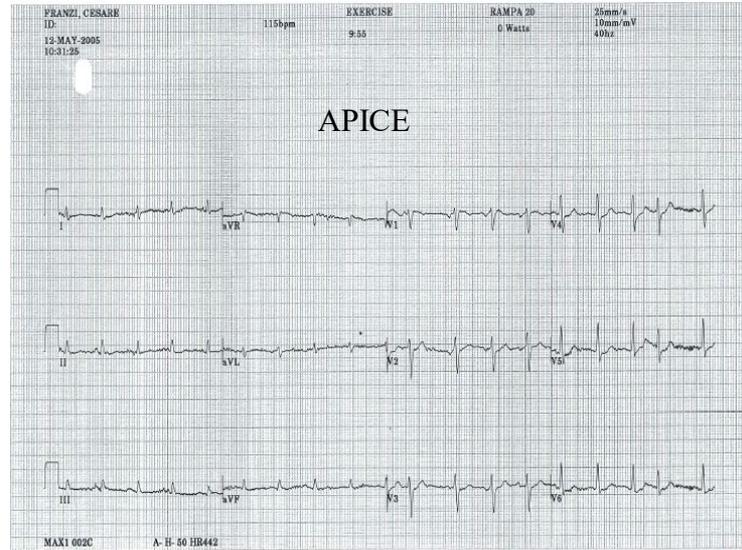
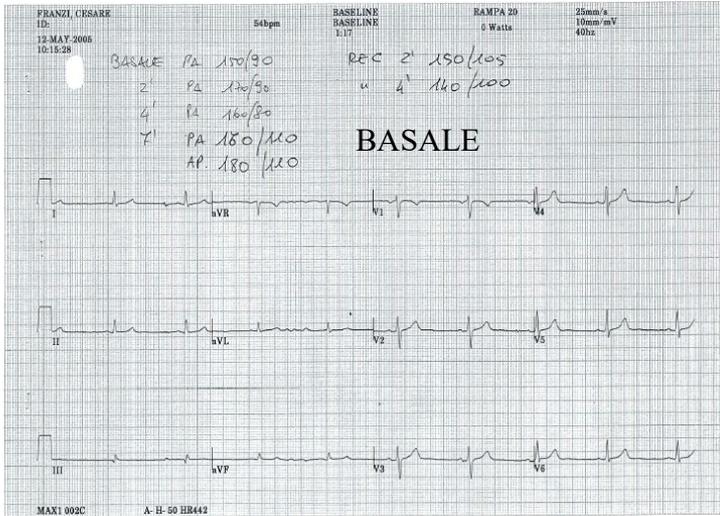
# Test da sforzo cardiopolmonare: peakVO<sub>2</sub>

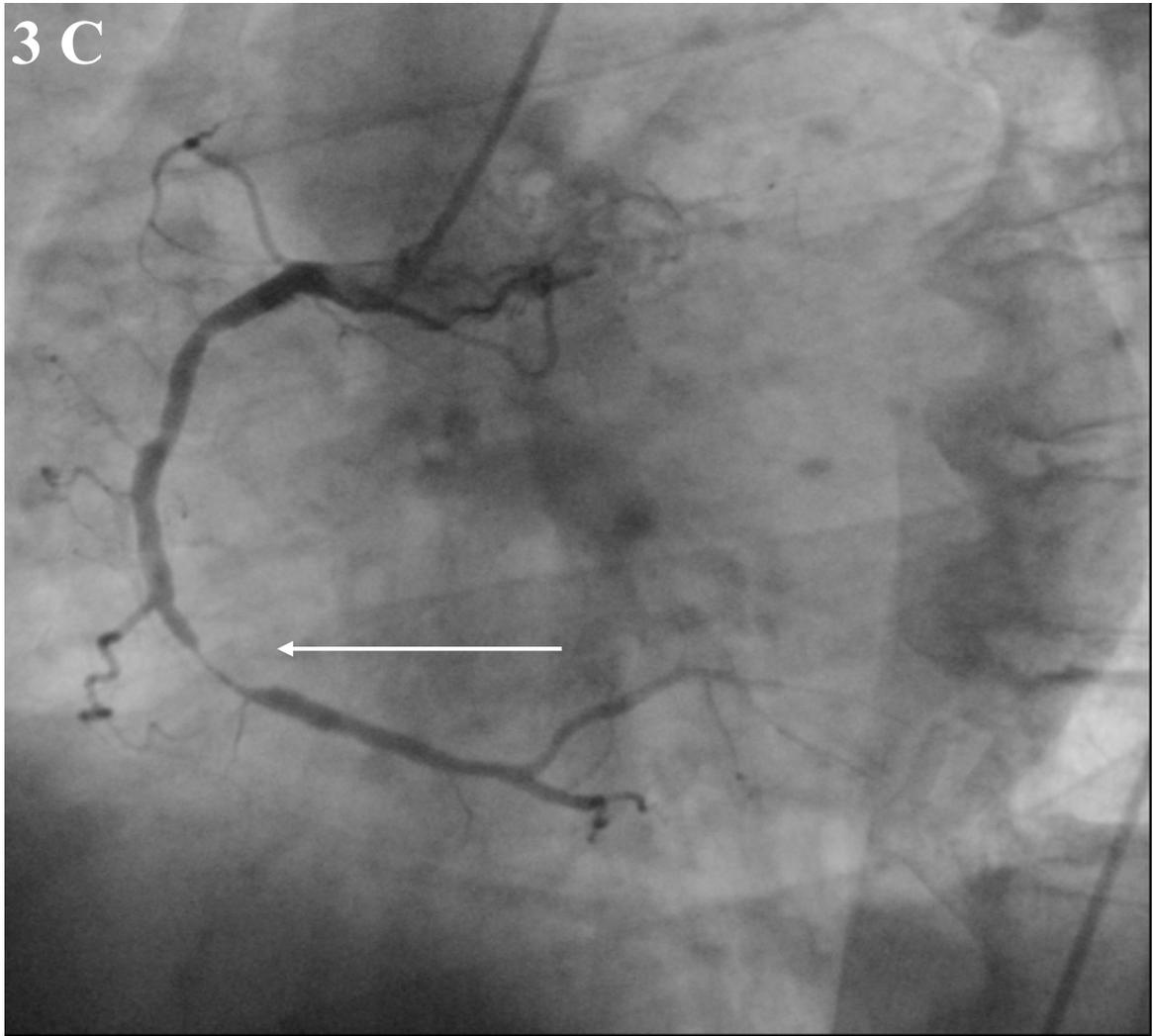
PATOLOGICO



DOLORE TORACICO

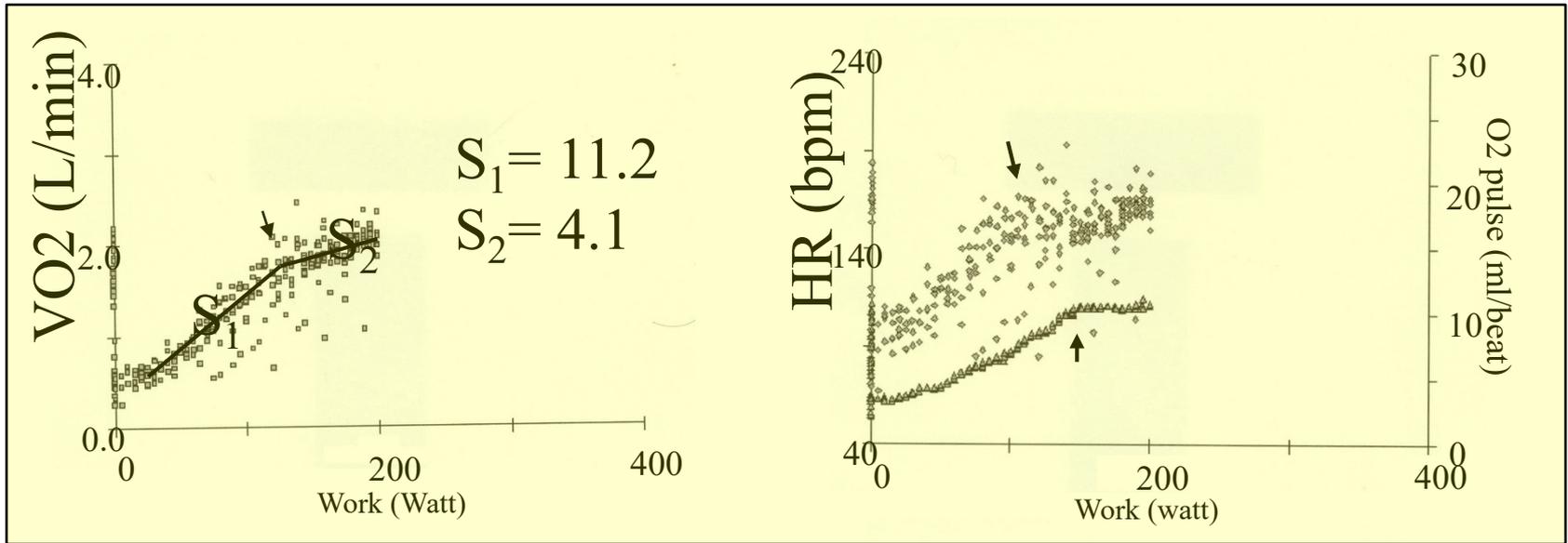
# $\Delta VO_2 / \Delta \text{Work}$



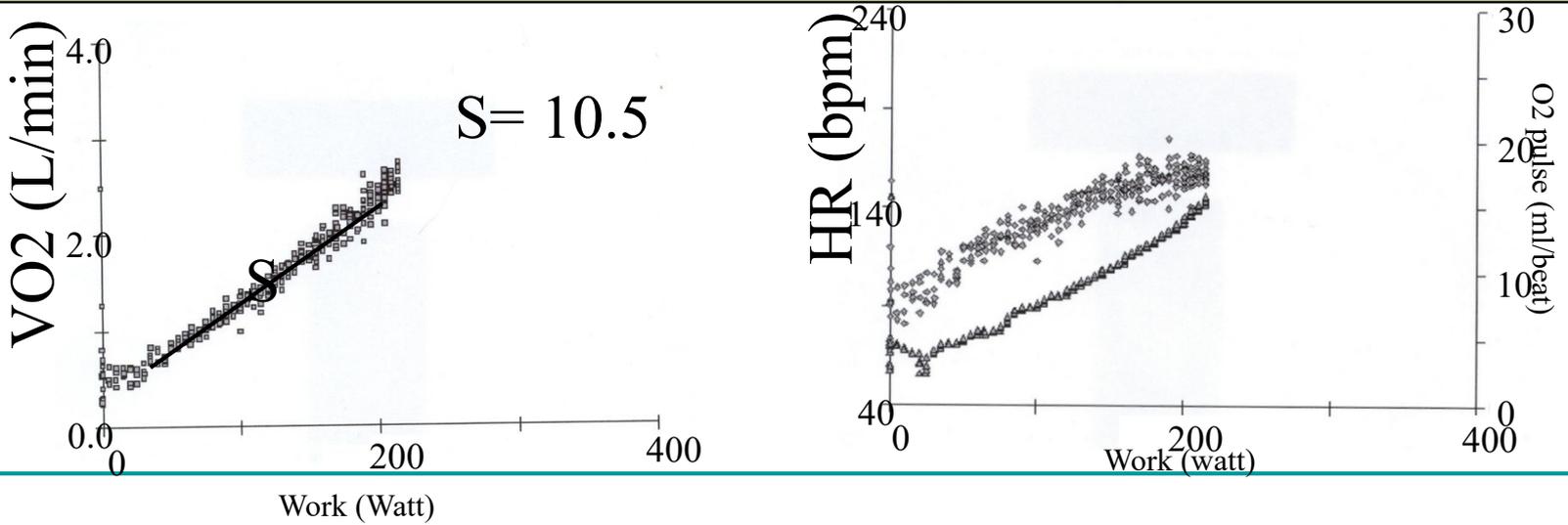


# $\Delta VO_2 / \Delta \text{Work}$

Pre PTCA



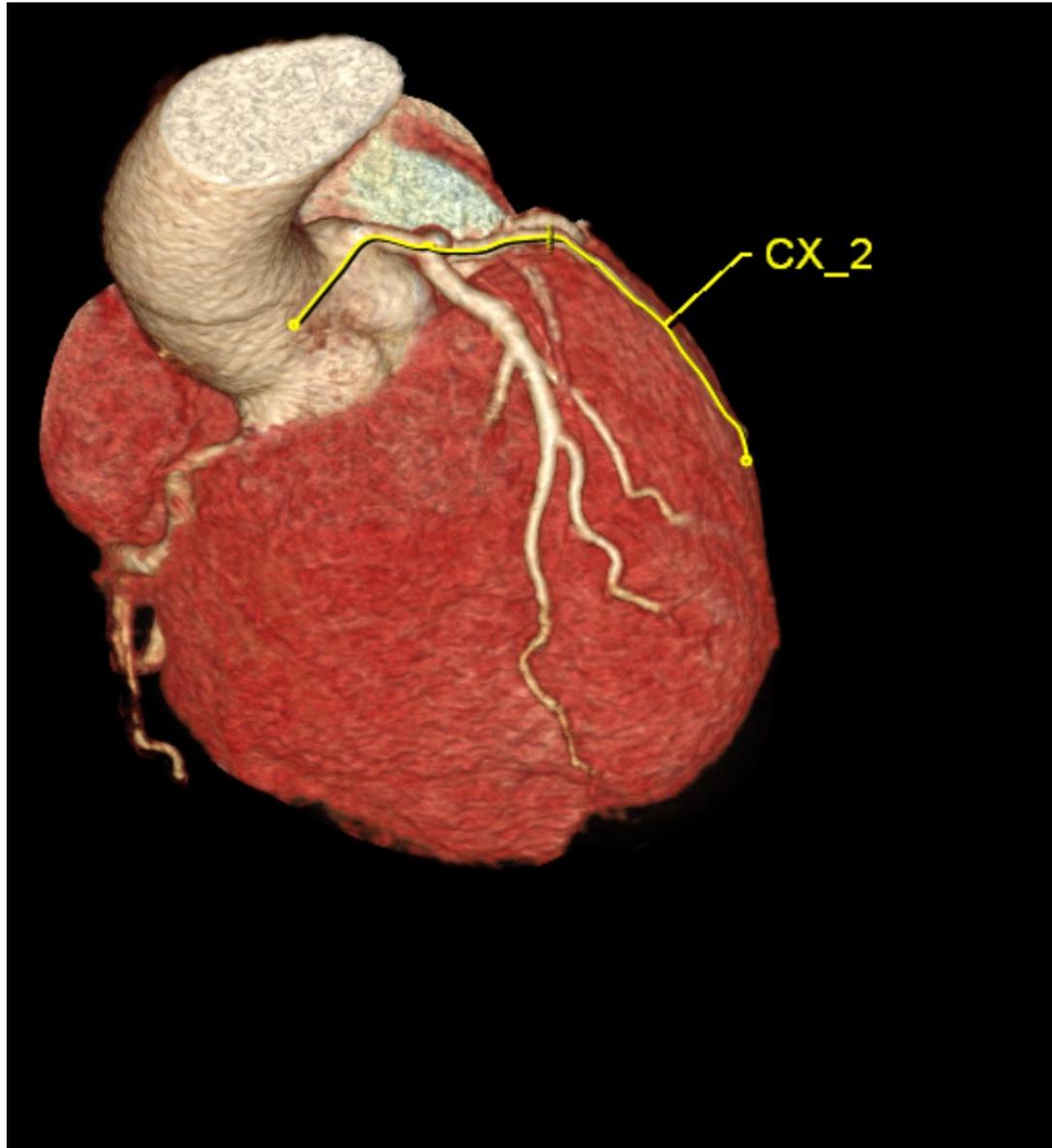
Post PTCA

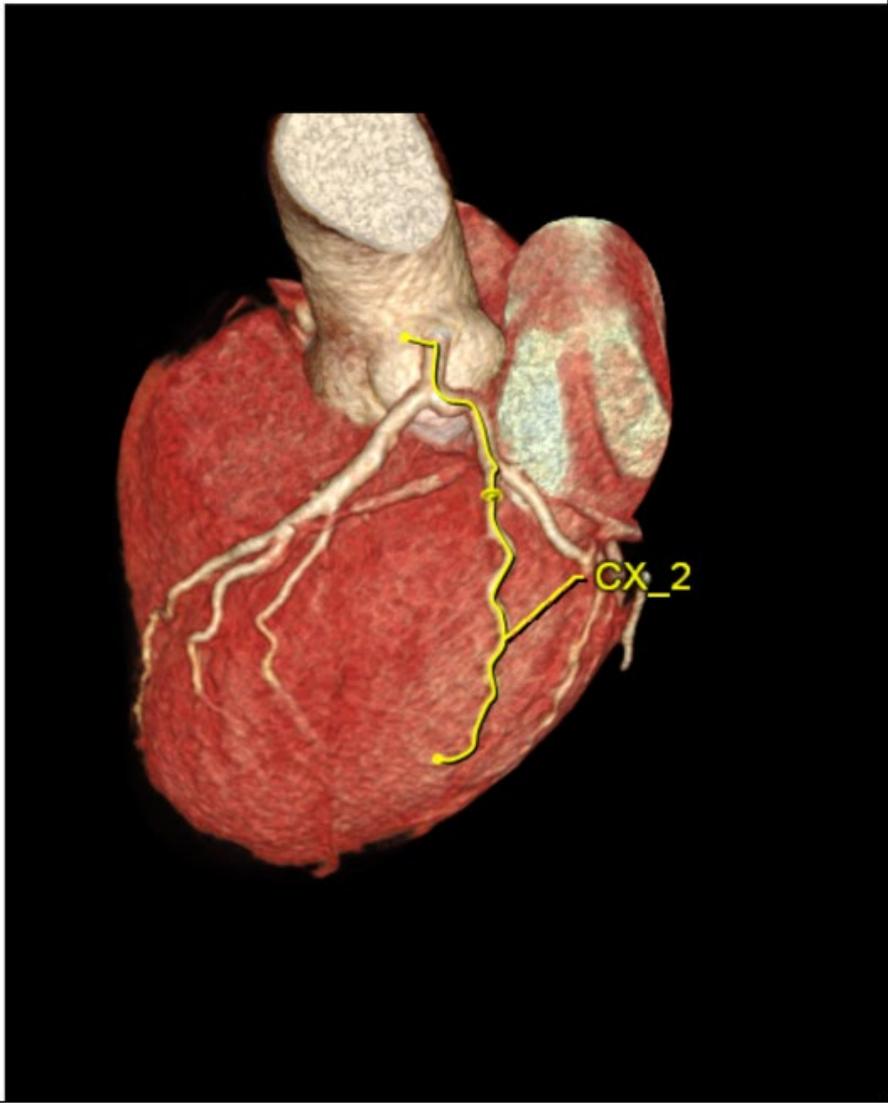


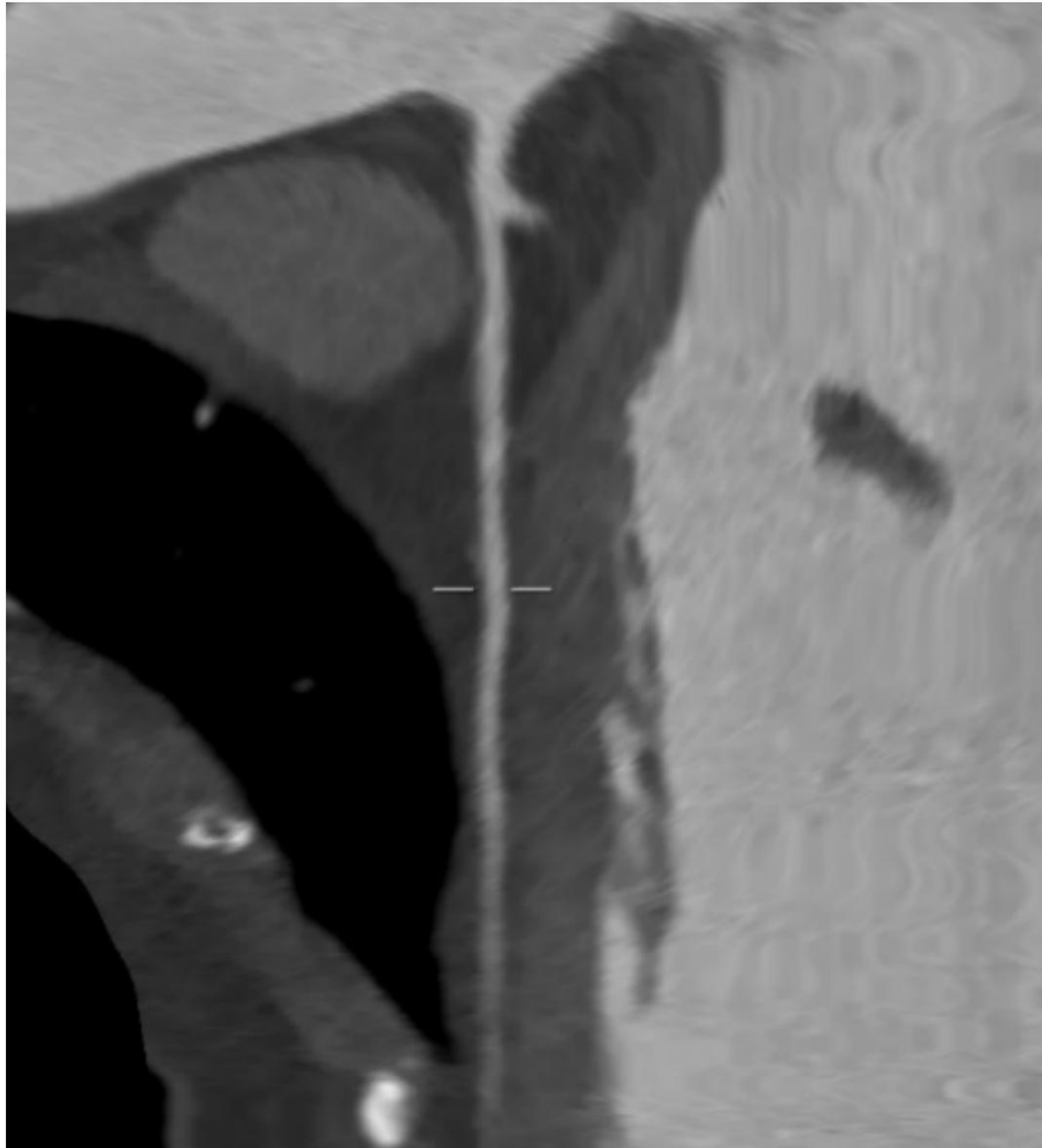
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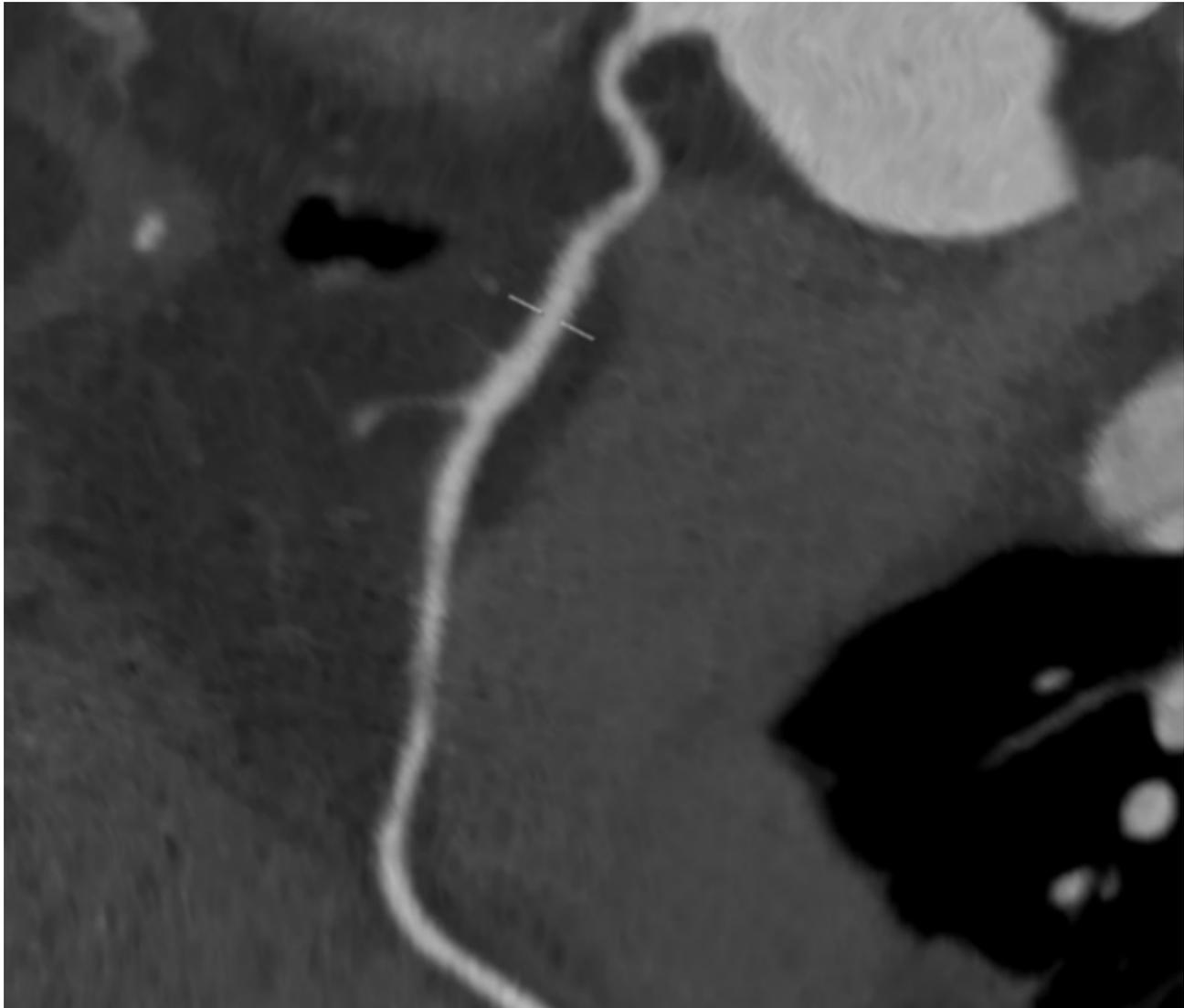
# TC CORONARICA

- Somministrazione di mdc
- Dose radiante

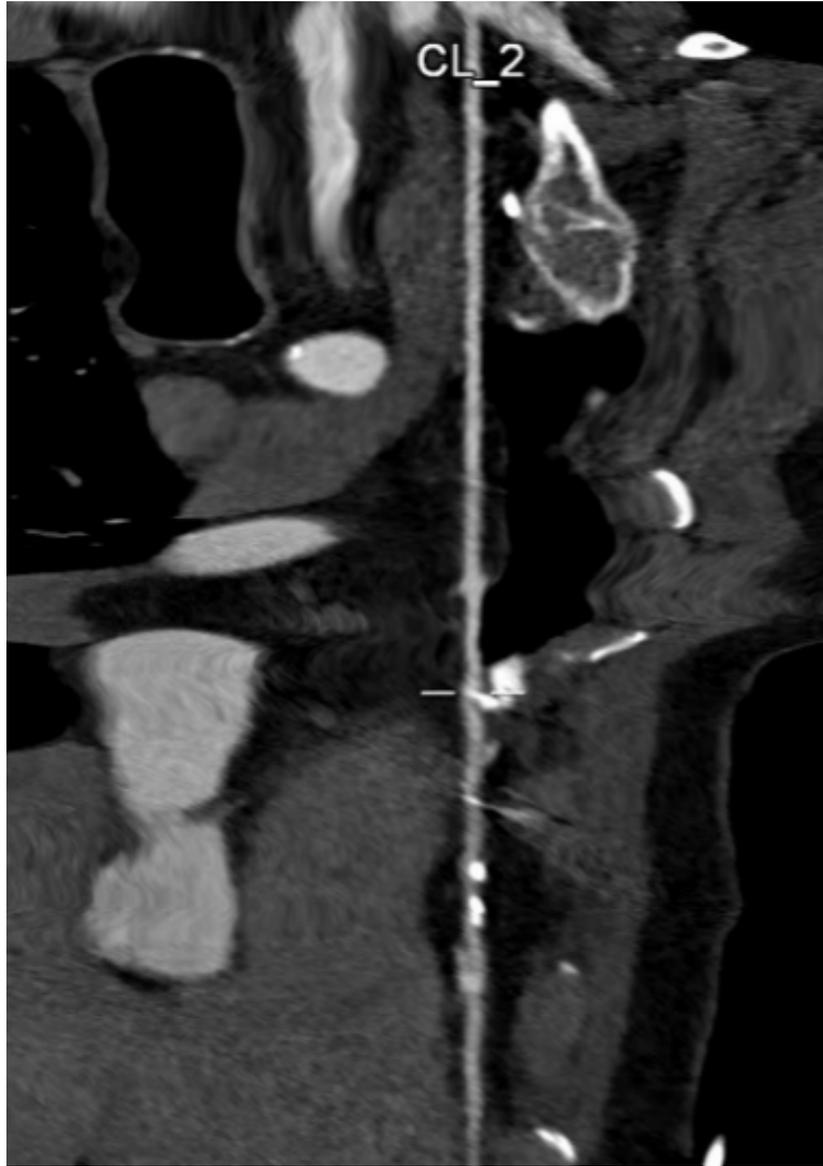












# INDICAZIONI

- Probabilità pre-test lieve-moderata (15-85%) di coronaropatia
- FC non elevata e regolare (attenzione alle extrasistoli!)
- Paziente collaborante
- GFR > 30 ml/min
- Attenzione alle allergie

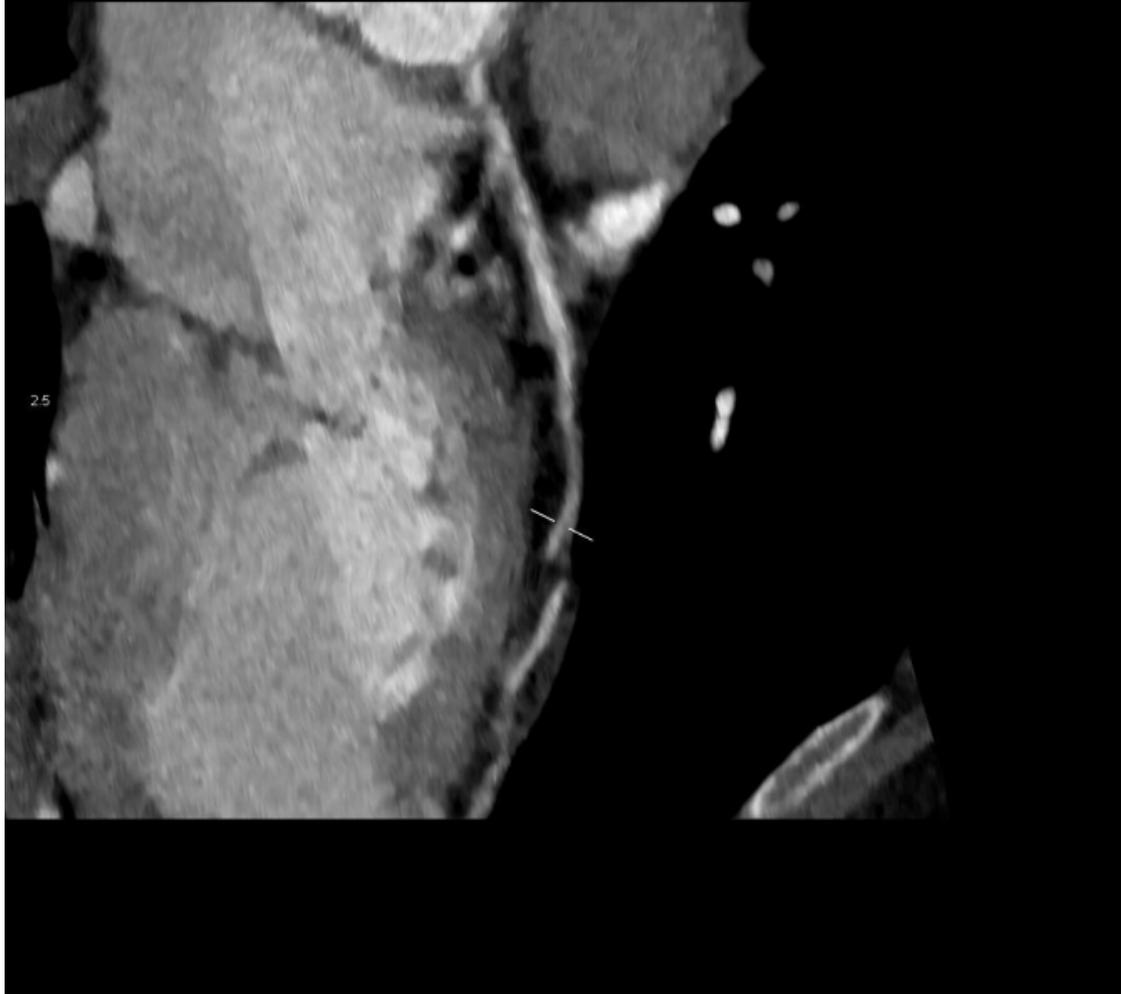
# LIMITI TECNICI

- ❑ FC (ed extrasistoli)
- ❑ Artefatti da presenza di calcio o metalli (effetto blooming)





LAD



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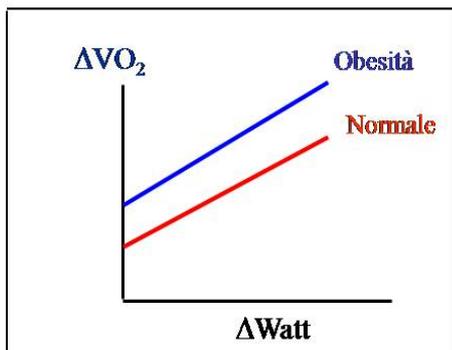
# TC CORONARICA

- Esame rapido e non invasivo
- Poche controindicazioni
- Alta sensibilità
- Alto VPN ( -> prognosi)

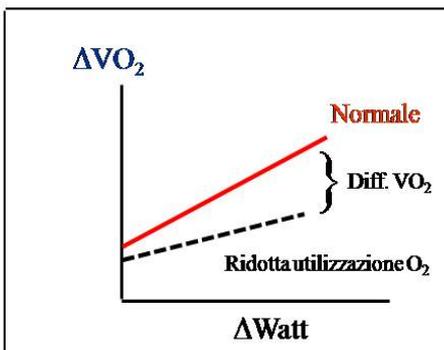
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...grazie per l'attenzione.

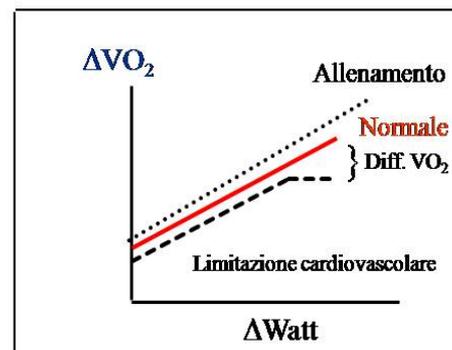
# $\Delta VO_2 / \Delta \text{Work}$



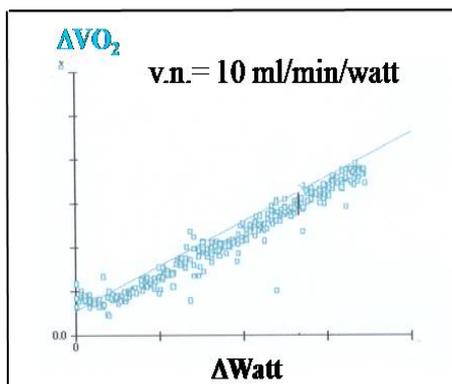
Posizione



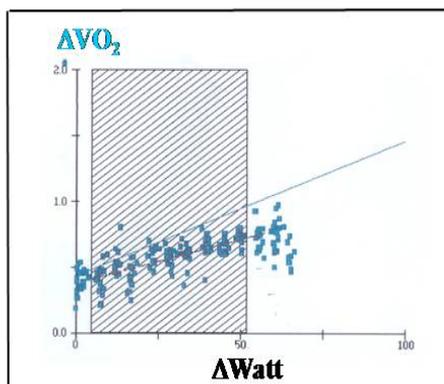
Pendenza



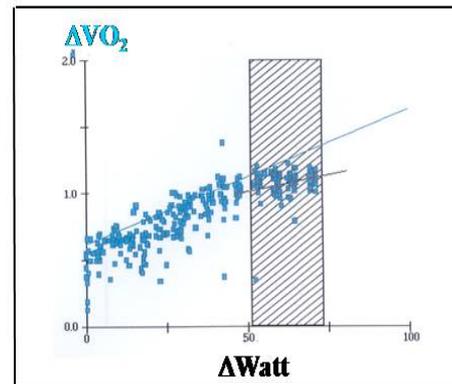
Linearità



Normale



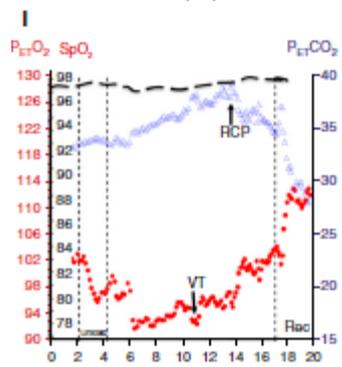
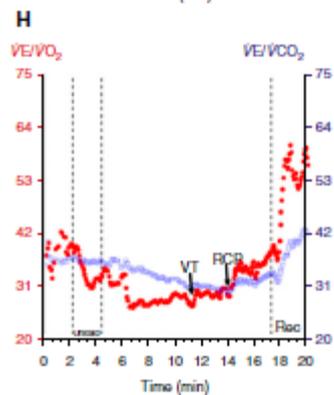
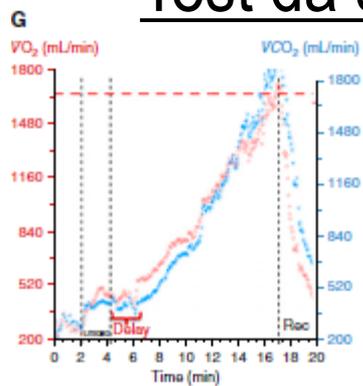
Scompenso cardiaco  
Ipertensione polmonare



Cardiopatia Ischemica

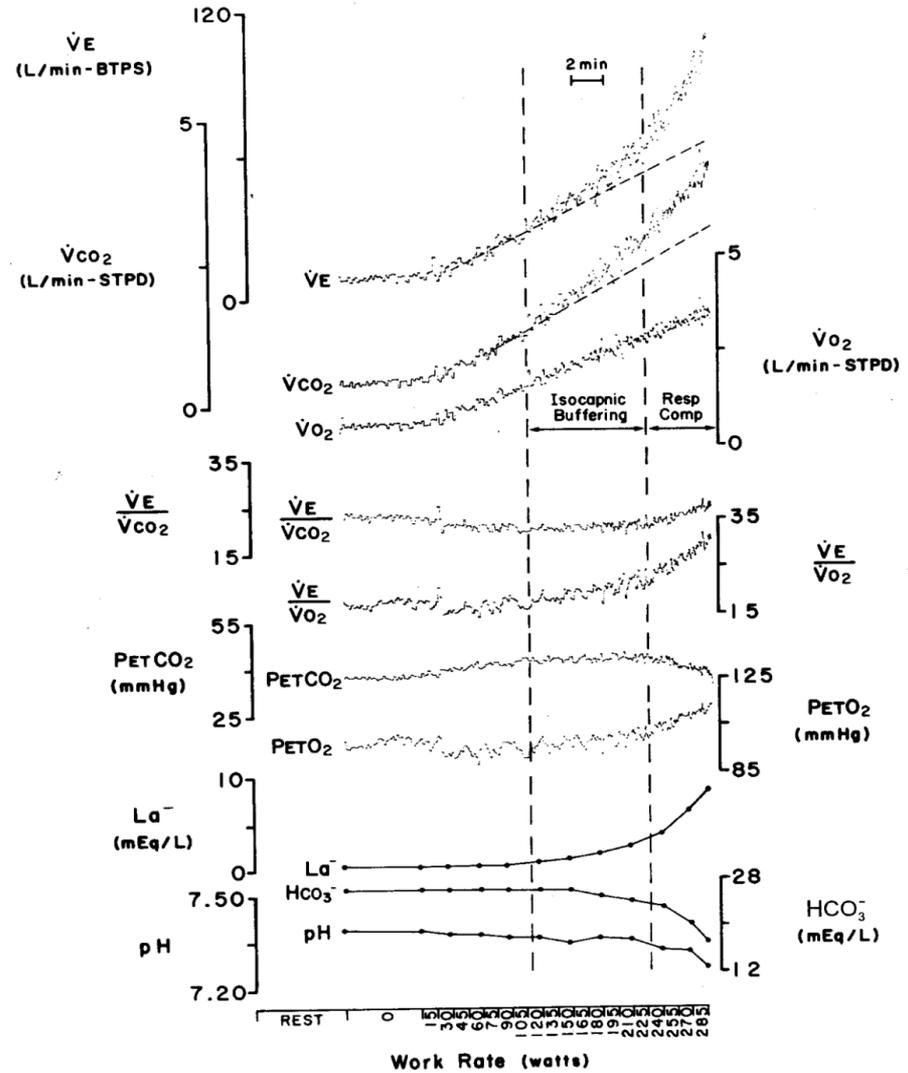
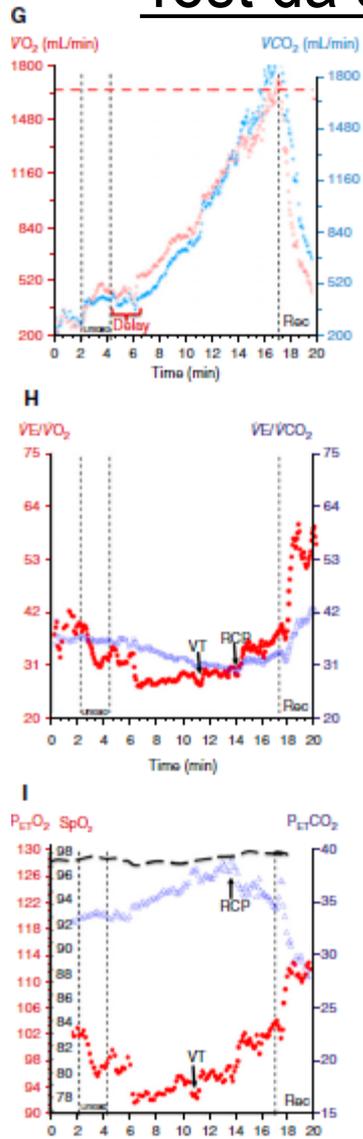
# Test da sforzo cardiopolmonare: soglia anaerobica

NORMALE



# Test da sforzo cardiopolmonare: soglia anaerobica

**NORMALE**





## Classificazione di Weber

<b>Class</b>	<b>Severity</b>	<b>VO<sub>2</sub> max</b> <i>(ml/kg/min)</i>	<b>VO<sub>2</sub>-AT</b> <i>(ml/kg/min)</i>
<b>A</b>	<b>None to mild</b>	<b>&gt; 20</b>	<b>&gt; 14</b>
<b>B</b>	<b>Mild to moderate</b>	<b>16-20</b>	<b>11-14</b>
<b>C</b>	<b>Moderate to severe</b>	<b>10-16</b>	<b>8-11</b>
<b>D</b>	<b>Severe</b>	<b>&lt; 10</b>	<b>&lt; 8</b>