Step I. PULMONARY ANALYSIS OF CARDIOPULMONARY EXERCISE TEST

Is the VO_2 reduced?

A normal VO_2 does not exclude mild cardiopulmonary disease!

Confidence intervals of predicted equations are wide and variable. ~85% of predicted is a commonly used lower limit value.

If VO_2 is ↓, ideally a subject should achieve a physiologic limitation (unless musculoskeletal or CNS limitations).

Respiratory limits: if >90% of predicted MVV achieved, excessive dead space ventilation (↑VE/VCO2), or hypoxemia.

Cardiovascular limits: ischemia, reduced anaerobic threshold (AT), or heart rate >85-90% of predicted maximum.

3 categories of pulmonary limitations (identified below in RED)

Pulmonary limiting parameters may also be caused by non-pulmonary diseases!

Example: hypoxia caused by cardiac shunt; or ↑ VE/VCO_2 from cardiac pump disease, metabolic causes of excessive ventilation, etc.

Only identify if parameters are abnormal or normal. After analysis of all non-pulmonary variables, then correlate.

1) Is there a ventilatory mechanical limitation?

Ventilatory Reserve (VR) = 100% – MVV%predicted***

***Multiple methods to determine the predicted MVV, i.e., directly measure the MVV, or FEV1 x 40.

A VR is <~10%, indicates subject has reached their ventilatory mechanical limits.

Diminished VR can be seen with normal VO_2 in mild lung disease, fit elderly, or with ↑ VO_2's with training.

Causes: parenchymal (obstructive/restrictive), chest wall, or neuromuscular disease, or obesity.

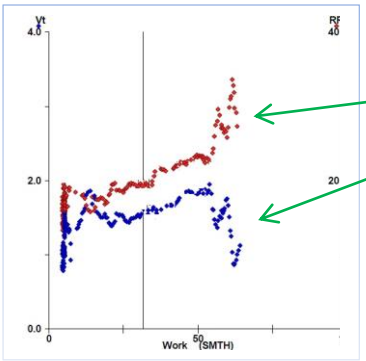
Are the tidal volume (TV) and respiratory rate (RR) responses abnormal?

Tidal volume normally doubles or triples at peak exercise. (in the elderly it may only double).

Peak respiratory rate (RR) normally reaches mid 30's to 40's.

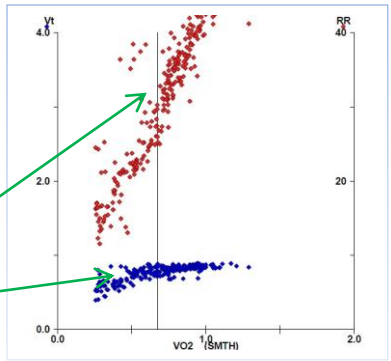
RR > 50 may indicate restriction (intra- or extra-pulmonary, i.e., ILD or obesity), or in CNS or metabolic causes.

Examine the graphs of TV to RR for abnormal patterns.



COPD: as respiratory rate rises↑dynamic hyperinflation causes TV to fall

ILD: causes excessive respiratory rate with flat tidal volume



2) Is there a limitation to the diffusion of O_2 resulting in desaturation?

An O_2 saturation decline of ≥ 4% is significant.

O_2 saturation less than 90% at AT may contribute to a reduced AT

Causes: Obstructive/restriction, ventilatory mechanical failure, cardiac pump failure, shunt, pulmonary hypertension.

3) Is there abnormal gas exchange or dead space ventilation (VE/VCO_2)?

An ↑ VE/VCO_2 of > 34 at AT or >40 at peak VO_2 considered high. VE/VCO_2 is directly related to V_D/V_T.

Assuming $PaCO_2 = P_{ET}CO_2$ is not accurate - $PaCO_2$ is required because $V_D/V_T = 1 – [(863 \times VCO_2) / VE \times PaCO_2]$

Causes are nonspecific: cardiac pump disease, hyperventilation, myopathy, obstruction/restriction, pulmonary vascular disease.

Excessive increases: >>>34 seen in pulmonary hypertension and some mitochondrial myopathies.

$PETCO_2$ curve: a ↓ from rest to AT, or ↑ after cessation, may be seen in pulmonary hypertension.

Accurate V_D/V_T is obtained from ABG's (not end-tidal breaths)

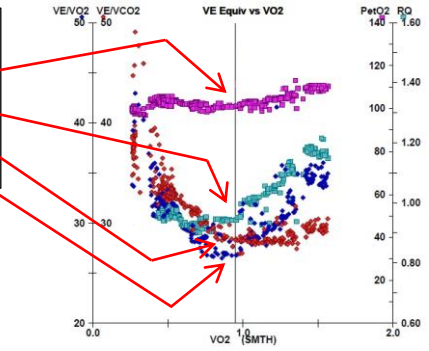
V_D/V_T normally decreases throughout exercise. If ≤ 40 yrs old normal < 0.28. If > 40 yrs old normal ≤ 0.30.

ABG's also useful for identifying anaerobic threshold when severe gas exchange is present by plotting serum lactate.

A PaO2 decline of >10 mmHg at peak exercises is not normal or a $PaCO_2$ >35 (or ΔCO_2 < 5 mmHg from rest).

Step II. NON-PULMONARY ANALYSIS OF CARDIOPULMONARY EXERCISE TEST

1st identify anaerobic threshold (AT): (all 4 should match)
$P_{ET}O_2$ increases (purple) . . . . . .
RQ begins to rapidly rise (turquoise) . . . . . .
V_E/V_{CO2} plateaus before increasing (isocapneic ventilation - red) . .
V_E/V_{O2} lowest point before increasing (blue) . . . . . .

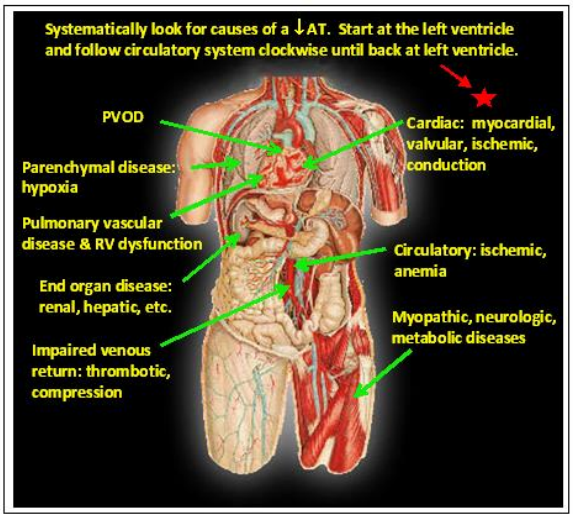


Is anaerobic threshold (AT) reduced?

Confidence intervals are highly variable depending on author.
Generally, <40% of predicted VO_2max is considered reduced.

There are many causes for a ↓ AT
Go through a systematic process (Figure to right).
Often multiple conditions are present simultaneously.
***Examine graphs at bottom of page to better assess stroke volume.

Did hypoxemia or anemia contribute to ↓ AT?



Are there resting/exercise ECG abnormalities?

Do conduction or ischemic changes correlate to chest symptoms?
Can they explain the reduced AT?

ΔHR/ΔVO_2 (rest to peak)?

>50 in deconditioning, cardiac & and peripheral myopathies

VO_2 ml/min/kg (ideal body weight)?

Used prognostically for cardiac & pulmonary transplant evaluations, surgical risk, rehabilitation planning.

Pulmonary Eval for Resection: If FEV1<80% Predicted, FEV1<1.5 L Lobectomy, & <2.0 L Pneumonectomy

If %Pred Postop FEV1 < 30% OR %Pred Postop FEV1 x %Pred Postop DLco < 1650

If %Predicted Postop FEV1 OR %Predicted Postop DLco < 40%

If %Pred Postop FEV1 AND %Pred Postop DLco > 40%

Perform CPET

If VO2 ml/min/kg IBW≤10

If VO2 ml/min/kg IBW >10 & <15

If VO2 ml/min/kg IBW≥15

Was bestVO2 achieved?

High Risk ---------- Moderate Risk ---------- Low Risk

Was bestVO2 achieved?

If RQ ≥ 1.15

If RQ <1.15

If peak VE/VCO2 >34

If peak VE/VCO2 ≤ 34

If VO2 ml/min/kg IBW≤10

If VO2 ml/min/kg IBW >10 & <18

If VO2 ml/min/kg IBW ≥18-20

Cardiac Prognosis for Chronic CHF

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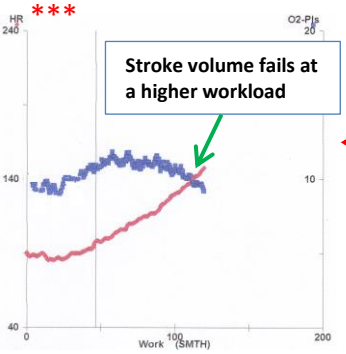

Stroke volume fails at a higher workload

Also examine these graphs:

O_2Pulse vs Work graph:

Plateaus at reduced VO_2: pump failure, anemia, neuromuscular or metabolic dis.

ΔVO_2/ΔWork slope:

≤8.5 seen in pump failure, metabolic & Neuromuscular disease, severe anemia