EXPIRED GAS ANALYSIS DURING PULMONARY EXERCISE STUDIES

by Jim Harvey MS, RPFT, RCP

Many pulmonary function technologists are becoming proficient in exercise physiology. Here is a short review of expired gas analysis. When measuring VO2 Max, anaerobic threshold and other expired gas analysis parameters, it is critical to know what the data means so that we can know when there is a problem. The major machines are very capable of spitting out the data, but do we all know if the data is accurate, consistent, and meaningful.

The purpose of a pulmonary exercise study is to expose hidden problems, which might not have been picked from static pulmonary function testing, by exercising or stressing the lung. The main measurement is of course VO2 or oxygen consumption. In the old days exercise as well as metabolism was measured by calories or kilocalories which is a measurement of heat produced indicated the rate of aerobic metabolism or the rate of the electron transport chain and oxygen consumption. Now, since metabolic heat produced is directly proportional to oxygen consumed, VO2 is universally considered, by exercise physiologist as well as by respiratory care practitioners, as the measurement indicating the level or amount of work performed. VO2 or oxygen consumption is directly proportional to work as well as to kcals consumed or produced.

Predicted VO2 Max is determined by a patient's age gender and height and weight. But this applies only to normal people like you or I. For extremely conditioned athletes, the predicted VO2 Max can be twice as large. But there are not reliable predicted data for these individuals.

VCO2 is a measurement of CO2 produced mainly in the trans carboxylic acid (TCA) cycle. Carbon dioxide is produced at a steady rate as carbons are broken off carbon-carbon fragments, releasing energy to make adenosine triphosphate which is used to energize muscle and enzymatic action. When oxygen begins to reach a maximum rate of uptake in the muscle cells, partly depending on lung diffusion, there is still an increasing energy demand, so anaerobic metabolism, including glycolysis is sped up to a higher rate producing extra ATP, extra CO2, and lactate as a by product. This is the point of the anaerobic threshold. The extra CO2 produced decreases the pH and causes a sharp rise in minute ventilation, which in turn cause an increase of CO2 released from the bicarbonate. Remember that VO2 and VCO2 are measured at STPD.

VO2 and VCO2 are calculated by measuring the fractional concentrations of oxygen and carbon dioxide in the expired air sample. In all commercial devices this is done through "breath by breath" end tidal sampling. "Breath by breath" systems talk about concepts such as waveform analysis which is reported to coordinate each single breath with its own gas analysis. But realistically, each specific VO2 and VCO2 is very dependent upon the tidal volume for that breath. So that looking at the VO2 and VCO2 of an individual breath is often meaningless, since a deeper individual breath can increase VO2 dramatically. Try breathing on your exercise system and take two deep breaths and see what happens to your VO2. Is this change accurate for those two breaths in relation to the adjacent breaths? This is why the proponents of breath by breath AT analysis always use 10 or 20 second breath averaging to make the exercise data more clear.

One way of measuring the approximate point of anaerobic metabolism is through the respiratory exchange ratio, RER, which is the VCO2 divided by the VO2, measured end tidally. The respiratory quotient, RQ, is also the VCO2 divided by the VO2 but at the cellular level. The RER can only equal the RQ at steady state. When doing an exercise study which has any type of ramp or step protocol, the term RER should be used.

When the RER goes above a ratio of 1, it is commonly assumed that the anaerobic threshold has been reached. Of course this only applies if the patient has, in the last two days, eaten a normal diet. If, within the last forty eight hours, a diet rich in carbohydrates, such as in "carbohydrate loading", was eaten, the resting RER could already be approaching 1. And if the patient had eaten a diet lacking in carbohydrate but rich in meat protein, the resting RER could be .75, and the RER would go above 1 only in severe exercise. The RER could also be elevated at rest if the patient hyperventilates.

A patient in normal or sedentary conditioning will reach the anaerobic threshold or AT from between a quarter to halfway to their VO2 Max. As a patient becomes better conditioned, the AT is postponed and in superior athletes might be reached at a point just before their VO2 Max, which might be twice the predicted normal.

Becoming conditioned or getting in shape involves, increasing respiratory muscle strength, increasing cardiac output through

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increased cardiac muscle content and strength of cardiac muscle fiber, increase in skeletal muscle fiber bifurcation and mass, and increase in muscle mitochondrial mass, allowing increased aerobic metabolism since the TCA cycle and electron transport chain are located in the inner membrane of the mitochondrion.

There are several other methods which can be used to measure the point of anaerobic threshold. Beyond RER, another way of measuring the point of AT is observing a graph of VCO2 on the Y axis versus VO2 on the X axis. When the CO2 production increases at AT, there will be evident a distinct change in slope. This is the point at which lactic acid production increases and marks the beginning of the end phase of exercise.

The best method is to observe the ventilatory equivalents for oxygen and carbon dioxide. We are looking at the rate of breathing as compared to the oxygen consumption and carbon dioxide production. The VE/O2 and VE/CO2 ratios are commonly graphed against workload. At the point of AT the O2 ventilatory equivalent rises and crosses the CO2 ventilatory equivalent ratio, indicating the onset of metabolic acidosis. The CO2 production increases in proportion to minute ventilation allowing the VE/VO2 line to go higher in proportion. A similar graph can be seen for end tidal oxygen and carbon dioxide end tidal measurements.

Arterial line placement is a good but time consuming technique to measure arterial blood gases and lactate during exercise studies. Remember to not place the arterial blood sample in ice slush before analysis as mentioned in my previous article in Focus, March/April issue, page 22. A significant increase in lactate is indicative of the AT. But remember that lactate is made constantly, even during rest. It is completely reasonable to choose not to place an arterial line and instead measure the oxygen saturation through the use of a pulse oximeter. Oxygen pulse, which is VO2 divided by the heart rate is indicative of normal heart function, as well as high VO2, normal blood pressure increases, and normal ECG.

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procaine penicillin to be given IM to a newborn infant who had been exposed to an infectious disease. As it turned out, the pharmacist erred in sending up a syringe which contained 10x the dose ordered - and the nurses decided to give the procaine penicillin intravenously rather than intramuscularly. The baby died.

But the point of this story is yet to come. While another nurse and I were discussing this case and its implications, we noted that one of nursings' 'golden rules' is to "give the right medication, in the right dose, at the right time, and by the right route." A third nurse, upon overhearing us, became very agitated and angry. She said, "You don't know what you're talking about. I change the route of administration all the time - and I don't consult anyone! All the nurses in peds do, otherwise the babies would be getting stuck all the time!" "Better stuck, than dead," I sweetly said. "Do you check the PDR before you do it?" "No," she shot back, "and I don't intend to waste the time doing it in the future, either!" She did not feel she was "wrong" and she clearly had no intention of changing her practice.

What's the point? Simply this: we tend to judge others by the results of their actions, and to judge ourselves by our good intentions. This tends to result in a double standard: one for everyone else, and one for me. What's interesting, is that when we try to justify making an exception of ourselves, we ten to do so by proclaiming that "everyone else does it, too! In our line of work that could be deadly!

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