MEASURING BMR IN THE PULMONARY LAB

by Jim Harvey MS, RPFT, RCP

Basal metabolic rate (BMR) is a measurement of oxygen consumption (VO2), carbon dioxide production (VCO2), and the respiratory exchange ratio (RER). These parameters, taken together, are measured through a process referred to as indirect calorimetry which is often a routine test in the Pulmonary Function Laboratory. Although the technique described below is referred to as "indirect", we will see that it is truly a direct measurement and can be very accurate and useful in providing a detailed picture of the body's metabolic processes at rest. Using this information, diagnostic decisions can be made and nutritional management can be undertaken to provide more effective nourishment for general health and to also encourage a more healthy respiratory status.

All cells in the human body undertake the same basic metabolic processes which are divided into anaerobic and aerobic enzymatic pathways. Glycolysis is the main process in anaerobic metabolism, and for anaerobic metabolism, the processes are the transcarboxylic acid cycle and the electron transport chain. Glycolysis uses simple carbohydrates, such as glucose, as substrate and produces two carbon dioxide molecules per glucose as well as adenosinetriphosphate (ATP) for energy demands in the cellular level. Nutrients including amino and fatty acids can be brought into glycolysis through the donation of their carbon atoms and glycolysis can be reversed in neural tissue to produce glucose for the brain, the only metabolite it can use. The transcarboxylic acid cycle in aerobic metabolism is the main site of carbon dioxide production and the electron transport chain is the main source of ATP, which is directly used a source of energy for enzymatic and cellular activity in all cells. Aerobic metabolism needs oxygen to function through the removal of hydrogen ions and their associated electrons at the bottom of the electron transport chain.

BMR can be very accurate and useful in providing a detailed picture of the body's metabolic processes at rest

During rest and very low levels of exercise, the rates of anaerobic and aerobic metabolism are equal. But during higher levels of exercise and especially during anaerobic metabolism, lactate is produced in order to temporarily store the extra carbons not immediately processes through aerobic metabolism. Lactate is produced by the reversal of a segment of glycolysis. The rates of both anaerobic and aerobic metabolism together at rest are directly proportional to the oxygen consumption, or VO2. At basal metabolism, the VO2 determines the overall metabolic rate of the body since the overall metabolic rate is directly coupled with hydrogen removal in the electron transport chain. Thirty or more years ago, calories, or kilocalories (kcal) generated were measured, through water tank immersion for the measurement of heat production, to quantify the BMR. Since the electron transport chain in aerobic metabolism produces metabolic heat in direct proportion to oxygen consumed, it is now the practice of all exercise physiologists, physicians, and pulmonary technologists to measure the VO2 as a direct measurement of total metabolic rate. For the same reason, in pulmonary exercise studies, VO2 is used to directly measure the exercise levels or metabolic rate during all levels of work. The measurement of the respiratory exchange ratio (RER) (VCO2/VO2) gives an indication of the major source or proportion of calories consumed: protein, or carbohydrate, or fat. Respiratory quotient (RQ) is also the measurement of VCO2/VO2, but at the cellular level, while the measurement end tidally is RER. RER and RQ are only equivalent at steady state, which is the requirement during BMR testing. The term indirect calorimetry is a misnomer since the actual VO2 and VCO2 are being measured and the results are more direct than measuring the temperature changes in a water bath after subject immersion.

The measurement of VO2, which is the equivalent of metabolic rate, and VCO2, as well as the measurement of urinary nitrogen (UN), can be used to determine the resting energy expenditure (REE). REE is expressed in kilocalories /day. The calculation of REE makes use of the Weir equation:

$$REE\ (kcal/24\ hr) = 5.68\ VO2 + 1.59\ VCO2 - 2.17\ UN$$

$$VO2 = ml/min\ (STPD)$$

$$VCO2 = ml/min\ (STPD)$$

$$UN = urinary\ nitrogen\ (g/24\ hr)$$

If UN is not available, the REE can be estimated using the following equation:

$$REE\ (kcal/24\ hr) = 5.46\ VO2 + 1.75\ VCO2$$

As all measurements discussed will be made at steady state, I will refer to the ratio of VCO2/VO2 as respiratory quotient or RQ. Although a normal RQ at rest is 0.85, the RQ can vary between 0.70 to 1.10, depending on the proportion of substrates being metabolized. A diet high in carbohydrate can produce a higher RQ because as the carbon rich carbohydrates are brought through metabolism, specifically through the tran-

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scarboxylic acid cycle, the high proportion of carbons are released in the form of CO2, which produces a larger RQ ratio. If the diet contains a larger proportion of protein, there is a lower level of CO2 produced as more energy comes through amino acid oxidation.

To determine if the RQ is attributable to carbohydrates or fats, the urinary nitrogen can be subtracted from the VO2 and VCO2 using the following equation to calculate the non protein RQ or RQnp:

RQnp = 1.44 VCO2 – 4.754 UN/1.44 VO2 – 5.923 UN

The following equations are used to determine the proportion of metabolism from fats, carbohydrates, or protein:

carbohydrate = 5.926 VCO2 – 4.189 VO2 – 2.539 UN
fat = 2.432 VO2 – 2.432 VCO2 – 1.3943 UN
protein = 6.250 UN

Carbohydrates, fats, and protein are oxidized in grams per 24 hrs (g/24 hr). Finally we can us the following conversion to obtain kilocalories.

4.18 grams of carbohydrate = 1 kcal
9.46 grams of fat = 1 kcal
4.32 grams of protein = 1 kcal
carbohydrate + fat + protein = total kcal

These calculations can only be done when the patient is in steady state.

The forgoing calculations are very useful but a simple observation of the RQ in itself provides information as to whether the patient is eating a significant proportion of carbohydrates or eating a larger proportion of protein. If the RQ ratio is above one, a diet significantly high in carbohydrates is probable and if the RG is below 0.90, there is a diet significantly high in protein.

With the information giving the proportion of carbohydrates, fats, and protein, or even with only the RQ, adjustments in diet can be made to decrease CO2 production, which in turn can have effects on acid base balance and the ease of breathing. The overall measurement of the BMR is useful in specific genetic metabolic disorders or as an indication for possible weight gain or loss. Measuring a patient's body weight and an evaluation of body fat levels through the use of upper arm skin fold measurements can be useful to assess the effects of a patient's nutrition but calorimetry provides a direct measurement of the patient's overall metabolic rate and the specifics of carbohydrate, fat, and protein oxidation.

In preparation for a BMR measurement any drug or other substances which could affect metabolism should be avoided for 24 prior to the test as well as caffeine, nicotine, and alcohol, and methylxanthine–type medications. The patient should be advised to avoid high sugar meals or snacks on the day of the test which would falsely increase overall metabolic rate and RQ. It is much better to schedule all patients and successive tests in the morning when BMR is stable and consistent. The patient should fast that until the testing is complete. As a basal or baseline metabolic measurement is desired, the final measurements should be taken after at least ten minutes of steady state with the patient supine or sitting comfortably. A steady state condition can be ascertained when the VO2, VE, and heart rate do not vary by more than ± 5% over a five minute period.

Types of calorimetry are described as closed-circuit and open circuit. Closed circuit meas- *continued on page 45*

Guilt

The fear that former co-workers really weren't that highly skilled and may be unemployed for months or years haunts those still on the payroll. "There but the grace of God, go I" becomes a mantra. Stop feeling guilty. Some of those people were undoubtedly reliever to get out. In the past 25 years of downsizings, rightsizings, and just plain dumpings we've learned that, once the initial shock passed, many of the people laid off were glad. The jobs weren't right for them – maybe hadn't been right for years – but they either lacked the resolve to leave or were hoping for a payoff on the way out. They'll job hunt with new energy and purpose.

Unsettled organizational politics

Power relationships are always disrupted after a layoff and a scramble to adjust them ensues. Long-term employees, who generally set the rules of what's politically acceptable, may be gone – or at least fewer in number – giving newer players chances to power grab if they care to.

Many survivors are too preoccupied with their own issues to notice that a redistribution of power is taking place. If you're not planning on hanging around long, you may not are. If you are, you can't afford to ignore who's becoming more powerful and who less so. For example, the CEO and the CFO were canned. They had worked together for years and could read each other's minds. The newly hired CEO may delegate a search firm to find a new CFO but will bring in one of his old pals to head marketing. Result: The entire finance department will be diminished and marketing will be enhanced because of the CEO's preferences. If you were in either department you'd need to know that before you made a stay/go decision.

Loss of respect for the organization

Public perceptions, especially press coverage of how – and why – the downsizing took place, can have an outsize effect on worker morale. Of course Enron employees felt shame and anger at what top management had done to the shareholders 0 not to mention their own employees. Ditto, other companies whose top management is under federal indictment. But it doesn't have to be nearly that public to cause survivor's remorse. Plenty of CEO's in not-for-profits have been indicted for mismanaging funds, a fact which the Board will try to keep under wraps for fear of donors jumping ship. When a layoff occurs 0 as it inevitably does in order to allow the organization to lick its wounds and reorganize – it's not only morale that's affected, but anger at the exploitation of the worker's commitment to the cause, or in case of a for-profit, abuse of worker loyalty. At the first opportunity, the formerly-faithful will leave.

Employee perceptions of layoffs have changed since the almost universal application of severance. There are still small organization who lay people off without a package but most don't because so much of the workforces is now over 40. Getting these people to sign a release agreeing not to sue for age discrimination – or to tell the truth about what happened – means paying people off. That leave the survivors wondering: Were the laid off actually fired for cause? Are the survivors all competent of just lucky? The suspicion is often the latter and that fact further contributes to survivors' anxiety.

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urements involve a system in which the patient is breathing through a mouthpiece and valve attached to volume displacement spirometer or to a Douglas bag filled with 100% oxygen. Any volume decrease will be the result of oxygen consumed or VO2. The VE can be measured at he same time by means of pneumotachograph. A CO2 scrubbing device must be made part of the breathing circuit so that CO2 will not build within the closed system. The scrubbing device contains a compound such as soda lime which binds the CO2 out of the system.

Open circuit technique involves the patient breathing through a pneumotachograph for volume measurement with an end tidal catheter attached, leading to one of the "off the shelf" metabolic systems which measure VO2, VCO2, and VE. These systems invariably advertise themselves as making use of "breath by breath" analysis but you will notice that they average ten second segments of data for final display and graphing since sighs or single deep breaths cause huge peaks in apparent VO2. Although these peaks seem to accurately represent metabolism at the end tidal level, they in no way represent accuracy in the cellular level, even during steady state. If the device allows, it is best to report data from a ten second average once steady state is established.

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