Weaning With Indirect Calorimetry

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Introduction

Obtaining metabolic measurements by Indirect Calorimetry for determining oxygen consumption (VO₂) and carbon dioxide production (VCO₂) has increased in popularity among clinicians since the early 1980’s. Not only have the methods of obtaining this information improved, but also the accuracy of the devices has become more reliable [1,2]. From analyzing expiratory gases with mass spectrometry, and from the more recent technology utilizing mixing chamber like in the Deltatrac™ (Datex-Ohmeda), metabolic monitors have now evolved to a small, bedside module enabling the bedside clinician to have accurate metabolic measurements for a wide variety of clinical conditions.

What Information can be obtained?

The patient’s energy expenditure can be determined by inserting gas exchange measurements into an equation developed by Weir [3]. The information gathered by indirect Calorimetry not only determines the resting energy expenditure (REE) as a guide to appropriate nutritional support, but also allows the clinician to tailor ongoing nutritional support to meet the patient’s need [4]. With subsequent measurements, adequacy and appropriateness can further be evaluated. In addition to the nutritional information, the relationship between oxygen delivery (DO₂) and VO₂ can be assessed, as can the cost of breathing. These can be used as a guide to weaning success and outcome [4].

Considerations for Metabolic Monitoring

Since 1919, the Harris-Benedict Equation [5] has been used to predict a normal, nourished individual’s REE, but this is unreliable in the malnourished patient [6]. Correction factors have been developed for various clinical conditions [7]. However, these values are approximations, and have been based on measurements of healthy individuals, not the critically ill patient. Elevated energy expenditure and a negative nitrogen balance on the other hand usually characterize Intensive Care Unit patients. These two values correlate with the severity of illness and the extent of injury.

Despite all of the advances in metabolic measurements, several clinical and physiological factors can influence the results of the gas exchange measurements. Some of the guidelines to be considered include:

- A steady state condition must be present to ensure that the gas exchange measurement is equivalent to the tissue gas exchange
- As Haldane Transformation is used in the VO₂ calculations, monitoring should be limited to patients using less than 60% oxygen.
- A stable FiO₂ must be achieved.
- Air leaks around endotracheal tubes or through chest tubes may result in false values.
- Metabolic monitors require routine calibration to ensure accuracy [8].
Metabolic monitors of the past were large and cumbersome, as they measured expired respiratory gases collected in a mixing chamber. They required varying stabilization times to achieve accurate data after a change in gas concentration [9]. Paramagnetic oxygen sensors could be used to measure the FiO₂ and FeO₂ values, and an infrared sensor to measure the CO₂.

The development of a bedside metabolic module (M-COVX) for a critical care patient monitor has replaced the need of collecting gases in a sample chamber. This new technology uses a mathematical integration of flow and time synchronized continuous gas sampling. This new module has been shown to be comparable to standard metabolic monitors [1].

How can indirect calorimetry contribute to weaning?

Malnutrition is a common entity in the critically ill patient [10]. Severe malnutrition is associated with a reduction in the strength of respiratory muscles. This may lead to ventilatory dependence, increased risk of infection, and an increase in hospital morbidity and mortality. Overfeeding can result in metabolic, hepatic, and cardiopulmonary complications, including hypercapnia and increased minute ventilation requirements, which reduce the ability to wean. Since the Respiratory Quotient (RQ) is the ratio of VCO₂/VO₂, we can determine what energy sources are at work. Underfeeding, which results in the use of endogenous fat stores, should result in decreases in the RQ. Overfeeding promotes lipogenesis, which can cause an increase in the RQ. With the additional measurement of urinary urea excretion, the distinction between protein oxidation and the relative contributions of fat and carbohydrates can be determined. Optimizing a patient’s nutritional status prior to a weaning trial including the composition and amount of feeding can contribute to overall success.

When initiating a weaning trial and incorporating indirect calorimetry, continuous measurements of the VO₂ and VCO₂ are available. With these values being monitored, reductions in ventilator support can be implemented while observing the VO₂ for an increase in the oxygen cost of breathing [11]. When monitoring a patient’s increase in minute ventilation, consideration of the reason for the acute increase in ventilatory demand must be determined. For example, this increase may be as a result of increase VCO₂ and/or an increase in lung dead space (Vd/Vt). The reason for each variable may lead to a further understanding of why the patient is unable to wean from the ventilator.

Summary

Bedside monitoring of accurate gas exchange in critically ill patients is now possible. Although the initial development of metabolic monitors was for monitoring nutritional regimes, today's technology allows for many potential areas for diagnostic and therapeutic modalities. In fact, there are new opportunities to investigate the information measured for ventilatory management of the patient. With the progression of new and varied ventilators and modes, permissive hypercapnia, and protective lung strategies, more research is required to validate the applicability of indirect calorimetry in each of these areas, and to utilize this technology to its fullest potential.

References

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