

Quick Review: The Metabolic Cart

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Abstract

This article gives a brief review of the metabolic cart.

TERMS & DEFINITIONS

CALORIMETRY

Direct calorimetry: Measurement of the amount of heat (energy) produced by a subject enclosed within a Chamber.

Indirect calorimetry: Measurement of the amount of heat (energy) produced by a subject by determination of the amount of oxygen consumed and the quantity of carbon dioxide eliminated

- The metabolic cart essentially measures the oxygen consumed and the carbon dioxide produced by the patient and then calculates (using the modified Weir equation) the energy expenditure for the patient
- Weir equation: $EE = (3.94 \times VO_2) + (1.1 \times VCO_2)$

Indirect calorimetry provides two pieces of information:

1. A measure of energy expenditure as reflected by the resting energy expenditure (REE)
2. A measure of substrate utilization as reflected in the respiratory quotient (RQ)

RESTING ENERGY EXPENDITURE (REE)

REE = 75 % - 95 % of total energy expenditure (diet-induced, environmental, activity)

- Metabolism in brain, liver, heart and kidney is relatively constant (60 - 70 % REE)
- Variability in REE:
 - between people
 - during the day 12 %
 - increases with critical illness
 - day to day - 23 %

Variability in REE can be due to:

- Size
- Gender
- Age
- Work of breathing (2 - 3 %)
- Diet-induced thermogenesis
- Sleep
- Illness
- Starvation
- Fever (13 % per degree C)
- Cold
- Activity
- Drugs

POINTS:

- REE correlates closely with fat free lean body mass.
- Work of breathing normally (2 - 3 %) can be as high as 25% of REE with impending respiratory failure
- Diet-induced thermogenesis normally 8-10% drops

to 4-8% with continuous enteral feeds

- REE drops with sleep
- Most disease states increase REE
- 20-50% increase seen with elective surgery and trauma, 100% increase in REE seen with severe burns
- Increases in REE are seen in the flow phase of injury and can be effected by therapy
- Increases in REE can be expected to reflect severity of illness but the response plateaus at
 - 2x the REE
- Increases in REE due to acute illness usually return to base line at 7 to 10 days
- Not all critically ill patients become hypermetabolic (35-60%)
- 15-20 % of ICU-patients are found to be normometabolic.
- 10 -20% of ICU-patients are found to be hypometabolic.
- Hypometabolic state may be due to the disease process: specific cancers ,cachexia ,spinal cord injuries paraplegics decreased REE by 10% quadriplegics by 30%
- Long-term starvation reduces EE by 30-40%
- Fever increases REE (13 % per degree C)
- Exposure to Cold /hypothermia increases REE by shivering and nonshivering thermogenesis
- General Activity is responsible for most of the variability in REE.
- Being awake and alert increase EE by 10%.
- Routine nursing care increases EE by 20 -30%.

Medications that affect REE:

- caffeine, aspirin increase EE
- catecholamines and pressor increase EE
- sedatives,analgesics, beta blockers

* general anesthesia decreases EE

** Acute hyperventilation increases EE, while Hypoventilation decreases EE

PREDICTING REE

Harris-Benedict is correct 80-90% of the time in healthy, normal volunteers. In 10-14% it over-estimates EE. In obese volunteers, the equation predicts EE correctly only 40-64% of the time. In critically-ill patients the Harris-Benedict equation is correct only 50% of the time. For most disease processes Harris -Benedict underestimates EE. Multipliers for various disease states attempt to improve the accuracy of the Harris-Benedict equation (though these multipliers tend to overestimate EE when compared to indirect calorimetry).

- RQ: Derived from actual measurements of VCO₂ and VO₂
- RQ is the ratio of carbon dioxide produced to oxygen consumed (VCO₂ / VO₂)
- Reflection of which fuels are being oxidized
- “Non-protein” RQ (npRQ) excludes protein metabolism

RESPIRATORY QUOTIENT

Ratio of CO₂ produced to O₂ consumed.

$$(VCO_2 / VO_2) = RQ$$

Carbohydrate: 1gm C + 0.83 L O₂ 0.83 L CO₂ + 0.56g H₂O + 4.17 Kcal
RQ =1

Fat: 1gm F + 2.02 L O₂ 1.43 L CO₂ + 1.07 g H₂O + 9.3 Kcal
RQ = 0.70

Protein: 1gm P + 0.96 L O₂ 0.78 L CO₂ + 0.41 H₂O + 0.16g Nu + 4.3 Kcal RQ = 0.81

Glucose oxidation RQ = 1.0

Fat oxidation RQ = 0.7

Protein oxidation RQ 0.8

Lipogenesis RQ 1.3

(npRQ of 0.85 - 50 % fat and 50 % carbohydrate oxidation)

“OPTIMAL RQ”

- Nutrition support should probably provide a balance between carbohydrate and lipid with an RQ in the 0.8 to 0.9 range

- Avoidance of RQ's > 1.0 which represents "overfeeding" and potential lipogenesis is a reasonable goal

FACTORS THAT AFFECT RQ:

Those that increase RQ

- Hyperventilation
- metabolic acidosis leading to increases in carbon dioxide,
- overfeeding leading to lipogenesis
- exercise

Those that decrease RQ

- Hypoventilation
- Mild starvation with ketosis
- Diabetes with ketoacidosis or high rates of urinary glucose loss
- Gluconeogenesis
- ETOH metabolism
- Hypothermia via continued gluconeogenesis

Resting energy expenditure of critically ill patients varies widely over the course of the day and over the course of an illness. Measurements from 10 - 23% of an "average" REE can be seen within a 24 hour period. Test patient at rest in

quiet, controlled environment. "Steady state" implies a 5 minute interval where the average V02 and the VC02 changes by less than 10% and the average RQ changes by less than 5%.

- Question validity of the test
- Steady state is not achieved
- RQ falls outside of the physiologic range of 0.67-1.3
- Measurements should fall within the range of V02 (1.7 to 3.4 mL/min/kg) and VC02 (1.4 to 3.1 mL/min/kg)

METABOLIC CART SOURCES OF ERROR:

- FiO2 >60%
- Air leaks (chest tubes etc).
- Hemodialysis (CO2 loss via the dialysis coil)

Use of the metabolic cart can prevent over-feeding, and under-feeding by accurately measuring energy requirements. Overfeeding critically ill patients results in hyperglycemia, hepatic steatosis, R.E.S. dysfunction and increased septic complications. Under-feeding patients can lead to the complications of malnutrition. The use of a metabolic cart can reduce the amount of "unnecessary" TPN which is administered (use of a metabolic cart reduced TPN use from 33,000 liters to 26,000 liters in one study - Mullen et al., Proc Nutr Soc 1991. 50:239-44).

References

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