Quick Review: The Metabolic Cart
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Citation

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 x VO2) + (1.1 x VCO2)

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 continues 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 reflex 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 do 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.

\[
\frac{\text{VCO2}}{\text{VO2}} = \text{RQ}
\]

**Carbohydrate:**

\[
\text{1gm C + 0.83 L O2 + 0.83 L CO2 + 0.56g H2O + 4.17 Kcal}
\]

\[
\text{RQ} = 1
\]

**Fat:**

\[
\text{1gm F + 2.02 L O2 + 1.43 L CO2 + 1.07 g H2O + 9.3 Kcal}
\]

\[
\text{RQ} = 0.70
\]

**Protein:**

\[
\text{1gm P + 0.96 L O2 + 0.78 L CO2 + 0.41 H2O + 0.16g Nu + 4.3 Kcal RQ} = 0.81
\]

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
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- 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 lose
- 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 then 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 with in 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 Sos 1991. 50:239-44).

References
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