Indirect Calorimetry and Bronchoscopy

Objectives

- Define the following terms:
  - Calorimetry
  - Indirect Calorimetry
  - Joules
  - Respiratory Exchange Ratio
  - Respiratory Quotient
  - Resting Energy Expenditure
- List the components of an Indirect Calorimetry system.
- Describe the effects on ventilation of the following food substrates:
  - Carbohydrate
  - Fat
  - Protein
- State two sources of error in measurement of metabolic parameters during indirect calorimetry.

Indirect Calorimetry-Definition

- Calorimetry: The measurement of heat production.
  - When something is burned, how much heat is released?
  - At the bedside, we can quantify the reduction-oxidation required to "fuel the fire" at the cellular level.
    - This is why it is "indirect" instead of "direct" (burning)

Luminaries

- Lavoisier (1780s)
  - Coined the term "caloric" – matter of fire.
- Leibig (1830s)
  - Demonstrated that carbohydrates, fats, and proteins were the oxidant substrates for the reduction-oxidation reaction in the cell.
- Joule (1850s)
  - Defined the unit of energy.
- So it became common knowledge that:
  - CHO, Fat or Protein + O_2 = CO_2 + H_2O + kCal/joule (Energy)

Fuel Oxidation

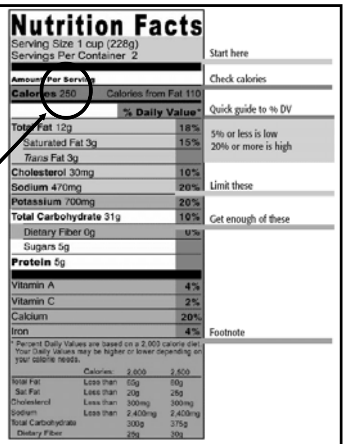
- Each metabolic substrate generates a different amount of carbon dioxide production for a given amount of oxygen burned:
  - Glucose/starch yields an equal amount of CO_2 to the O_2 consumed. RQ = 1.0
  - Fats create a far smaller amount of carbon dioxide than oxygen consumed and have an RQ of 0.70
  - Protein is a little bit tougher to measure (because of how protein is metabolized), but the RQ is somewhere around 0.82, which is also approximates the normal Respiratory Exchange Ratio (amount of CO_2 produced for a given amount of O_2 consumed) of 0.8.
    - RER is at the airway; RQ is at the cell.

Energy available per gram of substrate

- We can estimate how much energy you will get from a particular meal if we know how many grams of CHO, fat, and protein a food mixture has.
  - For every gram of
    - CHO: you have 4 kcal available.
    - Fat: you have 9 kcal available.
    - Protein: you have ~4 kcal available.
      - Note: Protein as an energy source is highly dependent on the protein involved.
    - And just for completeness, Alcohol has an RQ of around .67 and generates 7 kcal/gram

Try it!

- CHO: 31 g
  - 31x4=124 Kcal
- Fat: 12 g
  - 12 x 9 = 108 Kcal
- Protein: 5 g
  - 5 x 4 = 20 Kcal
- 124+108+20=
  - 252 Kcal



Technical Components of IC

- 3 measurements must be made:
  - Measure carbon dioxide production ($\dot{V}CO_2$)
    - $\dot{V}CO_2$=(V_E*$FECO_2$)-(V_I*$FICO_2$) or simply $\dot{V}CO_2$=(V_E*$FECO_2$) (since $FICO_2$ is near zero).
  - Measure minute ventilation ($\dot{V}_E$)
  - Measure oxygen consumption ($\dot{V}O_2$)
    - $\dot{V}O_2$=(V_I*FIO_2)-(V_E*FEO_2)
      - If V_I is not provided by ventilator, a complex formula (Haldane transformation) must be used to determine it:

Yeah RIGHT!

$$V_I = \frac{1.0 - FEO_2 - FECO_2}{1 - FIO_2 - FICO_2} V_E$$

Oxygen Measurement

- Rapid analyzer required.
  - High-end Polarographic or zirconium oxide
  - Need to be extremely sensitive (to four decimal places) since the difference between FIO_2 and FEO_2 is very small.
- Must have stable FIO_2 source.
  - Newer generation PSOL technology far more stable than prior generations.
  - Spontaneous breathing systems.

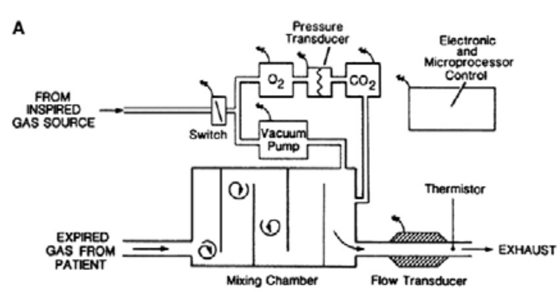
Carbon Dioxide Measurement

- Non-dispersive infra-red (IR) analyzer.
  - Standard capnography equipment.

Volume, Flow, Pressure, and Temperature Measurement

- Pressure-differential pneumotachs
- Turbine flowmeters
- Ultrasonic vortex flowmeters
- Also requires analysis of barometric pressure and temperature to make appropriate ATPS to BTPS conversions.

Commercially Available IC



Canopy System for Spontaneously Breathing Patient

- Tight-fitting system as an alternative to mask or mouthpiece.

Technical Considerations

- F_{IO_2} Stability
  – Monitor breath-to-breath stability of F_{IO_2}
- Problems with elevated F_{IO_2} values.
  – Haldane Transformation
- High levels of PEEP (greater than 12 cm H_2O)
- Acute hyper/hypoventilation conditions.
- Effects of other gases
  – Water vapor (dry gas samples)
  – Anesthetic agents
- System Leaks
  – The largest source of error!
    - Alters the gas concentrations
    - Alters the volume of gas measured
- Portability

Use of Data Obtained With IC

- The goal is to assess how much energy the patient is using (Resting Energy Expenditure or REE), use this information in various predicted equations to determine if the caloric intake matches that which the patient is exposed to.
  – There are over 200 equations available.
  – Most popular:
    - Harris-Benedict – Uses Height/Weight in regression equation
    - Weir
- Substrate analysis (CHO-Fat-Protein breakdown) requires the simultaneous collection of urine and measurement of the urinary urea nitrogen (UUN).
  – Urea nitrogen is an end-product of protein metabolism and is directly related to the amount of protein used and excreted in the urine.
- MUST HAVE STEADY STATE CONDITIONS!

Pilbeam, Box 11-5

Causes of Changes to Measured Values

- **Elevated $\dot{V}CO_2$**
  – Metabolic acidosis
  – Hyperventilation
  – Hypermetabolic state
  – Overfeeding
- **Decreased $\dot{V}CO_2$**
  – Metabolic alkalosis
  – Hypoventilation
  – Hypometabolic state
  – Gluconeogenesis
  – Starvation/ketosis
  – Underfeeding

Causes of Changes to Measured Values

- **Elevated $\dot{V}O_2$**
  – Sepsis
  – Hypermetabolic state
  – Hyperthermia
  – Blood transfusions
  – Shivering/agitation/excessive movement
  – Increased $\dot{V}_E$
  – Hemodialysis (wait at least 4 hours)
  – Overfeeding
- **Decreased $\dot{V}O_2$**
  – Hypothermia
  – Fasting/Starvation
  – Hypothyroidism
  – Advanced age
  – Paralysis
  – General anesthesia
  – Heavy sedation
  – Coma

Metabolic Response to Stress

- Three phases
  – Stress or Ebb Phase
    - 12 to 24 hours
    - Hemodynamic instability, hypometabolism, huge changes in counterregulatory hormones, and insulin resistance.
  – Catabolic Phase
    - 7 to 10 days (up to weeks)
    - Fever, hypercatabolism, gluconeogenesis, increased oxygen demands.
  – Anabolic Phase
    - Months
    - Rebuilding of previously destroyed muscle/tissue

Nutritional Support at the Various Phases

- Stress & Catabolic
  - Feed at or below 100% of measured REE with high-nitrogen feedings (1.5-2g/kg/d)
    - Preserve lean body mass without overfeeding.
    - Need to account for all sources
      - Dextrose in IV, propofol, renal replacement fluids
- Anabolic
  - Increased energy needs to rebuild
  - Feed up to 130% of measured REE with aggressive protein delivery.

Interpretation of Data - REE

- Compare measured REE to predicted REE from Harrison-Benedict equation.
  - If $\pm$ 10% of equation, consider to be in a normal metabolic state.
  - Greater than 110% of predicted – Hypermetabolic state
  - Less than 90% of predicted – Hypometabolic state.

Interpretation of Data - RQ

- RQ measurements on critically ill patients normally range between 0.85 and 0.90.
- Lots of variability, so the value should not be taken in isolation.
- Measurements outside of **0.67** to **1.3** are suspect.
- RQ **greater than 1.0** usually indicates overfeeding and the total caloric intake should be reduced.
- RQ values between **0.9 and 1.0** indicate primarily CHO oxidation and the amount of CHO should be reduced and the amount of lipids increased to maintain the correct amount of calories.
- RQ values between **0.8 and 0.9** indicate a mixed level of substrate oxidation and is the target range for RQ.
- RQ values between **0.7 and 0.8** indicate fat and protein are the primary substrates used for metabolism OR starvation is present and the total caloric intake should be increased.

Insufficient Energy Consumption

- Malnutrition stems from inadequate caloric intake over time.
- Leads to impaired metabolism and catabolism.
- High-risk patients
  - Underweight
  - Anorexic
  - Nutrient loss: GI fistulas, draining abscesses, renal dialysis
  - Hypermetabolic state: Sepsis, fever, trauma, burns
  - Chronic alcohol use

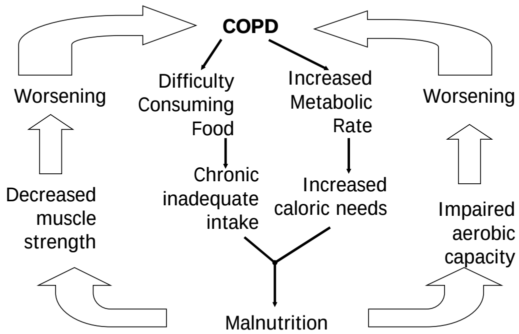
Protein-Energy Malnutrition

- Caused either by reduced protein intake or secondarily due to diseases that cause protein loss before absorption (diarrhea) or increase protein needs beyond normal intake levels.
- Inadequate protein supply leads to decreased metabolic activity, ventilatory drive, and thyroid activity.
- Liver converts its limited stores of glycogen to glucose (gluconeogenesis).
- Endogenous fats are mobilized in the form of free fatty acids (ketogenesis)
- Once fats are depleted, skeletal muscles are catabolized.
- Two types of protein-energy malnutrition are marasamus (starvation) and kwashiorkor (hypercatabolic state).

Micronutrient Malnutrition

- Often overlooked.
- Vitamins
  - C and B_{12}
- Minerals
  - Zinc
  - Magnesium
  - Phosphate
  - Iron
  - Selenium
- Other
  - Glutamine
  - Omega-3 fatty acids

Malnutrition in COPD



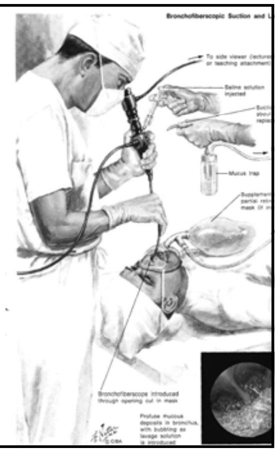
Nutrient Replacement

- Proteins
  - Normal intake: 0.8 g/kg/day
  - With increased catabolic rate: 1.5 to 2.5 g/kg/day
  - Watch out for excessive intake by monitoring BUN (azotemia)
- Carbohydrate
  - Normal intake: 300 to 400 g/day
  - High carbohydrate loads place excessive CO_2 loads on the ventilatory system that may lead to respiratory failure or failure to wean.
- Fat
  - Usually 20 to 30% of caloric intake
  - Excessive administration can lead to reduced oxygenation.

Resources

- Ninth Edition of Egan!
- Wooley, J. Indirect Calorimetry: Applications in Practice, 2006. Respiratory Care Clinics of North America: 12; 619-633.

Bronchoscopy



Objectives

- Define bronchoscopy.
- List three indications for bronchoscopy.
- Differentiate between the two types of bronchoscopes.
- Describe the function of equipment typically found on a bronchoscopy cart.
- State two contraindications to bronchoscopy.
- State two complications of bronchoscopy and describe the Respiratory Therapist's role in assisting the physician in treatment of these complications.
- State the four areas of intervention during a bronchoscopy.
- List three common medications used in the preparation stage for a bronchoscopy.

Definition

- Bronchoscopy is the general term used to describe the insertion of a visualization instrument (endoscope) into the airways.
  - Inspect the airways
  - Remove objects from the airways
  - Collect tissue samples from the airways
  - Place devices into the airways

Indications (AARC CPG)

- The presence of lesions of unknown etiology on the chest x-ray film or the need to evaluate recurrent or persistent atelectasis or pulmonary infiltrates;
- The need to assess patency or mechanical properties of the upper airway;
- The need to investigate hemoptysis, persistent unexplained cough, localized wheeze, or strider;
- Suspicious or positive sputum cytology results;
- The need to obtain lower respiratory tract secretions, cell washings, and biopsies for cytologic, histologic, and microbiologic evaluation;
- The need to determine the location and extent of injury from toxic inhalation or aspiration;
- The need to evaluate problems associated with endotracheal or tracheostomy tubes (tracheal damage, airway obstruction, or tube placement);
- The need for aid in performing difficult intubations;
- The suspicion that secretions or mucus plugs are responsible for lobar or segmental atelectasis;
- The need to remove abnormal endobronchial tissue or foreign material by forceps, basket, or laser;
- The need to retrieve a foreign body (although under most circumstances, rigid bronchoscopy is preferred).

Contraindications to Bronchoscopy

- Absolute
  - Absence of informed consent (except for emergency)
  - Absence of experienced bronchoscopist
  - Lack of adequate facilities and equipment
  - Inability to oxygenate patient

Contraindications to Bronchoscopy

- Perform only if benefit outweighs risk
  - Coagulopathy or bleeding disorders that cannot be corrected
  - Severe obstructive airways disease
  - Severe refractory hypoxemia
  - Unstable hemodynamic status including dysrhythmias

Contraindications to Bronchoscopy

- Relative contraindications (or conditions involving increased risk),
  - Lack of patient cooperation;
  - Recent myocardial infarction or unstable angina;
  - Partial tracheal obstruction;
  - Moderate-to-severe hypoxemia or any degree of hypercarbia;
  - Uremia and pulmonary hypertension (possible serious hemorrhage after biopsy)
  - Lung abscess (danger of flooding the airway with purulent material);
  - Obstruction of the superior vena cava (possibility of bleeding and laryngeal edema);
  - Debility, advanced age, and malnutrition;
  - Respiratory failure requiring mechanical ventilation;
  - Disorders requiring laser therapy, biopsy of lesions obstructing large airways, or multiple transbronchial lung biopsies;
  - Known or suspected pregnancy because of radiation exposure.

Hazards/Complications of Bronchoscopy

- Adverse effects of medication used before and during the bronchoscopic procedure
- Hypoxemia
- Hypercarbia
- Wheezing
- Hypotension
- Laryngospasm, bradycardia, or other vagally mediated phenomena
- Mechanical complications such as epistaxis, pneumothorax, and hemoptysis
- Increased airway resistance
- Death
- Infection hazard for health-care workers or other patients
- Cross-contamination of specimens or bronchoscopes

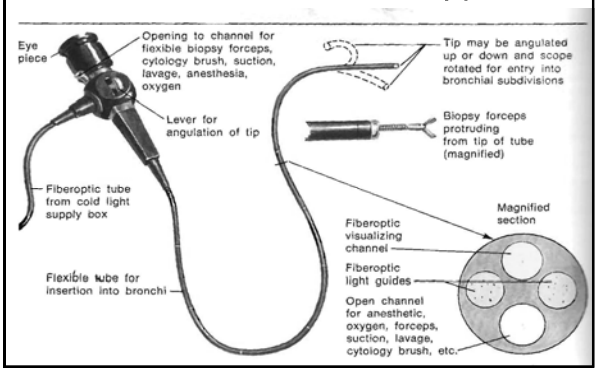
Types of Bronchoscopy

- Flexible Fiberoptic Bronchoscopy
- Rigid Tube Bronchoscopy

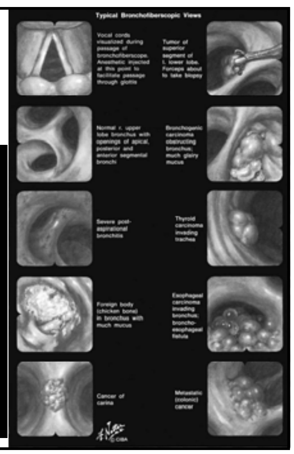
Rigid Tube Bronchoscopy

- Open metal tube with a distal light source.
- Large internal diameter.
  - Ideal for removal of aspirated objects.
- Not commonly used at bedside.
  - Uncomfortable for conscious patients.
  - Cannot access smaller airways.

Flexible Bronchoscopy

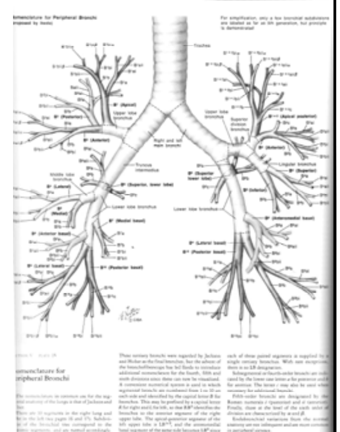


Airway Views



Airway Nomenclature

- To facilitate description of what area of the lung is being viewed.
- R or L
- B for Segmental Bronchus (1-10)
- Small case letter for sub-segmental bronchi (fourth-order)
- Small case Roman numeral for fifth-order bronchi.
- Example: $RB^{10}bii$ for one of the two fifth-order bronchi arising from second of three divisions of the Posterior basal segmental bronchus on the right.



Bronchoscopy Procedure

- Four aspects of the bronchoscopy procedure:
  - Premedication
  - Equipment preparation
  - Airway preparation
  - Monitoring

Premedication

- Premedication should be done 1 to 2 hours before procedure.
  - Calm but alert
    - Benzodiazepines (Valium, Versed)
    - Morphine or fentanyl diminish laryngeal reflexes
  - Dry the patient's airway
    - Atropine

Equipment Preparation

- Personal protection gear for bronchoscopist and assistant.
- Airway Management
  - Endotracheal tube, laryngoscope handle & blade, stylet, water-soluble lubricant, bite block, and mechanism to secure tube.
  - Suction machine, tubing, and tonsil and endotracheal tube suction catheters

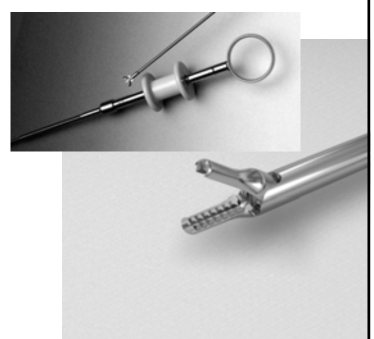
Equipment Preparation

- Syringes, Needles, and Solutions
  - 10- and 20-mL syringes with Luer-lok tip
  - 10- and 20-mL syringes with Slip-fit tip
  - Needles
    - Sharp tip
    - Blunt tip
  - Normal Saline
  - Nonbacteriostatic saline
  - Sharps container

Equipment Preparation

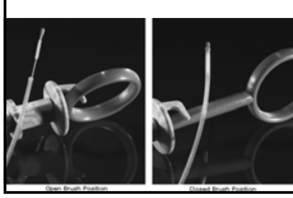
- Equipment for obtaining and handling specimens
  - Forceps
    - Regular
    - Alligator Biopsy
    - Needle Biopsy
  - Brushes
    - Cytology
    - Microbiology
  - Retrieval Basket
  - Specimen Cups
  - Sputum (Luken's) Traps
  - Specimen slides with covers
  - 10% Formalin
  - Cytology Fixative

Alligator Forceps

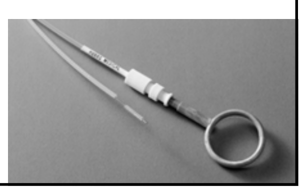


Biopsy Forceps

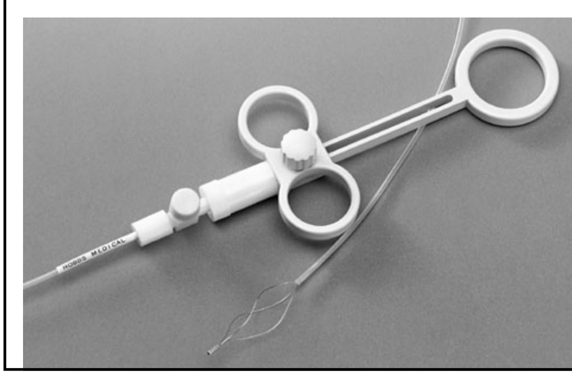
Microbiology Brushes



Cytology Brushes



Retrieval Baskets



Equipment Preparation

- Monitoring Equipment
  - Pulse Oximeter
  - EKG
- Oxygen Equipment
- Resuscitation Equipment
- Paperwork

Equipment Preparation

- Medications
  - Versed
  - Morphine sulfate
  - Valium
  - Atropine
  - Epinephrine (1:10,000)
  - Acetylcysteine
  - Lidocaine jelly (2%)
  - Lidocaine IV bolus (4%)
  - Cetaciane
  - Romazicon
  - Naloxolone
  - Albuterol
  - Ipratropium bromide

Airway Preparation

- Goals
  - Prevent bleeding
  - Decrease coughing and gagging
  - Decrease pain
- Topical anesthesia
  - Cetacaine, lidocaine
- Bleeding control
  - Epinephrine
- Pain management
  - Morphine

Monitoring

- Pulse Oximeter
  - Turn on the beep!
  - Ready access to oxygen source
- ECG
  - Dysrhythmia recognition and treatment
- Assisting physician through anticipation
- Recovery of patient