Objectives

• Briefly review pulmonary anatomy and physiology
• Review lung volumes and capacities
• Provide an overview of pulmonary function tests
• Discuss spirometry and review its clinical applications
Anatomy

• Lungs comprised of
  – Airways
  – Alveoli

http://www.aduk.org.uk/gfx/lungs.jpg
The Airways

- Conducting zone: no gas exchange occurs
  - Anatomic dead space
- Transitional zone: alveoli appear, but are not great in number
- Respiratory zone: contain the alveolar sacs

*Weibel ER: Morphometry of the Human Lung. Berlin and New York: Springer-Verlag, 1963*
The Alveoli

- Approximately 300 million alveoli
- 1/3 mm diameter
- Total surface area if they were complete spheres 85 sq. meters (size of a tennis court)
Mechanics of Breathing

• Inspiration
  – Active process

• Expiration
  – Quiet breathing: passive
  – Can become active
Lung Volumes

- 4 Volumes
- 4 Capacities
  - Sum of 2 or more lung volumes
Tidal Volume (TV)

- Volume of air inspired and expired during normal quiet breathing
Inspiratory Reserve Volume (IRV)

- The maximum amount of air that can be inhaled after a normal tidal volume inspiration.
Expiratory Reserve Volume (ERV)

- Maximum amount of air that can be exhaled from the resting expiratory level.
Residual Volume (RV)

- Volume of air remaining in the lungs at the end of maximum expiration
Vital Capacity (VC)

- Volume of air that can be exhaled from the lungs after a maximum inspiration
- FVC: when VC is exhaled forcefully
- SVC: when VC is exhaled slowly
- VC = IRV + TV + ERV
Inspiratory Capacity (IC)

- Maximum amount of air that can be inhaled from the end of a tidal volume
- \( IC = IRV + TV \)
Functional Residual Capacity (FRC)

- Volume of air remaining in the lungs at the end of a TV expiration
- The elastic force of the chest wall is exactly balanced by the elastic force of the lungs
- $FRC = ERV + RV$
Total Lung Capacity (TLC)

- Volume of air in the lungs after a maximum inspiration
- TLC = IRV + TV + ERV + RV
Pulmonary Function Tests

- Evaluates 1 or more major aspects of the respiratory system
  - Lung volumes
  - Airway function
  - Gas exchange
Indications

• Detect disease
• Evaluate extent and monitor course of disease
• Evaluate treatment
• Measure effects of exposures
• Assess risk for surgical procedures
Pulmonary Function Tests

• Airway function
  – Simple spirometry
  – Forced vital capacity maneuver
  – Maximal voluntary ventilation
  – Maximal inspiratory/expiratory pressures
  – Airway resistance

• Lung volumes and ventilation
  – Functional residual capacity
  – Total lung capacity, residual volume
  – Minute ventilation, alveolar ventilation, dead space
  – Distribution of ventilation
Pulmonary Function Tests

- Diffusing capacity tests
- Blood gases and gas exchange tests
  - Blood gas analysis
  - Pulse oximetry
  - Capnography
- Cardiopulmonary exercise tests
- Metabolic measurements
  - Resting energy expenditure
  - Substrate utilization
- Chemical analysis of exhaled breath
Spirometry

- Measurement of the pattern of air movement into and out of the lungs during controlled ventilatory maneuvers.
- Often done as a maximal expiratory maneuver
Importance

- Patients and physicians have inaccurate perceptions of severity of airflow obstruction and/or severity of lung disease by physical exam
- Provides objective evidence in identifying patterns of disease
Lung Factors Affecting Spirometry

- Mechanical properties
- Resistive elements
Mechanical Properties

• Compliance
  – Describes the stiffness of the lungs
  – Change in volume over the change in pressure

• Elastic recoil
  – The tendency of the lung to return to its resting state
  – A lung that is fully stretched has more elastic recoil and thus larger maximal flows
Resistive Properties

• Determined by airway caliber
• Affected by
  – Lung volume
  – Bronchial smooth muscles
  – Airway collapsibility
Factors That Affect Lung Volumes

- Age
- Sex
- Height
- Weight
- Race
- Disease
Technique

- Have patient seated comfortably
- Closed-circuit technique
  - Place nose clip on
  - Have patient breathe on mouthpiece
  - Have patient take a deep breath as fast as possible
  - Blow out as hard as they can until you tell them to stop
QuickTime™ and a decompressor are needed to see this picture.
Terminology

- Forced vital capacity (FVC):
  - Total volume of air that can be exhaled forcefully from TLC
  - The majority of FVC can be exhaled in <3 seconds in normal people, but often is much more prolonged in obstructive diseases
  - Measured in liters (L)
• Interpretation of % predicted:
  – 80-120%  Normal
  – 70-79%   Mild reduction
  – 50%-69%  Moderate reduction
  – <50%     Severe reduction
Terminology

- Forced expiratory volume in 1 second: (FEV$_1$)
  - Volume of air forcefully expired from full inflation (TLC) in the first second
  - Measured in liters (L)
  - Normal people can exhale more than 75-80% of their FVC in the first second; thus the FEV1/FVC can be utilized to characterize lung disease
FEV₁

- Interpretation of % predicted:
  - >75% Normal
  - 60%-75% Mild obstruction
  - 50-59% Moderate obstruction
  - <49% Severe obstruction
Terminology

• Forced expiratory flow 25-75% (FEF\textsubscript{25-75})
  – Mean forced expiratory flow during middle half of FVC
  – Measured in L/sec
  – May reflect effort independent expiration and the status of the small airways
  – Highly variable
  – Depends heavily on FVC
• Interpretation of % predicted:
  – >60% Normal
  – 40-60% Mild obstruction
  – 20-40% Moderate obstruction
  – <10% Severe obstruction
Acceptability Criteria

- Good start of test
- No coughing
- No variable flow
- No early termination
- Reproducibility
Flow-Volume Loop

- Illustrates maximum expiratory and inspiratory flow-volume curves
- Useful to help characterize disease states (e.g. obstructive vs. restrictive)

Categories of Disease

- Obstructive
- Restrictive
- Mixed
Obstructive Disorders

- Characterized by a limitation of expiratory airflow
  - Examples: asthma, COPD
- Decreased: FEV$_1$, FEF$_{25-75}$, FEV$_1$/FVC ratio (<0.8)
- Increased or Normal: TLC
Spirometry in Obstructive Disease

- Slow rise in upstroke
- May not reach plateau
Restrictive Lung Disease

- Characterized by diminished lung volume due to:
  - change in alteration in lung parenchyma (interstitial lung disease)
  - disease of pleura, chest wall (e.g. scoliosis), or neuromuscular apparatus (e.g. muscular dystrophy)
- Decreased TLC, FVC
- Normal or increased: FEV$_1$/FVC ratio
Restrictive Disease

- Rapid upstroke as in normal spirometry
- Plateau volume is low
Large Airway Obstruction

- Characterized by a truncated inspiratory or expiratory loop
Lung Volumes

- Measured through various methods
  - Dilutional: helium, 100% oxygen
  - Body plethysmography
Changes in Lung Volumes in Various Disease States

Clinical Applications
Case #1

**SPIROMETRY**

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<th>Test</th>
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Case #2

SPIROMETRY

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Case #3

SPIROMETRY

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Case #4

**SPIROMETRY**

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Case #5

**SPIROMETRY**

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