**COMPREHENSIVE RESPIROMETRY**

**Respiratory System Structure**
- Complex pathway for respiration
  1. Specialized tissues for:
     - Conduction
     - Gas exchange
  2. Position in respiratory pathway determines cell type
     - Two parts
       - Upper respiratory tract
       - Lower respiratory tract

**Ventilation:**
- The process of exchange of air between the lungs and the ambient air
- Airflow in respiratory system is directly proportional to the pressure gradient and inversely related to the resistance of the airways.
- A single respiratory cycle = inspiration + expiration + expiratory pause

**Inspiration**
- Active process in which Lung air pressure < Atmosphere air pressure
  - Diaphragm & inspiratory muscles contract → Thoracic cavity expands → negative pressure → air flows into lungs

**Expiration**
- Passive process resulting from natural elastic recoil of the expanded lung walls. During rapid breathing, internal intercostal and abdominal muscles contract to help force air out at a more forceful, rapid rate

**CLASSIFICATIONS**

1. Pulmonary measurements (volumes and capacities)
2. Central respiratory function Control Of Breathing
   - Ventilatory Response to Hypoxia/Hypercapnea/ Acid Base Balance
   - Measures of Ventilatory Drive
3. Cardiopulmonary exercise Testing
4. Bedside PFTs
5. Peripheral respiratory function
6. Mechanical properties of Respiratory system (static-dynamic)

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<tr>
<th>Conducting part</th>
<th>Gas exchange part (Gas Transfer diffusion)</th>
<th>Static mechanical properties</th>
<th>Dynamic mechanical properties</th>
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<tr>
<td>→ Large air ways Function, (spirometry)</td>
<td>• O₂ Uptake &amp; CO₂ Elimination</td>
<td>• Static compliance of lungs/ chest wall</td>
<td>• Forced vital capacity/ Flow-volume loop.</td>
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<tr>
<td>→ Small airways Function</td>
<td>• Diffusing Capacity</td>
<td>• Respiratory muscle strength</td>
<td>• Maximal voluntary ventilation/ Respiratory resistance</td>
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<tr>
<td>• Dynamic Compliance/ Closing Volume</td>
<td>• Arterial Blood Gas</td>
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<td>• Measurement of exhaled nitric oxide</td>
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<tr>
<td>• Helium-Oxygen Flow-Volume Curves</td>
<td>• Ventilation perfusion mismatch</td>
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<tr>
<td>→ Air ways reactivity (Bronchoprovocation Testing)</td>
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<tr>
<td>• Indications Precautions &amp; Contraindications methods</td>
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**What is a spirometry ??**
- Spirometry is a measure of airflow and lung volumes during a forced expiratory maneuver from full inspiration
  - Spirometer
- Apparatus used to measure static & dynamic lung volumes/capacities using a closed system
- Registers the amount and rate of air moved into or out of the lungs
- 2 main types;
  1. Volume triggered: records the amount of air exhaled or inhaled within a certain time*
  2. Flow triggered: measures how fast the air flows in or out as the volume of air inhaled or exhaled increases

**Contraindications to Use of Spirometry**
- Uncooperative patient,
- Infectious diseases (TB)
- Acute disorders
  1. Vomiting, nausea, vertigo
  2. Sever dyspnea
  3. Hemoptysis of unknown origin.
  4. Pneumothorax
- Recent event 4-6 weeks-
  1. Abdominal surgery - thoracic surgery - eye surgery
  2. Recent myocardial infarction or unstable angina
- * Thoracic aneurysms
  - (risk of rupture because of increased thoracic pressure)
**Indications of Spirometry**

- Evaluating disability or impairment
- Social Security or other compensation programs
- Legal or insurance evaluations

<table>
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<tr>
<th>Detecting pulmonary disease</th>
<th>Assessing severity/ progression of ds</th>
<th>Risk stratification of patients for surgery</th>
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</table>
| Persistent history of pulmonary symptoms  
1. Chest pain  
2. Cough or sputum production  
3. Dyspnea or wheezing | Pulmonary diseases  
- COPD  
- Cystic fibrosis  
- Interstitial lung diseases  
- Sarcoïdosis  
**Cardiac diseases**  
- Congestive heart failure  
- Congenital heart disease  
- Pulmonary hypertension | Thoracic surgeries  
1. Lobectomy  
2. Pneumonectomy |
| Physical findings  
1. Chest wall abnormalities  
2. Cyanosis  
3. Decreased breath sounds  
  Finger clubbing | Neumorskeletal diseases  
1. Amyotrophic lateral sclerosis  
2. Guillain-Barré syndrome  
3. Multiple sclerosis  
4. Myasthenia gravis | Cardiac surgeries  
- Coronary bypass  
- Correction of congenital abnormalities |
| Abnormal laboratory findings denoting pulmonary diseases  
Abnormal blood gases  
Abnormal chest radiograph | | Valvular surgery  
- Organ transplantation |

**Limitations of Spirometry**

- Not disease specific
- Not sensitive enough to show abnormalities before extensive and in some cases irreversible damage has been done mostly for restrictive diseases
- Should not be used as the sole screening tool of a respiratory surveillance program.

**EQUIPMENT AND TECHNIQUE**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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</table>
| **Volume Spirometers**  
- Real time tracings record volume in relation to time |  
- Portable versions  
- Leak tests and calibrations are easy to perform  
- Can produce flow/volume curves and loops with the addition of special electronic or digital circuitry.  
- Calibration is stable for months to years |  
- Not practical by hand to determine peak expiratory flow or instantaneous volumes,  
- Coughs and submaximal efforts are not as obvious  
- Heavy, cumbersome  
- Prone to fostering mold or bacterial growth if not cleaned properly |

| 1. Measure how quickly air flows past a detector & then derives the volume by electronic means.  
2. Records flow rate at brief intervals (30-300/sec) and use data to reconstruct the flow rate at each point in time and volume (digitization).  
3. Tracings measure flow in relation to volume |  
- Produce volume-time tracings  
- Lighter and more portable  
- Disposable, single-use flow sensors, available on some flow spirometers eliminate the risk (low) of cross-contamination. |  
- No real-time or hard copy tracings  
- Reliance on electronic equipment  
- FEV1.0 cannot be calculated by hand unless the time is indicated in seconds on a flow-volume tracing  
- Difficult to calibrate and may lose their calibration over time if not well maintained. |
Basic Measurements
- Forced vital capacity (FVC)
- FEV1: The forced expiratory volume in one second
  - Ratio FEV1/FVC

<table>
<thead>
<tr>
<th>LUNG VOLUMES</th>
<th>Tidal Volume</th>
<th>TV</th>
<th>The volume of air inhaled &amp; exhaled at each breath during normal quiet breathing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inspiratory Reserve Volume</td>
<td>IRV</td>
<td>The volume of air that can be forcefully inspired following a normal quiet inspiration</td>
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<tr>
<td>Expiratory Reserve Volume</td>
<td>ERV</td>
<td>The volume of air that can be forcefully expired after a normal or resting expiration</td>
<td></td>
</tr>
<tr>
<td>Vital Capacity</td>
<td>VC</td>
<td>The maximum amount of air that can be exhaled after the fullest inspiration possible (TV + ERV + IRV)</td>
<td></td>
</tr>
<tr>
<td>Inspiratory Capacity</td>
<td>IC</td>
<td>The maximum amount of air that can be inhaled after a normal exhalation (TV + IRV)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LUNG CAPACITIES</th>
<th>Forced Vital Capacity</th>
<th>FVC</th>
<th>The total volume expired by a forced maximal expiration from a position of maximal inspiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forced Expiratory Volume in 1 sec</td>
<td>FEV1s</td>
<td>The volume of air expired in the first second of maximal forced expiration from a position of full inspiration</td>
<td></td>
</tr>
<tr>
<td>Forced Expiratory Flow from 25-75% of exhalation</td>
<td>FEF25-75s</td>
<td>The average flow rate during the middle 50% of the forced vital capacity maneuver.</td>
<td></td>
</tr>
</tbody>
</table>

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<tr>
<th>Other volumes &amp; capacities</th>
<th>Minute Respiratory Vol (MRV)</th>
<th>quantity of air moved into &amp; out of the lungs in 1 minute (TV x Respiratory rate).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal Ventilatory Vol (MVV)</td>
<td>Maximal amount of air that a person can breathe in or out in a short period of time, typically 10, 12, or 15 sec.</td>
<td></td>
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</tbody>
</table>

How to do it??
1. Stand or sit up straight (The patient places a clip over the nose)
2. Inhale maximally
3. Get a good seal around mouthpiece of the spirometer
4. Blow out as hard as fast as possible and count for at least 6 seconds.
5. Record the best of three trial

*Pt should hold short acting bronchodilator 12hrs before the test and long acting 24 hours*
1. Volume Time Graph

2. Flow-volume loops

3. Volume Time Graph
The volume is plotted against the time, it displays expiration.

1. **Volume Time Graph**

2. **Flow-volume loops**

3. **Volume Time Graph**

**Forced Vital Capacity (FVC)**
The total amount of air expired as quickly as possible after taking the deepest possible breath.

Interpretation of % predicted:
- 80-120% Normal
- <80% Mild reduction
- <70% Moderate reduction
- <50% Severe reduction

**FEV1**
Volume of air which can be forcibly exhaled from the lungs in the first second of a forced expiratory maneuver.

Interpretation of % predicted:
- >80% Normal
- <75% Mild obstruction
- <60% Moderate obstruction
- <50% Severe obstruction

**FEV1/FVC**
Ratio of FEV1 to FVC:
It indicates what percentage of the total FVC was expelled from the lungs during the first second of forced exhalation.
This value is critically important in the diagnosis of obstructive and restrictive diseases.

**FEF25-75**
Interpretation of % predicted:
- >60% Normal
- <60% Mild obstruction
- <40% Moderate obstruction
- <10% Severe obstruction

At the level of small airways

**FEV1 & FVC**
- Forced expiratory volume in 1 second
  - 4.0 L
- Forced vital capacity
  - 5.0 L
  - usually less than during a slower exhalation
- $\text{FEV1/FVC} = 80\%$

**FEF25%**
Amount of air that was forcibly expelled in the first 25% of the total forced vital capacity test.

**FEF75%**
The amount of air expelled from the lungs during the first (75%) of the forced vital capacity test.

**FEF25%-75%**
The amount of air expelled from the lungs during the middle half of the forced vital capacity test.
Predictors: Sex, Age, Ht ??
The measurements are related to the following factors:

**Age:**
- FVC and flow rates decline with age. The value of FVC increases up to 24 years of age and remain stable to age 35.

**Height:**
- All spirometric measurements increase with body weight. It is due to an increase in number and/or size of alveoli relative to airways, the larger lungs are likely to take longer than smaller one.

**Sex:**
- Most pulmonary function values are lower in female than male.

**Weight:**
- A spirometric results are positively correlated with weight to the extent that increased weight means growth or muscle mass. Beyond this (in obesity) spirometric values (and lung values specially ERV) decrease with greater weight.

**Flow-volume loops**
- Is a plot of inspiratory and expiratory flow in the vertical axis against volume in the horizontal axis, during the performance of maximally forced inspiratory and expiratory maneuvers.
- The contour of the loop assists in the diagnosis and localization of airway obstruction as different lung disorders produce distinct, easily recognized pattern.
Useful also in assessing acceptability of the manoeuvres:
1. Lack of early peak suggest poor effort.
2. Sudden tailing off of expiration curve suggest that the patient stopped blowing too early
3. Cough

Interpretation of PFTs

**Step 1.** Look at the Flow-Volume loop to determine acceptability of the test pattern.

**Step 2.** Look at the FEV₁ to determine if it is normal (≥ 80% predicted).

**Step 3.** Look at FVC to determine if it is within normal limits (≥ 80%).

**Step 4.** Look at the FEV₁/FVC ratio to determine if it is within normal limits (≥ 70%).

**Step 5.** Look at FEF₂₅-₇₅% (Normal (≥ 60%)

<table>
<thead>
<tr>
<th>FEV₁</th>
<th>FVC</th>
<th>FEV₁/FVC</th>
<th>FEF₂₅-₇₅%</th>
<th>PFT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Early obstruction/ small airways obstruction.</td>
</tr>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>≤ 60%</td>
<td>≤ 70%</td>
<td>Obstructive defect</td>
</tr>
<tr>
<td>≤ 80%</td>
<td>Normal: pure obs ≤ 80%: + restriction</td>
<td>≥ 70%</td>
<td>Restrictive defect (get lung volumes to confirm.)</td>
<td></td>
</tr>
</tbody>
</table>

**CONCLUSION**
QUESTIONS

CASE 1
76 year old smoker for assessment of RLL mass, on chest X-ray. Has chronic SOB on exertion (1 flight of stairs) and chronic productive cough. History of asthma since childhood.

- FVC% : 82%
- FEV1% : 48%
- FVC% / FEV1: 60
- FEF25%:19%
- FEF50%:16%
- FEF75%: 23%

CASE 2
65 year old man with progressive shortness of breath, with SpO2 = 81% on room air. Non smoker, no pets, no past medical history.

- FVC% : 53%
- FEV1% : 55%
- FVC% / FEV1: 88
- FEF25%: 90%
- FEF50%: 120%
- FEF75%: 82%