Author(s): Louis D’Alecy, 2009

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Respiratory Mechanics II

M1 – Cardiovascular/Respiratory Sequence
Louis D’Alecy, Ph.D.

Fall 2008
Friday 11/14/08, 9:00
Mechanics of Ventilation II
30 slides, 50 minutes

1. Tidal Volume
2. Intraplural Pressure
3. Alveolar Distending Pressure
4. Lung Compliance
5. Airway Resistance
6. Lung volumes (Spirometer)
7. Functional Residual Capacity
8. Forced vital capacity
9. Measurement of airway resistance
Tidal Volume (TV) -- air volume entering or leaving the respiratory system in a single breath. It adds to, and mixes with, alveolar gases.

Contrast with:
Minute ventilation that is total
Ventilation per minute = TV X Rate
Tidal Volume & Intraplural (P_{ip})

Inspiration

Air Entering Lung

Expiration

Air Leaving Lung

P_{ip} is

Mechanics of Breathing

Tidal Volume
Figure shows opposite direction, “down”, but volume is same

- Esophagus balloon
- Flow meter
- Calculated $P_A$
Trans-pulmonary or alveolar-distending pressure:

\[ \text{Transpulmonary pressure} = P_A - P_{ip} \]

- "across" lung wall
- \( P_{ip} \) always negative
- not symmetrical
- max @ end of Insp.
Transpulmonary Pressure by “pumping” into isolated lung (positive)

Isolated Lung

Compliance = (slope) $\frac{\Delta V}{\Delta P}$

“ease of stretching” or “inverse of elasticity”

Figure 2-6  Pressure-volume curve for isolated lungs.

Transpulmonary Pressure by “sucking” on outside of isolated lung (negative)

Hysteresis = difference on inflation and deflation

-Surfactant
-Recruiting alveoli

Same with positive or negative pressure.
Fibrosis or stiffer lung needs more pressure to get same volume.

\[
\text{Compliance} = \frac{\Delta \text{Lung volume}}{\Delta (P_{\text{alv}} - P_{\text{ip}})}
\]
Abnormal Compliance

\[ \frac{\Delta V}{\Delta P} \]

Emphysema
Greater volume change with smaller pressure change
Static P / V Excised Isolated Lung

Air filled harder to inflate than saline filled BUT...

No air = no surface tension.

Thus most inflation pressure is to overcome surface tension.
### TABLE 15–3 Some Important Facts about Pulmonary Surfactant

1. Pulmonary surfactant is a mixture of phospholipids and protein.
2. It is secreted by type II alveolar cells.
3. It lowers surface tension of the water layer at the alveolar surface, which increases lung compliance (that is, makes the lungs easier to expand).
4. A deep breath increases its secretion (by stretching the type II cells). Its concentration decreases when breaths are small.
Infant Respiratory Distress Syndrome

- No functional pulmonary surfactant
- Great difficulty inflating lungs
- If inflated for them -- tend to collapse
- Very low compliance (very stiff)
- Strenuous effort needed to breathe
- Die from complete exhaustion
Work of breathing

Work ~ Pressure change \times Volume change

Elastic work overcomes:
recoil of chest wall
recoil of lung parenchyma
surface tension of alveoli

Resistive Work overcomes:
Tissue resistance
Airway resistance
Airway Resistance

The major determinant of airway resistance is the radius ($r$) of the airway, just as in blood vessels.

The walls of the airways are subjected to the same changes in transmural pressures as alveolar walls.

During inspiration as the intrapleural pressure decreases (becomes more negative), the transmural pressure across the airway walls will increase and the radius of the airway will increase resulting in a **decrease in airway resistance during inspiration.**
During inspiration, lung volume increases and airway resistance decreases. This is due to:

- lateral traction
- transpulmonary P or alveolar distending P

Airway resistance decreases during inspiration, while forced expiration increases it. The increase in airway resistance is associated with a decrease in lung volume.
Measurement of Lung Volumes by Spirometer

Measurement of lung volumes and capacities and their relationships under different conditions is used clinically to distinguish obstructive and restrictive disease.
The sum of four volumes determine the total lung capacity (TLC).
Each “capacity” is the sum of two or more volumes.

FRC is rest position and made of ERV + RV.

VC is maximum tidal volume.
Levitzky Volumes & Capacities

\[ \text{FRC} = \text{ERV} + \text{RV} \]
FRC = ERV + RV
FRC & RV

Neither functional residual capacity (FRC) nor residual volume (RV) can be measured with simple spirometer.

THREE CLINICAL OPTIONS

1) Gas (helium) dilution****** (poor solubility) (no metabolism) (no diffusion)

2) Nitrogen-Washout Technique

3) Body plethysmography
Measurement of Functional Residual Capacity

Before Equilibration

\[ C_1 \times V_1 = C_2 \times (V_1 + V_2) \]

Amount of He “Before” = Amount of He “After”

Solve for \( V_2 \).
Measure by

Helium dilution

Spirometry

\[ FRC = ERV + RV \]

Calculate
Standing increase FRC by increasing ERV

Body position

FRC liters

Source Undetermined
FRC Standing is Larger Than FRC Supine
FRC Standing & Supine

When standing the abdominal contents pull down on diaphragm increasing FRC so chest has more air in it at rest (FRC).

When supine abdominal contents push diaphragm up into chest reducing FRC so chest has less air in it at rest (FRC).
"Static" Volumes & Capacities

FRC = ERV + RV
Airway Resistance 1 (Normal)

Forced expired volume in 1 sec (FEV$_1$) as a faction of Forced Vital Capacity (FVC)

\[
\frac{3.6}{4.5} = \frac{\text{FEV}_1}{\text{FVC}} = 80\%
\]

Fig 2-21

Forced Expiratory Flow 25-75%

Airway Resistance 2 (Obstruction)
More resistance so less and slower flow

\[
\frac{\text{FEV}_1}{\text{FVC}} = 50\%
\]

Forced Expiratory Flow 25-75%
Airway Resistance 3
“Rolling Seal Spirometer”

Alternative method
Not tested M1
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