LUNG VOLUMES AND CAPACITIES

PULMONARY FUNCTION TESTS

Learning Objectives

At the end of today's practical, student will be able to:

• Explain the principles of spirometry and how integration of the flow signal gives a volume.
• Relate your recorded lung volumes and capacities, to those of a typical person of the same gender, height and age.
• Perform pulmonary function tests, describe the common measurements made from them (PIF, PEF, FVC and FEV1) and relate these measurements to those of a typical person of the same gender, height and age.
• Describe the effect of airway restrictions on PIF, PEF, FVC and FEV1.

Primary Lung Volumes

• VT: Tidal volume – air inhaled during quiet breathing.
• IRV: Inspiratory reserve volume – maximal volume inhaled from quiet breathing.
• ERV: Expiratory reserve volume – maximal volume exhaled from quiet breathing.
• RV: residual volume – volume remaining after maximal exhalation.

Lung Capacities = Sum of Primary Lung Volumes

• TLC: Total lung volume - The volume of the lung after maximal inspiration. The sum of all four lung volumes, cannot be measured by spirometry because it includes residual volume:
  \[ \text{IRV} + \text{TV} + \text{ERV} + \text{RV} = \text{IC} + \text{FRC} \]
• VC: Vital capacity – volume exhaled from maximal inspiration to maximal expiration
  \[ \text{IRV} + \text{TV} + \text{ERV} = \text{IC} + \text{ERV} \]
• FRC: Functional residual capacity – Volume of gas remaining in lung after normal expiration, cannot be measured by spirometry because it includes residual volume:
  \[ \text{ERV} + \text{RV} \]
• IC: Inspiratory capacity- maximal volume inhaled from FRC
  \[ \text{IRV} + \text{TV} \]

Spirometry

• Measurement of air movement in and out of the lung during different respiratory maneuvers.

Values measured are:
  – FVC: Forced Vital Capacity
  – FEV1: The forced expiratory volume in one second
  – MVV: Maximum Voluntary Ventilation
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**

- **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

**Spirometry 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)

**FVC**

- Interpretation of % predicted:
  - 80-120% Normal
  - 70-79% Mild reduction
  - 50%-69% Moderate reduction
  - <50% Severe reduction

**Terminology**

- **Forced expiratory volume in 1 second** (FEV₁)
  - 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<sub>25-75</sub>)
  - 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

FEF<sub>25-75</sub>

- 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

**Equipment Setup**

- Connect the Spirometer Pod to Input 1 on the PowerLab.
- Since the Spirometer Pod is sensitive to temperature and tends to drift during warm-up, turn on the PowerLab for at least 5 minutes before use. To prevent temperature drift due to heating of the Pod, place it on a shelf or beside the PowerLab, away from the PowerLab power supply.
- Connect the two plastic tubes from the respiratory flow head to the short pipes on the back of the Spirometer Pod.
- Attach **Clean Bore tubing**, a filter and mouthpiece to the flow head.
- Make sure you have access to the following equipment for different parts of the experiment.
  - Tape measure for measuring volunteer height.
  - Duct tape and a pen, or sharpened pencil, for the simulated airway restriction exercise.
  - Extra mouthpieces and disposable air filters for each volunteer.
Caution

- If you are suffering from a respiratory infection, do not volunteer for this experiment.

Zeroing the Spirometry Pod

- The Spirometry Pod is susceptible to thermal drift of the baseline signal. In order to give appropriate volume measurements, it is important to always reset the baseline by clicking the Zero Pod button prior to making any new recording.

Procedure for zeroing the spirometer pod

- Leave the flow head apparatus undisturbed on the bench and click the Zero Pod button. This will reset the offset of the Flow channel to zero.
- Click Start. The volunteer can now put the mouthpiece in his or her mouth, and hold the flow head carefully with two hands. In order to calculate volume from the flow recording correctly, it is crucial that recording be started prior to breathing through the flow head.

Procedure continued

- Put the nose clip on the volunteers nose. This ensures that all air breathed passes through the mouthpiece, filter and flow head.
- Observe the trace. The signal should show a downward deflection on expiration. If the signal deflects upward, stop recording and either reverse the orientation of the flow head, or swap the tubular connections to the Spirometer Pod.
- When the volunteer has become accustomed to the apparatus and is breathing normally through it, stop recording and proceed to the next page.

Volume Correction

- Your instructor may not require you to perform this volume correction.
Expired air is greater in volume than inspired air under most atmospheric conditions. This increase, due to warming and humidification, is typically 5-10%. For this reason it is common to apply a volume correction factor to the Volume channel.

**Procedure for volume correction**

- Re-zero the Spirometry Pod using the Zero Pod button. Remember that the flow head must be left undisturbed on the bench during the zeroing process.
- Click Start. Once recording has started ask the volunteer to pick up the flowhead and start breathing through it.
- Have the volunteer perform a full expiration through the flowhead and then continue normal tidal breathing for one minute.
- While recording continues add the comment “Volume correction procedure” to the data.
- At the end of one minute, have the volunteer perform another full expiration.
- Click Stop. The volunteer can now stop breathing through the flow head and remove the nose clip.

**Your recording should resemble this**

- Flow, Volume and Volume Correction
- Note the relation between Flow and Volume. When the flow signal is positive (inspiration), the Volume trace rises; when the flow is negative (expiration), the Volume trace falls.
- Find a part of the recording where the flow is zero. Note that at this time the Volume trace does not change (it is horizontal) because integrating a zero signal does not add anything to the integral.
- Experiment with changing the volume correction ratio to see the effect on the Volume channel. With the default value of 1.0, i.e., no correction, you should see a downward trend in the Volume channel with time. If your volume correction ratio is appropriate this downward trend should be corrected when the Apply button is clicked. Remember to apply the appropriate factor before continuing.

**Analysis**

- Select the entire recording of tidal breathing data, including the two forced expirations by double-clicking in the Time axis beneath the trace (this selects a record).
- The default value for the volume correction factor is 1.08. Once you have selected the appropriate data, LabTutor will suggest a new volume correction factor. If you wish to accept this value click the Apply button.

**EXERCISE 1**

**Lung Volumes and Capacities**

- **OBJECT:**
In this exercise, you will examine the respiratory cycle and measure changes in volume.

It is important when recording normal respiration that the volunteer is not consciously controlling breathing. The volunteer should turn away from the computer screen and may have to stare out a window or read a book to distract themselves.

**Procedure**

- Re-zero the Spirometer Pod using the Zero Pod button. Remember that the flow head must be left undisturbed on the bench during the zeroing process.
- Click Start. Once recording has started ask the volunteer to replace the nose clip and breathe normally through the flow head. Record normal tidal breathing for 1 to 2 minutes.
- During recording add the comment “Normal tidal breathing” to the data.
- After the tidal breathing period and at the end of a normal tidal expiration, ask the volunteer to **inhale** as deeply as possible and then **exhale** as deeply as possible. Afterwards, allow the volunteer to return to normal tidal breathing then stop recording.
- Add the comment “Lung volume procedure” to this deep breath.

**THE VARIOUS LUNG VOLUMES AND CAPACITIES Analysis**

- Examine the normal tidal breathing data. Calculate how many breaths there are in a one-minute period (bpm). Type this into the appropriate cell in the table.
- Determine the volume of a single tidal inspiration by dragging the Marker from its box to the Volume channel at the start of a normal tidal inspiration. Move the Waveform Cursor to the next peak on the Volume channel (this should be 0.5 to 1.5 s to the right of the Marker).
- Click to place the selected data in the Value panel and drag the value from the Value panel into the Tidal Volume (VT) cell of the table. Expired minute volume will be calculated by LabTutor for you.

**Analysis**
Repeat steps 2-3 to determine the Inspiratory Reserve Volume (IRV) and Expiratory Reserve Volume (ERV). Note, the Marker should remain at the start of a normal tidal inspiration (trough) for the ERV procedure, it should be moved to the end of a normal tidal inspiration (peak) for for the IRV procedure.

Click on this link and use the calculator to determine predicted values for Residual Volume (RV).

The Lung Capacities will be calculated by LabTutor for you.

PULMONARY FUNCTION TEST
EXERCISE 2
Objective
- In this exercise, you will measure parameters of forced expiration that are used in evaluating pulmonary function.

Procedure
- Re-zero the Spirometer Pod using the Zero Pod button. Remember that the flow head must be left undisturbed on the bench during the zeroing process.
- Click Start. Once recording has started ask the volunteer to replace the nose clip and breathe normally through the flow head.
- Prepare a comment "FVC procedure".
- Have the volunteer breathe normally for 10 to 20 seconds.
- Ask the volunteer to inhale and then exhale as forcefully, as fully and for as long as possible, until no more air can be expired.
- In the comment box, click Add.
- Allow the volunteers breathing to return to normal, then click Stop.
- Repeat this procedure twice more, so that you have three separate Forced Vital Capacity recordings.

Analysis
- Using the Waveform Cursor and the Marker tool as necessary, examine each of the three Forced Vital Capacity recordings (FVC).
- On the Flow channel determine which of the three recordings shows a maximum Peak Inspiratory Flow (PIF).
• Click to place this data in the Value panel. Drag this value into the appropriate cell in the table.
• Repeat this step to determine the maximum Peak Expiratory Flow (PEF), and enter this into the table also.
• On the Volume channel determine which of the three recordings shows a maximal FVC.
• Place the Marker on the peak inhalation in the Volume channel and move the Waveform Cursor to the maximal expiration also on the Volume channel. Click to place the selected data in the Value panel, and drag the value from the Value panel into the FVC cell of the table.
• Using the same recording as gave a maximal FVC measure the Forced Expired Volume in 1 second (FEV1). Place the Marker on the peak inhalation in the Volume channel, move the pointer to a time 1.0 s from the peak. Click to place the selected data in the Value panel, and drag the value from the Value panel into the FVC cell of the table.
• The ratio of FEV1 to FVC expressed as a percentage, will be calculated by LabTutor for you.

QUESTIONS
• Comment on the differences between the experimental and predicted values for VC, FRC and TLC. What could cause these differences, if any?
• Differences in actual and predicted values for these variables will mostly be due to individual variation. Predicted values are based on large scale population studies and are merely averages. If the experimental values are consistently lower than the predicted it may be due to poor technique on behalf of the volunteer, i.e.; insufficient inspiratory and/or expiratory effort.
• In quiet breathing, muscular effort is used mainly in inspiration, and expiration is largely passive, due to elastic recoil of the lung. Can you relate this fact to the pattern of expiratory and inspiratory flow?
• Hint: the normal pattern of breathing is efficient in that it requires muscular effort for only a short time.
• The normal pattern of inspiration and expiration should shows a quiet period prior to each inspiration. Muscles must contract before inspiration can begin. There is a latency associated with this contraction.
• Explain why RV cannot be determined by ordinary spirometry?
• Residual Volume cannot be determined by spirometry because it is the volume of air that remains in the lungs after a full expiration.

THANKS