Module 7 – Diagnostics

This module will allow the learner to describe the included non-invasive and invasive cardiopulmonary testing in terms of indications and contraindications, details of the procedures, as well as the significance of the results.

Rationale

Why is it important for you to learn this material?

A major role for Respiratory Therapists working in acute and/or community care is aiding the physician in the diagnosis and treatment of cardiopulmonary disorders. It is therefore imperative that Respiratory Therapists have a comprehensive understanding of these diagnostics as well as the ability to evaluate treatment. Respiratory Therapists must have an excellent grasp on indications, contraindications, variables, complications, and results of diagnostic tests. As well, Respiratory Therapists must utilize these tests with proper technique.

Learning Outcome

When you complete this module you will be able to…

Describe the included non-invasive and invasive cardiopulmonary testing in terms of indications and contraindications, details of the procedures, as well as the significance of the results.

Learning Objectives

Here is what you will be able to do when you complete each objective.

1. Describe the indications and contra-indications of the various pulmonary function tests.
2. Explain the significance of spirometry testing measurements including volumes and flowrates.
3. Describe pre- and post-bronchodilator testing.
4. Describe tests to measure respiratory muscle strength and pulmonary mechanics.
5. Describe tests to determine lung volumes and gas distribution within the lung.
6. Describe ventilation and ventilatory control tests and measurements.
7. Discuss lung diffusion testing.
8. Describe testing procedures that obtain exercise-related values.
9. Explain the variables that alter the predicted normal result values for a variety of pulmonary function tests.
10. Differentiate patterns of impaired pulmonary function between obstructive, restrictive, combination, and diffusion defects.
11. Describe the principle of operation of a variety of electrodes.
12. Describe how to use expired gas analysis to evaluate mechanical ventilation.
13. Describe how to use oxygenation monitoring to evaluate mechanical ventilation.
14. Describe how to use electrocardiograms to evaluate mechanical ventilation.
15. Describe how to use hemodynamic monitoring to evaluate mechanical ventilation.
16. Describe how to use pressure, volume, and flow waveform analysis to evaluate mechanical ventilation.

Requirements

You will require the following texts to complete this module…

1. Manual of Pulmonary Function Testing, 7th Edition, Ruppel, Gregg L.: Mosby.
2. Respiratory Care Equipment, 7th Edition, Cairo, J.M. and Susan P. Pilbeam: Mosby.
3. Rapid Interpretation of Ventilator Waveforms, Waugh, Jonathan B. et al: Prentice Hall.

Objective 1

When you complete this objective you will be able to…

Describe the indications and contra-indications of the various pulmonary function tests.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 1, pp 5 - 8

Objective Checklist:

- Can you describe the indication for spirometry?
- Can you describe the indications for measuring lung volumes?
- Can you describe the indications for measuring diffusing capacity?
- Can you describe the indications for exercise testing?
- Can you suggest a particular PFT regime for any given patient?

Objective 2

When you complete this objective you will be able to…

Explain the significance of spirometry testing measurements including volumes and flowrates.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 2, pp 27 - 49

Objective Checklist:

- Can you explain the Slow Vital Capacity (SVC) manoeuvre?
- Can you differentiate between an SVC and a Forced Vital Capacity (FVC) manoeuvre?
- Can you explain all of the volumes and capacities that make up the various lung compartments?
- Can you explain how and why volumes and flows measured in spirometry are converted to BTPS? (Body Temperature, and Pressure-Saturated)
- Can you explain how the normal range for Vital Capacity (VC) is derived for any given individual?
- Can you describe all of the possible causes for a decreased VC?
- Can you list the variety of forced expiratory volume time intervals, time interval percents, and forced expiratory flows that are commonly reported from an FVC?
- Can you explain the criteria that make an FVC manoeuvre acceptable or not?
- Can you explain the significance of low values in the following categories: FVC, FEV1, $FEV_{1\%}$, and $FEF_{25\%-75\%}$?
- Can you draw a normal flow-volume loop and its variations for the following pathophysiologies: asthma, emphysema, restriction, variable intrathoracic and extrathoracic obstructions, and fixed obstruction?
- Can you describe the flow-volume loops and values, including the Peak Expiratory Flow Rate (PEFR), in small airway obstruction and compare with large airway obstruction spirometry results?
- Can you describe the acceptable procedure and significance of the results for the Maximum Voluntary Ventilation (MVV) test?
- Can you evaluate a patient's lung status based on spirometry results?

Objective 3

When you complete this objective you will be able to…

Describe pre- and post-bronchodilator testing.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 2, pp 49 - 52

Objective Checklist:

- Can you give the indications for pre- and post-bronchodilator spirometry?
- Can you list the proper instructions or technique for Metered Dose Inhalers (MDIs)?
- Can you suggest the length of time that particular bronchoactive medications should be withheld prior to pre- and post-bronchodilator testing?
- Can you interpret whether a bronchodilator had a significant effect or not?
- Can you evaluate a patient's pulmonary drug regime based on the results of pre- and post-bronchodilator studies?

Objective 4

When you complete this objective you will be able to…

Describe tests to measure respiratory muscle strength and pulmonary mechanics.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 2, pp 52 - 59, and Appendix F, p 346

Objective Checklist:

- Can you compare the testing procedure for Maximal Inspiratory Pressure (MIP) or Negative Inspiratory Force (NIF) with Maximal Expiratory Pressure (MEP)?
- Can you compare what is actually being assessed with NIF versus MEP?
- Can you suggest when NIFs and MEPs would be indicated?
- Can you explain the significance of low NIF and low MEP results?
- Can you define the terms Airway Resistance (Raw) and Airway Conductance (Gaw) and provide their units?
- Can you explain the procedure for obtaining Raw (and Gaw) using the principle of body plethysmography?
- Can you list the criteria for acceptable Raw and Gaw results?
- Can you provide the formula for Raw using the values obtained for flow and alveolar pressure, and the plethysmographic pressures obtained with the shutter open and closed?
- Can you explain how Raw and Gaw can be expressed at different lung volumes, and explain how and why these values can change?
- Can you describe how different lung pathologies and conditions may be reflected in the sRaw and sGaw results?
- Can you explain the technique for determining pulmonary compliance in a non-intubated patient?
- Can you report the range that Compliance of the Lung (C_L) is usually reported in, in terms of lung volume?
- Can you explain how elastic recoil is measured?
- Can you discuss how a variety of diseases and conditions alter the value of C_L?
- Can you explain why a certain patient's C_L using the esophageal balloon method would produce a significantly higher value than if measuring static compliance on the same patient who is intubated and ventilated by the end inspiratory pause method?

Objective 5

When you complete this objective you will be able to…

Describe tests to determine lung volumes and gas distribution within the lung.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 3, pp 69 - 94

Objective Checklist:

- Can you describe the measurement of lung volumes using both the open-circuit and closed-circuit methods?
- Can you explain the advantages of measuring lung volumes using body plethysmography?
- Can you utilize Boyle's Law to explain the principle of operation of a body plethysmograph?
- Can you calculate residual volume, total lung capacity, and related lung volumes using functional residual capacity?
- Can you identify uneven gas distribution in the lungs by both the single breath, and multiple breath nitrogen techniques?
- Can you define and measure closing volume and closing capacity?

Objective 6

When you complete this objective you will be able to…

Describe ventilation and ventilatory control tests and measurements.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 4, pp 95 - 108

Objective Checklist:

- Can you collect and calculate tidal volume and minute ventilation from other associated data?
- Can you describe two methods of identifying the breathing response to oxygen?
- Can you describe the ventilatory response to carbon dioxide?
- Can you calculate alveolar ventilation and deadspace ventilation?

Objective 7

When you complete this objective you will be able to…

Discuss lung diffusion testing.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 5, pp 111 - 131

Objective Checklist:

- Can you explain why carbon monoxide is used to determine diffusing capacity?
- Can you explain the process of obtaining a DL_{CO} with the $DL_{CO}SB$ (breath hold) technique?
- Can you discuss the criteria for acceptability of a single breath diffusion capacity?
- Can you describe how the following factors influence the diffusing capacity in the lung: hemoglobin, carboxyhemoglobin, $PACO_2$, pulmonary capillary blood volume, body position, and altitude?
- Can you discuss how the following pathologies affect the diffusing capacity of the lung: pulmonary fibrosis, alveolitis, lung tumours and therapy, end-stage congestive heart failure, emphysema, and treatment with amiodarone?

Objective 8

When you complete this objective you will be able to…

Describe testing procedures that obtain exercise-related values.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 7, pp 159 - 203

Objective Checklist:

- Can you discuss the selection of exercise protocols?
- Can you explain the changes that occur with ventilation during an exercise test?
- Can you discuss exercise limitations including cardiovascular, ventilatory, and gas exchange limitations?
- Can you explain the terms oxygen consumption, carbon dioxide production, respiratory exchange ratio, and anaerobic threshold as they apply to exercise?
- Can you describe two methods of measuring cardiac output during exercise?
- Can you list reasons why a cardiopulmonary stress/exercise test would be discontinued?

Objective 9

When you complete this objective you will be able to…

Explain the variables that alter the predicted normal result values for a variety of pulmonary function tests.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Appendix B, pp 326 - 334

Objective Checklist:

- Can you explain how age, gender, height, race, and sometimes weight can alter the predicted norms for flows and volumes?
- Can you explain how a standard deviation is determined?
- Can you determine if a value is either within or out of a +/- 20% range from a predicted value?

Objective 10

When you complete this objective you will be able to…

Differentiate patterns of impaired pulmonary function between obstructive, restrictive, combination, and diffusion defects.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Manual of Pulmonary Function Testing, Chapter 1, pp 8 - 19

Note: Information to meet objective ten is found throughout all the chapters of this text.

Objective Checklist:

- Can you explain how the pathophysiology of emphysema alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of chronic bronchitis alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of bronchiectasis alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of asthma alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of cystic fibrosis alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of upper airway obstruction alters Pulmonary Function Testing results?
- Can you explain how the pathophysiology of interstitial lung disease alters Pulmonary Function Testing results?
- Can you explain how the pathophysiologies of the chest wall and pleura alter Pulmonary Function Testing results?
- Can you explain how the pathophysiologies of neuromuscular diseases alter Pulmonary Function Testing results?
- Can you explain how the pathophysiology of congestive heart failure alters Pulmonary Function Testing results?
- Can you explain how lung transplants alter Pulmonary Function Testing results?
- Can you differentiate, in general, between the pulmonary function of obstructive, restrictive, combination, and diffusion defects?

Objective 11

When you complete this objective you will be able to…

Describe the principle of operation of a variety of electrodes.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Respiratory Care Equipment, Chapter 10, pp 295 - 302 and pp 309 - 311

Objective Checklist:

- Can you describe the principle of operation for the Sanz electrode?
- Can you describe the principle of operation for the Stowe-Severinghaus electrode?
- Can you describe the principle of operation for the Clark electrode?
- Can you describe the principle of operation for ion-selective electrodes?
- Can you describe the principle of operation for sensors used to measure metabolites such as glucose?

Objective 12

When you complete this objective you will be able to…

Describe how to use expired gas analysis to evaluate mechanical ventilation.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Respiratory Care Equipment, Chapter 8, pp 240 - 253

Objective Checklist:

- Can you define capnography?
- Can you describe Infrared Spectroscopy?
- Can you describe Mass Spectroscopy?
- Can you differentiate between sidestream and mainstream capnographs?
- Can you describe the four phases of a normal capnogram waveform?
- Can you remember the term and abbreviation for the main value reported from a capnometer?
- Can you explain how variations on deadspace will influence the relationship between PaCO2 and PETCO2?
- Can you explain how you would use capnometry to monitor the severity of pulmonary disease and evaluate response to therapy?
- Can you explain how you would capnometry to evaluate the placement of the endotracheal tube post-intubation?
- Can you explain how you would use capnometry to evaluate the degree of cardiac compromise induced by positive pressure ventilation?
- Can you explain how you would identify that the paralytic is wearing off from an electively paralyzed and mechanically ventilated patient?
- Can you describe Closed-Circuit Indirect Calorimetry?
- Can you describe Open-Circuit Indirect Calorimetry?
- Can you explain how the Respiratory Quotient (RQ) is derived?
- Can you remember the RQ values for carbohydrates, fats, proteins, and during lipogenesis?
- Can you describe how to use metabolic monitoring to evaluate the body's inability to utilize carbohydrates when suffering from sepsis?

Objective 13

When you complete this objective you will be able to…

Describe how to use oxygenation monitoring to evaluate mechanical ventilation.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Respiratory Care Equipment, Chapter 10, pp 304 - 309

Objective Checklist:

- Can you explain the principles of spectrophotometry and photoplethysmography?
- Can you describe the many values that are obtained by a pulse oximeter, as well as the ratio/formula in which these values are arranged, in order to determine a patient's oxygen saturation?
- Can you differentiate between the functional saturation and the fractional saturation?
- Can you describe how perfusion can affect the pulse oximeter reading?
- Can you describe how carboxyhemoglobin (COHb) and methemaglobin (MetHb) can affect the pulse oximeter reading?
- Can you explain other causes of inaccurate pulse oximeter readings?
- Can you explain how pulse oximeters are calibrated?
- Can you explain how a pulse oximeter would be used to assess and monitor the oxygenation of a patient receiving mechanical ventilation?

Objective 14

When you complete this objective you will be able to…

Describe how to use electrocardiograms to evaluate mechanical ventilation.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Respiratory Care Equipment, Chapter 9, pp 254 - 275

Objective Checklist:

- Can you define the terms excitability, automaticity, and conductivity?
- Can you describe the process of a cardiac muscle cell depolarizing?
- Can you draw a diagram detailing the electrical conduction pathway through the heart?
- Can you explain how electrical activity is measured in the heart?
- Can you list the twelve traditional leads of an electrocardiogram (ECG) and group these leads into standard limb, augmented limb, and precordial leads?
- Can you explain the term Einthoven's triangle?
- Can you describe how to locate the proper positions for attaching each of the 9 electrodes in a standard 12-lead ECG?
- Can you describe the standardized ECG tracing paper?
- Can you describe the normal appearance of an ECG including details of the following: the P wave, the PR interval, the QRS complex, the ST segment, the T wave, the QT interval, and the U wave (if present)?
- Can you describe the process of determining the atrial and ventricular rates from an ECG strip?
- Can you provide a description of a Normal Sinus Rhythm (NSR) and the following arrhythmias in lead II: tachycardia, bradycardia, paroxysmal atrial tachycardia, supraventricular tachycardia, atrial flutter, atrial fibrillation, junctional rhythm, ventricular tachycardia, ventricular fibrillation, Wolff-Parkinson-White syndrome, bundle branch blocks, atrioventricular (AV) blocks [first, second (both Mobitz 1 and 2), and third degree], premature beats/depolarizations (atrial, junctional, and ventricular)?
- Can you describe the damage caused over time by a myocardial infarction and how this translates onto the ECG?
- Can you describe a 12-lead ECG when the following localized myocardial infarctions occur in these areas: anterolateral, anteroseptal, apical, anterobasal, posteroseptal, posteroinferior, and posterolateral?
- Can you explain how ECG results may alter mechanical ventilation application?

Objective 15

When you complete this objective you will be able to…

Describe how to use hemodynamic monitoring to evaluate mechanical ventilation.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Respiratory Care Equipment, Chapter 9, pp 274 - 289

Objective Checklist:

- Can you describe the cardiac cycle?
- Can you explain how a sphygmomanometer measures blood pressure?
- Can you describe the indications and procedure for inserting an arterial line catheter?
- Can you describe the indications and procedure for inserting a pulmonary artery catheter?
- Can you draw and label a diagram displaying the waveforms and normal pressure ranges for a pulmonary artery catheter reporting pressures in the right atrium, right ventricle, pulmonary artery, and during a pulmonary artery occlusion?
- Can you describe the procedure for obtaining a Pulmonary Artery Occlusion Pressure (PAOP) and explain the possible results related to pathophysiology?
- Can you explain how pressure transducers provide vascular pressure readings?
- Can you explain how the following methods determine cardiac output: thermodilution, dye-dilution, and direct Fick method?
- Can you explain how impedance cardiography and the indirect Fick method can determine cardiac output?
- Can you define Right Ventricular End-Diastolic Pressure (RVEDP) and Left Ventricular End-Diastolic Pressure (LVEDP) and which two pressures read from a pulmonary artery catheter these correspond to?
- Can you provide the equation for vascular resistance as it applies systemically and in the pulmonary system?
- Can you explain factors that may increase or decrease vascular resistance from normal?
- Can you provide the equations and explain Left Ventricular Stroke Work Index (LSWI) and explain Right Ventricular Stroke Work Index (RSWI)?
- Knowing that positive pressure ventilation can reduce venous return, can you explain how you could use hemodynamic monitoring to evaluate mechanical ventilation – in terms of evaluating PEEP as well as Ti – two parameters that can greatly affect oxygenation and mean airway pressure?

Objective 16

When you complete this objective you will be able to…

Describe how to use pressure, volume, and flow waveform analysis to evaluate mechanical ventilation.

Learning Activity

Complete each of the Learning Activities listed below.

Please read and review the following:

1. Rapid Interpretation of Ventilator Waveforms

The entire text is an excellent resource; however, beside each Objective the associated page numbers will be included.

Objective Checklist:

- Can you draw typical "Assist/Control (A/C), volume targeted" flow/time (f/t), volume/time (v/t), and pressure/time (p/t) waveforms over a number of breaths? And on each graph, can you identify the following: the beginning of inspiration, inspiration, end of inspiration, beginning of expiration, expiration, and end of expiration? (Chapter 1, pp 9 and 10)
- Can you draw f/t, v/t, p/t waveforms for the following modes of ventilation?
    - Synchronized Intermittent Mandatory Ventilation (SIMV) volume targeted
    - SIMV (volume targeted) with Pressure Support (PS) and also Positive End-Expiratory Pressure (PEEP)
    - Pressure Control (PC) Ventilation (Chapter 1, pp 10 - 22 **More detailed information can be found in Chapter 3, pp 55 - 75*
- On a pressure/volume (p/v) curve, can you identify the following: inspiration and exhalation, tidal volume, peak inspiratory pressure, inflection points, negative volume deflections? (Chapter 2, pp 23 - 29)
- Can you draw separate p/v curves that demonstrate the following: increased compliance, decreased compliance, increased inspiratory airway resistance, increased expiratory resistance? (Chapter 2, pp 29 - 33)
- Can you draw separate one or two ventilator waveforms that best demonstrate the following undesirable effects: overdistention or "beaking", a lung suffering from atelectrauma due to repeated opening and closing of alveoli, active exhalation, bronchospasm, dynamic hyperinflation, dynamic compression or early small airway collapse, kinked endotracheal tube, inadequate inspiratory flow, trigger not sensitive enough? (Chapter 4, pp 77 - 93)
- Can you make appropriate suggestions (changes to the ventilator and/or other treatments) to treat the inappropriate ventilator settings discussed in the above bulleted question?