The Persing Workshop

Therapist Multiple-Choice Review Study Guide

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Symptoms of Pulmonary Disorders

I. Assessment of Pulmonary Symptoms

A. Pulmonary symptoms are assessed to determine the following:

1. Immediate or potential danger
2. Underlying cause and disease process
3. Impact and effectiveness of treatment modalities

B. The most common symptoms associated with pulmonary disorders are cough, sputum production, shortness of breath (dyspnea), wheezing and chest pain.

II. Primary Pulmonary Symptoms

A. Cough

1. The most common symptom associated with lung disorders.

2. Coughing is a protective airway reflex mechanism that arises from stimulation of receptors located in the pharynx, larynx, trachea, large bronchi, lung and the visceral pleura. When a foreign particle or body enters the airway, these reflexes attempt to remove it by stimulating a cough.

3. Inflammatory, mechanical, chemical or thermal stimulation of cough receptors located anywhere from the oropharynx to the terminal bronchioles can produce coughing.

    a. inflammatory – infection, lung abscess, allergy, TB, pneumoconiosis (occupational lung disorders), edema

    b. mechanical obstructive – inhaled dusts, foreign bodies, aspiration of nasal secretions, tumor or granuloma, aortic aneurysm, atelectasis, fibrosis, pulmonary edema

    c. chemical – inhaled irritant gases, smoke, fumes

    d. thermal – inhaled hot or cold air

4. The cough reflex may be voluntary or involuntary. The efficiency of the cough is determined by the depth of inspiration and the amount of pressure that can be generated in the airways.

5. An ineffective cough may be the result of:

    a. Weakness of the inspiratory or expiratory muscles
    b. Inability of the glottis to open or close correctly
    c. Obstruction, collapse or alteration in shape of the airways (emphysema, for example)
    d. Decrease in lung recoil as seen in patients with emphysema
    e. Abnormal quantity or quality of mucus production

6. Cough may be classified as **acute** (sudden onset), **chronic** (persistent, usually for more than 3 weeks) or **paroxysmal** (periodic, prolonged, forceful episodes).

    a. acute cough – usually due to the common cold

    b. chronic persistent cough – usually caused by postnasal drip syndrome; other causes include asthma, chronic bronchitis (especially in smokers), bronchiectasis, bronchogenic cancer, left heart failure

    c. paroxysmal – related to allergies and asthma

7. Coughing may also occur in conjunction with other pulmonary disorders such as wheezing, stridor (harsh snoring sound), chest pain and dyspnea.

8. Because of the vigorous muscle activity related to coughing, problems such as fatigue, torn chest muscles, rib fractures, pneumothorax, cardiac arrhythmia, esophageal rupture or syncope (fainting) can occur.

9. Description of cough:

    a. effective – strong enough to clear secretions from the airways
    b. inadequate – audible but too weak to mobilize secretions
    c. productive – mucus or other material is expectorated
    d. dry or non-productive – secretions are not produced

B. Sputum Production

1. Sputum is the term used for material that is expelled from the tracheobronchial tree, pharynx, mouth sinuses, and nose by coughing or clearing the throat. (The term *phlegm* refers strictly to secretions from the lungs and tracheobronchial tree.)

2. Sputum may consist of mucus, blood, pus, cellular debris, microorganisms and foreign particles. It should not be confused with saliva.

3. The tracheobronchial tree secretes up to 100 mL of sputum each day. It is part of the mucociliary blanket that traps inhaled particles and is then propelled by cilia (tiny hair-like structures) upward into the back of the throat where the trapped particles are swallowed or coughed out.

4. Sputum should be described by its color, quantity, odor, consistency and presence of blood.

    a. Color – the color of sputum can be highly indicative of the underlying lung disorder.

        Clear, colorless – normal

        Green or yellow – purulent or mucopurulent (containing pus, indicates infection) - *Pseudomonas* pneumonia, bronchiectasis (divided into layers)

        Frothy white or pink – pulmonary edema

        Red currant jelly – *Klebsiella* pneumonia

        Mucoid (clear, thin, sometimes thick) – emphysema, tuberculosis, neoplasms (cancer)

        Blood-streaked or frank blood – hemoptysis

        Pink, thin, blood-streaked – streptococci or staphylococci

        Rusty – Pneumococci

    b. quantity – may be described as scanty (small amount) to copious (large amount)

c. odor – odorous or foul-smelling sputum may indicate Pseudomonas pneumonia, lung abscess, aspiration, anaerobic infections bronchiectasis

d. Consistency – may be described as thin, thick, viscous (gelatinous), tenacious (extremely thick), or frothy.

C. Hemoptysis

1. The term used to describe the expectoration of sputum containing blood. It may vary from blood-streaked to frank bleeding. It may indicate serious disease and massive hemorrhage.

2. Hemoptysis may be caused by:

   a. trauma - torn blood vessel
   b. lung tumor (bronchogenic carcinoma) – may erode through tissue or artery
   c. infection – may lead to abscess formation that erodes through a blood vessel
   d. chronic bronchitis – inflammation may cause erosion into a blood vessel (Most common cause of hemoptysis—almost 50%)
   e. bronchiectasis – inflammation
   f. tuberculosis – inflammation

3. Massive hemoptysis (400 mL in 3 hours or more than 600 mL in 24 hours) is seen with lung cancer, tuberculosis, bronchiectasis and trauma. This is an emergency situation with a mortality rate as high as 75%.

4. With massive hemoptysis, immediate action is required to maintain an adequate airway, and emergency bronchoscopy and surgery may be necessary to stop bleeding.

5. Important to determine if the blood is coming from the lungs or from the stomach. Vomited blood is referred to as hematemesis.

D. Shortness of Breath (Dyspnea)

1. Shortness of breath (SOB) or difficulty breathing is the most distressing symptom of respiratory disease and is also an important symptom of cardiac disease.

2. **Dyspnea** is a subjective symptom, in other words, what the patient feels. It refers to the patient stating “I’m short of breath” or “I’m having difficulty breathing.”

3. There are scoring systems such as the *Modified Borg Scale* and the *American Thoracic Society Shortness of Breath Scale* that helps quantify the degree of dyspnea. On both scales, the higher the score, the more severe the dyspnea.

4. In patients with respiratory disorders, dyspnea usually occurs when one or more of the following are present:

    a. Breathing is impeded
    b. The mechanics of breathing are abnormal
    c. Lungs are stiff (low lung compliance)
    d. Ventilatory muscles are weakened
    e. Chemoreceptor input is increased

5. Clinical types of dyspnea

    a. Restrictive dyspnea

        (1) Refers to low compliance of the lungs or chest wall
        (2) Patients are generally comfortable at rest but become intensely short of breath when exertion causes ventilation to approach their greatly limited breathing capacity.
        (3) Examples include pulmonary fibrosis, pneumothorax, chest wall deformities (kyphosis, kyphoscoliosis), pleural effusion

    b. Obstructive dyspnea

        (1) Refers to increased resistance to air flow
        (2) Breathing is labored and slow especially during exhalation, with increased ventilatory effort, resulting in dyspnea at rest.
        (3) Examples are emphysema and asthma

    c. Physiologic dyspnea

        (1) exercise
        (2) acute hypoxia (low oxygen levels in body), for example, at high altitude
        (3) breathing high concentration of carbon dioxide (CO_2) in a closed space; for example, inadequate flow to an O_2 mask

    d. Cardiac and circulatory-related dyspnea

(1) Generally occurs when there is an inadequate amount of oxygen.
(2) Heart may fail to pump adequately resulting in heart failure.
(3) May result in orthopnea or paroxysmal nocturnal dyspnea (discussed later)
(4) Anemia (low red blood cell count) may result in dyspnea due to low oxygen carrying capacity in the blood.

e. Psychogenic dyspnea

(1) Dyspnea related to pain or anxiety (panic disorder)
(2) Results in continuous hyperventilation (discussed later)

6. Acute vs. Chronic Dyspnea

a. Acute dyspnea is caused by the following:

(1) asthma
(2) chest trauma
(3) pleural effusion
(4) pneumonia
(5) pulmonary edema
(6) pulmonary embolism
(7) pulmonary hemorrhage
(8) spontaneous pneumothorax
(9) upper airway obstruction

b. Chronic dyspnea is caused by the following:

(1) asthma
(2) congestive heart failure (CHF), left ventricular failure
(3) cystic fibrosis
(4) pleural effusion
(5) chronic obstructive pulmonary disease (COPD)
(6) pulmonary vascular disease
(7) severe anemia
(8) interstitial lung disease

7. Other Abnormal Breathing Conditions

Note: The term **eupnea** refers to the normal rate and depth of breathing. Normal rate is considered 10-20 breaths/min with a depth or tidal volume (V_T) of 3-4 mL/lb (5-6 mL/kg) of ideal body weight.

a. Paroxysmal nocturnal dyspnea (PND)

(1) Sudden onset of dyspnea when sleeping in the supine (lying down) position and is generally relieved when the patient sits up.

(2) Occurs in patients with CHF as blood pools in the lungs and occurs 1-2 hours after lying down. Also occurs in COPD patients and is often relieved by coughing and expectorating sputum.

b. Orthopnea

(1) Difficulty breathing while lying down.
(2) Is often described as two- or three-pillow orthopnea depending on the number of pillows the patient must use to reduce the dyspnea.

(3) PND and orthopnea are both often associated with left-heart failure. Orthopnea also seen with COPD and obese patients.

c. Treopnea

(1) Dyspnea that occurs by lying on one side but is relieved by turning on the opposite side.

(2) Associated with unilateral lung disorders such as unilateral pleural effusion or unilateral airway obstruction

d. Platypnea

(1) Opposite of orthopnea, or dyspnea caused by an upright posture which is relieve by lying down.

(2) It is often associated with intracardiac right-to-left shunts where more blood is shunted through the foramen ovale or atrial septal defect when the patient is upright. This means blood is going from the right side of the heart to the left side without picking up oxygen.

(3) This right-to-left shunt while standing is referred to as *orthodeoxia*, meaning positional hypoxia, or a reduced amount of oxygen to the tissues as a result of a specific position.

e. Bradypnea

(1) Less than normal rate of breathing

(2) May be caused by respiratory center depression due to head trauma or drug overdose

f. Tachypnea

(1) Rapid rate of breathing, generally more than 25 breaths/min

(2) Caused by hypoxemia, atelectasis, fever, exercise, metabolic acidosis, pain

g. Apnea

(1) Absence of spontaneous breathing

(2) Caused by head trauma, drug overdose, obstruction (obstructive sleep apnea), or respiratory center impairment (central sleep apnea)

h. Hyperventilation

(1) Breathing at a rate or depth in excess of the body's metabolic demands, **indicated by a decreased $PaCO_2$ level.** (Increased alveolar ventilation)

(2) Results in a decrease in cerebral blood flow that can cause faintness or lightheadedness

(3) May be caused from anxiety or respiratory center impairment

i. Hypoventilation

(1) Breathing at a rate or depth that is inadequate to meet the patient's metabolic needs, **indicated by an increased $PaCO_2$ level**. (Decreased alveolar ventilation)

(2) May be caused by obstruction, muscle weakness, chest pain, respiratory center depression

j. Hyperpnea

(1) Increased depth of breathing, with or without an increased rate

(2) Similar to hyperventilation

k. Hypopnea

(1) Decreased depth of breathing

(2) Similar to hypoventilation

E. Wheezing

1. Another common symptom observed in pulmonary patients.

2. It's a whistling or musical-type sound produced as air passes through narrowed bronchi and bronchioles.

3. The airway narrowing occurs from spasm, tissue swelling (edema), mucus plugging or from pressure surrounding the lung.

4. It is primarily heard during expiration but may be heard during inspiration as well. Although wheezes may be audible to the patient and others near the patient, they frequently are only heard using a stethoscope.

5. Wheezing nearly always indicates disease of the lower airways from bronchoconstriction, most commonly asthma. **But not all wheezing indicates asthma**. In patients over 40 years old, it may indicate CHF.

6. In asthma patients wheezing is reduced by the administration of bronchodilators that open up the airways by increasing their inside diameter. It's important to remember that decreased wheezing may also be an indication of a worsening condition, where the airway is closing off more.

7. Wheezing may be heard due to an obstruction to airflow in the upper airway. **Stridor** is a harsh "crowing" sound that can be heard during inspiration or expiration when one of the major airways is obstructed. Stridor results from obstruction of the trachea or larynx (glottis) by inflammation, tumor, foreign body or vocal cord paralysis.

Note: Stridor may be observed following removal of the patient's endotracheal tube. Since the ET tube rests between the vocal cords, inflammation and swelling can occur. Once the tube is removed, the swelling obstructs airflow through the vocal cords and glottis.

8. Stridor may indicate a medical emergency. Medications such as racemic epinephrine or steroids will help reduce the swelling. If medications are unsuccessful, the patient will need to be intubated with an endotracheal tube.

E. Chest Pain

1. Most commonly results from inadequate blood supply to the tissues (ischemia) or inflammatory disorders affecting the heart, trachea, main airways, chest wall, pleurae, esophagus, stomach, gallbladder or pancreas.

2. Chest pain is the cardinal symptom of heart disease. It is a pain that radiates down the arms, usually the left and often to the hand or up into the jaw.

3. Intervention to open a clogged coronary artery to reestablish blood flow to the heart muscle must be done within 4 hours of the onset of chest pain or irreversible damage to the heart muscle will occur.

4. Pulmonary Causes of Chest Pain

    a. Pneumonia
    b. Pleural disorders (pleurisy)
    c. Lung abscess
    d. Pulmonary infarction (embolus)

F. Dizziness and Fainting (Syncope)

1. **Syncope** is a temporary loss of consciousness caused by reduced blood flow to the brain resulting in a reduced amount of oxygen and nutrients as well.

2. Pulmonary causes of syncope:

    a. pulmonary emboli
    b. pulmonary hypertension
    c. prolonged coughing spells
    d. hypoxia (low oxygen levels)

e. hypocapnia (low carbon dioxide levels)
f. orthostatic hypotension (drop in blood pressure when standing up)

G. Pedal Edema (swelling of the ankles)

1. This refers to an accumulation of fluid in the subcutaneous tissues of the ankles. .

2. This symptom is commonly observed in patients with chronic pulmonary disease, in which their chronic hypoxemic state results in pulmonary vasoconstriction.

3. This make the right side of the heart work harder as it pumps blood through narrowed pulmonary vessels. This results in an increased workload on the right heart, right ventricular hypertrophy, and eventually, right heart failure (cor pulmonale).

4. As right-sided heart pressures increase, venous blood flow returning to the heart is diminished, and the peripheral blood vessels become engorged. The ankles are most affected as a result of gravity. This is often accompanied by **jugular venous distention (JVD).** The jugular veins returning blood from the upper body also become engorged as a result of elevated right heart pressure.

H. Headache, Altered Mental Status and Personality Changes

1. Patients with low blood oxygen levels may suffer from headaches resulting from decreased oxygen to the brain. High carbon dioxide levels increase blood flow to the brain, also resulting in headaches.

2. As cerebral hypoxia and hypercapnia persist, progressive changes in the patient's mental status may occur. Thought processes and memory deteriorate. Headaches, tremors, uncontrolled movements, hallucinations, and nightmares may also occur.

3. In patients with advanced pulmonary disease, personality changes are not uncommon. The patient may experience depression, forgetfulness, and the inability to concentrate. The patient may be anxious and demanding while denying the disease process and refusing to follow the treatment regimen.

4. Sudden personality changes or alteration in mental status are indicative of an acute problem, most likely acute hypoxia or hypercapnia.

Vital Signs

I. Measurement of Vital Signs

A. The four most common vital sign measurements **are temperature, pulse, respirations and blood pressure.** Routine vital sign measurements are generally done every 4-6 hours but are dependent on the patient's condition. After surgery vital signs are often measured after 15 minutes for 2 hours, then every 30 minutes for 1-2 hours.

The physician's order may state: "Vitals q15 minutes x 8, q30 minutes x 4, qh until stable, then q4-6h."

B. To evaluate whether a patient has "normal" vital signs, the therapist must understand what "normal" is for each individual patient's age, disease and environment.

C. Serial vital signs or vital sign measurements observed over a specific time is more important clinically than any one single measurement.

D. Vital signs should always be compared to previous measurements in order to determine a trend that may indicate the patient's condition is changing. Because monitoring the trend of vital signs is so clinically important, they are often recorded in the patient's chart on a multiple-day graph.

E. Comparing multiple vital signs and symptoms to arrive at the patient's diagnosis is referred to a *differential diagnosis*.

II. Vital Signs and Assessment

A. Temperature

1. Normal value: 98.6^{o}F (37^{o}C); normal range: 97^{o}F – 99.5^{o}F

2. Fever: An elevated body temperature and is referred to as hyperthermia. A patient with a fever is said to be **febrile**. If body temperature is normal, it is referred to as **afebrile**.

    a. Hyperthermia results in an increased metabolic rate of the body functions and produces an increase in oxygen consumption and carbon dioxide production by the body tissues.

b. For every 1°C increase in body temperature, oxygen consumption and carbon dioxide production increase by about 10%.

c. **Because of the body's demand for more O_2 to the tissues and removal of CO_2 from the tissues, there is an increase in blood circulation and ventilation**. **That's why the assessment of a febrile patient often indicates an increased heart rate and respiratory rate**. This may not be that taxing on generally healthy patients, but for the patient with significant cardiac or pulmonary disease, the increased demand on these systems may result in an intolerable stress level to the body.

3. Hypothermia: A body temperature below normal.

   a. May be observed in patients with head-injury where damage to the hypothalamus has occurred and in patients exposed to cold environmental temperatures.

   b. Hypothermia results in a decreased O_2 consumption and CO_2 production by the body tissues, therefore the patient generally has a slow and shallow breathing pattern, and a decreased heart rate.

4. Body temperature is measured at one of four sites: mouth, ear, axilla (under arm), or rectum.

   a. Rectal: The rectal temperature most accurately reflects the body's core temperature. Most commonly measured on comatose patients or patients in ICU. Not measured in neonates.

      Normal range: 98.7°F – 100.5°F (37.1°C – 38.1°C)

NOTE: Use the following equations to convert from Fahrenheit to Celsius and vice versa:

°C to °F = (°C x 1.8) + 32
°F to °C = (°F – 32) x .55

   b. Axillary: Method of choice for neonates since it closely approximates their core temperature. Not as accurate in adults. Reads about 1°F lower than oral temperature and

2°F lower than rectal. Takes 5-10 minutes to get the most accurate measurement.

Normal range: 96.7°F – 98.5°F (35.9°C – 36.9°C)

c. Oral: Most convenient and acceptable method for adults. May be measured accurately on patient with nasal cannula in place. May be slightly inaccurate if heated or cool aerosol is being administered, but probably is not clinically significant. Takes 3-7 minutes for most accurate measurement and there should be a 15 minute waiting period after drinking hot or cold fluids or smoking.

Normal range: 97.0°F – 99.5°F (36.5°C – 37.5°C)

d. Tympanic (ear): A handheld probe is placed in the ear canal which measures infrared emissions from the tympanic membrane and ear canal. Reflects a close approximation to rectal or core temperature. Used mostly on pediatric patients and in emergency rooms. Takes only 2-3 seconds to obtain an accurate measurement.

Normal range: approximately the same as rectal

B. Pulse

1. Normal rates:

Newborn: 90 – 170/min

-3-

1 year old: 80 – 160/min
Preschool: 80 – 120/min
10 years: 70 – 110/min
adult: 60 – 100/min

2. **Tachycardia**: A heart rate of greater than 100/min.

Causes of tachycardia:

a. anxiety
b. hypoxemia (low blood oxygen level)
c. medications
d. low blood pressure
e. anemia
f. fever

g. fear

3. **Bradycardia**: A heart rate of less than 60/min.

   Causes of bradycardia:

   a. heart disease
   b. medications
   c. well-conditioned athletes
   d. stimulation of vagus nerve

4. Pulse Rhythm and Pattern

   a. Pulse rhythm is the equality of the intervals between beats and can be described as regular, regularly irregular or irregularly irregular.

      (1) Regularly irregular: a pulse with an irregularity that occurs in a definite pattern. For example, beat, beat, pause, beat, beat, pause. Two beats and a pause are termed bigeminy. Three beats and a pause are referred to as trigeminy. This is better assessed by observing ECG to determine the arrhythmia (irregular heart beat) present.

      (2) Irregularly irregular: a pulse that has no pattern

      (3) In very irregular heart rhythms the heartbeats may not be able to generate enough of a pulse wave to measure peripheral pulse so a stethoscope over the heart is used to count pulse.

   b. The volume of blood is assessed by the feel of the artery as blood flows through it with each beat. The volume of the pulse is described as bounding, full, normal, weak, thready or absent.

      (1) A *bounding* pulse is a full pulse that is difficult to depress with the fingertips.
      (2) A *weak* or *thready* pulse has a low volume and can be easily depressed and often difficult to obtain.

   c. The fullness of the pulse may be reduced for various reasons:

      (1) dehydration
      (2) blood clot
      (3) atherosclerosis

(4) diabetes mellitus
(5) other conditions reducing blood flow such as cold temperature

B. Respiratory Rate

1. Respiratory rate varies according to the age and condition of the patient.

Newborn:	35-45-70 breaths/min with excitement
1 year old:	25-35 breaths/min
Preschool:	20-25 breaths/min
10 years:	15-20 breaths/min
Adult:	12-20 breaths/min

2. **Tachypnea**: above normal respiratory rate

3. **Bradypnea**: below normal respiratory rate

C. Blood Pressure

1. Arterial blood pressure is the force exerted against the walls of the arteries as the blood flows through the arterial vessels.

2. Blood pressure is recorded with the systolic pressure over the diastolic pressure: 120/80 mm Hg, for example.

   a. **systolic pressure**: the peak force exerted against the arterial walls as the left ventricle contracts.
   b. **diastolic pressure**: force exerted against the arterial walls when the heart is relaxed (between beats)

   c. **pulse pressure**: the difference between systolic and diastolic pressures. For example, a BP of 120/80 mm Hg equals a pulse pressure of 40 mm Hg. **Normal pulse pressure is 35-40 mm Hg**.
   When pulse pressure is less than 30 mm Hg, the peripheral pulse is difficult to detect.

3. Normal ranges for blood pressure:

   Systolic pressure: 90 – 130 mm Hg
   Diastolic pressure: 60 – 85 mm Hg

   Normal BP is <120/80.

4. **Hypertension**: blood pressure persistently above normal, or above 140/90.

   a. Primary hypertension has no known cause but may be the result of family history, smoking, diet, etc.

   b. Secondary hypertension is the result of some other physical condition.

   c. Hypertension increases the risk for the development of heart, vascular and renal disease.

5. **Hypotension**: blood pressure less than 90/60 mm Hg.

   a. Causes of hypotension

      (1) peripheral vasodilation
      (2) left ventricular failure
      (3) hypovolemia (low blood volume)

   b. When hypotension occurs, the body's vital organ systems have reduced blood flow. When blood flow is impaired, oxygen delivery to the tissues is impaired resulting in tissue hypoxia.

6. **Postural hypotension**: a drop in blood pressure when moving from a supine position to a sitting or standing position. It is most significant when hypovolemia or vasodilation is already present.

7. **Measurement of Blood Pressure**

   a. The most common technique for measuring BP is with the use of a sphygmomanometer which including the cuff, stethoscope and manometer.

   b. The cuff is applied to an extremity, typically the upper arm and is inflated. When the pressure in the cuff exceeds the systolic pressure, blood flow through the artery is occluded and the pulse can longer be felt. When the cuff is gradually deflated, blood flow in the artery resumes and the pulsations can be felt or heard with a stethoscope.

   c. Blood pressure generally decreases slightly, by 2-4 mm Hg, during normal inhalation. If the BP drops by more than 10 mm Hg during inspiration while at rest, **paradoxical pulse** is

present, an abnormal finding. It is also referred as **pulsus paradoxus**.

d. Paradoxical pulse is observed in respiratory and cardiac conditions such as asthma and cardiac tamponade.

e. This fluctuation in blood pressure during inspiration is most likely the result of the negative pressure created in the chest by the respiratory muscles. The drop in pressure increases blood flow from the body back into the right ventricle and reduces blood flow out of the left ventricle.

f. The increased blood flow into the right ventricle increases the pressure in the right ventricle, which causes the interventricular septum to distend into the left ventricle, which reduces the amount of blood that can enter the left ventricle. Therefore, left ventricular filling decreases which reduces stroke volume and decreases blood pressure.

III. Other Assessments

A. Height and weight

1. These are routinely measured as part of the physical examination.

2. The weight is often recorded in kilograms. **(1 kg = 2.2 lb)**

3. We often use the patient's weight to determine what tidal volume to set on the patient's mechanical ventilator.

4. The weight is usually measured every 1-2 days, along with the patient's fluid intake and output each shift to determine fluid overload or dehydration.

B. Level of Consciousness (Sensorium)

1. Abbreviated on the chart as LOC, it is a simple but important assessment to make. In order for the patient to be conscious, alert and well oriented, adequate cerebral oxygenation must be present.

2. The conscious patient should be evaluated for orientation to *time, place and person*. If normal, this is often referred to in the chart as being *"oriented x 3."*

3. An abnormal sensorium and a loss of consciousness may occur when cerebral perfusion is inadequate or when poorly oxygenated blood is delivered to the brain. Initially, the patient becomes confused, restless and disoriented, followed by unconsciousness (comatose) if the tissue hypoxia continues.

4. An abnormal sensorium may also occur as the result of a drug overdose or as a side effect of certain medications.

5. As the patient's sensorium deteriorates, the need for mechanical ventilation is often indicated since the patient's respiratory status becomes affected.

6. **The Glasgow Coma Scale** is based on a 15 point scale for estimating and categorizing the outcomes of brain injury on the basis of overall social capability or dependence on others.

This information was obtained from Traumatic Brain Injury.com

The test measures the motor response, verbal response and eye opening response with these values:

I. Motor Response
6 - Obeys commands fully
5 - Localizes to noxious stimuli
4 - Withdraws from noxious stimuli
3 - Abnormal flexion, i.e. decorticate posturing
2 - Extensor response, i.e. decerebrate posturing
1 - No response

II. Verbal Response
5 - Alert and Oriented
4 - Confused, yet coherent, speech
3 - Inappropriate words and jumbled phrases consisting of words
2 - Incomprehensible sounds
1 - No sounds

III. Eye Opening
4 - Spontaneous eye opening
3 - Eyes open to speech
2 - Eyes open to pain
1 - No eye opening

The final score is determined by adding the values of I+II+III.

This number helps medical practitioners categorize the four possible levels for survival, with a lower number indicating a more severe injury and a poorer prognosis:

Mild (13-15):

Concussion

Mild brain injury

Moderate Disability (9-12):

Loss of consciousness greater than 30 minutes

Physical or cognitive impairments which may or may not resolve

Benefit from Rehabilitation

Severe Disability (3-8):

Coma: unconscious state. No meaningful response, no voluntary activities

Vegetative State (Less Than 3):

Sleep wake cycles

Arousal, but no interaction with environment

No localized response to pain

Persistent Vegetative State:

Vegetative state lasting longer than one month

Brain Death:

No brain function

Specific criteria needed for making this diagnosis

Physical Examination of the Patient with Cardiopulmonary Disease

I. Examination of the Head, Face and Neck

A. Exam of the head will basically entail examining the patient's facial expression and other assessments in the facial region.

B. Abnormalities produced by respiratory disease include:

1. nasal flaring – observed by outward flaring of the nostrils during inspiration. Commonly seen in neonates as a sign of respiratory distress.

2. cyanosis – a bluish discoloration of the skin that indicates inadequate oxygenation of the tissues. Cyanosis is usually detected around the lips and oral mucosa. The absence of cyanosis does not rule out inadequate oxygenation.

   (a) **Central cyanosis** is present when the patient's trunk or more central regions such as the oral mucosa or lips are cyanotic. This occurs when the lungs are not oxygenating the blood adequately.

   (b) **Peripheral cyanosis** (acrocyanosis) is cyanosis in the extremities, such as the hands and feet. It is most often caused by a significant reduction in systemic blood flow, for example, as a result of decreased cardiac output. Peripheral cyanosis often results due to poor circulation to the extremities, for example, as a result of cold temperature.

   Note: Central cyanosis indicates respiratory failure; peripheral cyanosis indicates circulatory failure.

3. pursed-lip breathing – an expiratory breathing technique where the patient exhales through "pursed" lips.

   (a) This technique is most often observed with patients who have chronic obstructive pulmonary disease (COPD), especially emphysema.

   (b) Some patients are taught the technique while others have discovered on their own that this technique helps relieve their shortness of breath.

   (c) The airways and alveoli of emphysema patients may collapse prematurely during exhalation trapping exhaled air in the

lungs. Exhaling through pursed lips produces a resistance to flow which creates a slight back pressure into the airway, thereby splinting the airway and keeping it open longer so that less air remains trapped in the lungs.

4. jugular venous distention (JVD) – observation of swollen or distended jugular veins in the neck. Should be evaluated at the end of exhalation.

   (a) Jugular venous pressure (JVP) is estimated by examining the level of the column of blood in the jugular veins. JVP reflects the volume and pressure of the venous blood in the right side of the heart. Observing the internal jugular veins is most reliable. Patients with large necks may not have visible neck veins even if distention is present.

   (b) The degree of venous distention may be estimated by measuring the distance the veins are distended above the sternal angle. With the head of the bed elevated at a 45^{o} angle, venous distention greater than 3-4 cm above the sternal angle is abnormal.

   (c) The most common cause of JVD is right heart failure. Right heart failure may occur secondary to chronic hypoxemia. Chronically low PaO_2 levels cause pulmonary blood vessels to constrict which increases the resistance to blood flow through the pulmonary vasculature, increasing the workload on the right ventricle. This may result in right ventricular hypertrophy, or enlargement of the right ventricle. This is referred to as **cor pulmonale** or right heart failure.

   (d) JVD may also result from left heart failure. As the left side of the heart fails to pump blood out to the body adequately, less blood from the right side of the heart can enter the already partially filled left heart chambers. This may result in **pulmonary edema** as the pulmonary blood vessels become engorged and spill their fluid across the alveolar-capillary membrane. Right heart pressure increases as the resistance to blood flow through the pulmonary vasculature increases.

   (e) The elevated right atrial pressure, referred to as **central venous pressure (CVP)**, results in less venous blood being able to return to the right heart, thereby causing JVD and pedal or ankle edema.

   Note: Normal CVP is 2-6 mm Hg.

NOTE: Left heart failure resulting in pulmonary edema is referred to as **cardiogenic pulmonary edema**. The pressure in the left atrium, referred to as **pulmonary capillary wedge pressure (PCWP)** is normally **5-10 mm Hg**. Pulmonary edema occurs as PCWP exceeds about 22 mm Hg.

II. Examination of the Thorax

A. **Chest inspection** - should be performed with the patient seated and clothing removed above the waist. If patient isn't able to sit in a chair he/she should be placed in bed in the Fowler's position (head of bed elevated 45 degrees).

1. The rate, depth and regularity of breathing compared to the normals for the patient's age and activity level.

2. Skin color, temperature and condition such as bruises or scars. Is skin diaphoretic (perspiring)?

3. **Chest symmetry** - comparison of one side of the chest to the other.

a. Observe chest excursion while standing in front of the patient to determine if both sides are expanding equally.

b. Unequal expansion may indicate:

(1) atelectasis
(2) pneumothorax
(3) chest deformities
(4) flail chest - may observe paradoxical chest movement, where chest moves in on inspiration and out on expiration.

4. Shape and size of chest - compared to normal

a. Observe the anterior/posterior diameter (A-P diameter).

b. An increased A-P diameter is called a barrel chest and indicative of chronic lung disease resulting from accessory muscle use during resting breathing.

Note: The intercostal muscles and diaphragm are the major muscles for normal ventilation. The accessory muscles are made up of the scalenes and the sternomastoid muscles in

the neck, and the pectoralis major muscle in the anterior chest.

5. Abnormal Breathing Patterns

   a. Apnea – absence of breathing; caused by obstruction, cardiac arrest, drug overdose, head trauma

   b. Biot's – irregular breathing with long periods of apnea; caused by increased intracranial pressure (ICP)

   c. Cheyne-Stokes – irregular breathing observed by increasing and decreasing depth and rate of breathing with periods of apnea; caused by CNS disease or CHF

   d. Paradoxical – Portion or all of chest wall moves in, instead of out, during inspiration and out with exhalation. Observed with flail chest.

6. Barrel chest

   a. Results from the premature closure of the airways resulting in air trapping and hyperinflated lungs giving the chest a barrel appearance.

   b. Also contributing is the increased musculature from the accessory muscles, which are used during normal breathing with COPD patients.

   c. Seen almost exclusively on patients with chronic lung disease.

   d. This hyperinflated state of the lungs pushes down on the diaphragm restricting its movement. The diaphragm is a dome-shaped muscle, which contracts when innervated by the phrenic nerve. This causes a drop in pressure within the lungs below atmospheric and air enters into the airway. Hyperinflated lungs tend to flatten the diaphragm diminishing its contracting ability. This decreases alveolar ventilation and chest excursion resulting in an increased work of breathing.

   e. Muscles normally used for ventilation are the **diaphragm and external intercostals**, but since the diaphragm of the COPD patient is flattened, they use their accessory muscles during normal ventilation.

B. **Palpation of the Chest**

1. Using the sense of touch on the chest wall to assess physical signs.

2. Hands are placed on the chest to assess chest movement and vibration.

3. Tactile "fremitus"

a. Fremitus means vibration.

b. With hands on the patient's chest, the patient is asked to say certain words such as "ninety-nine" and the therapist feels over different areas of the chest.

c. Conditions with decreased tactile fremitus:

(1) atelectasis
(2) pleural effusion
(3) pneumothorax
(4) hyperinflation

d. Increased fremitus felt over areas of consolidation (pneumonia)

C. **Percussion of the chest wall**

1. Tapping on the chest directly with one finger or indirectly by placing one finger on chest area and tapping on that finger over different areas of the chest.

2. There are five different sounds heard from percussion:

a. **hyperresonance**

(1) observed by a loud, low pitched sound produced over areas that contain a greater proportion of air than tissue
(2) Examples: emphysema, pneumothorax

b. **resonance**

(1) observed by a low pitched sound produced over areas with equal distribution of air and tissue.

Example: normal lung tissue

c. **dullness**

(1) observed by a sound of medium intensity and pitch produced over areas containing a higher proportion of tissue or fluid than air.

Examples: atelectasis, consolidation, pleural effusion, pulmonary edema

d. **flatness**

(1) observed by a sound of low amplitude and pitch produced over areas containing a higher proportion of tissue than air.

Examples: massive pleural effusion, massive atelectasis, pneumonectomy

e. **tympany**

(1) observed by a "drum-like" sound

Example: tension pneumothorax

D. **Position of the trachea**

1. Assessed by placing both thumbs on each side of the suprasternal notch and gently pressing inward. One should feel soft tissue only. If the trachea is felt, this indicates the trachea has shifted and is no longer positioned midline as it should be.

2. A shift of the trachea may be the result of a pneumothorax or atelectasis.

a. tension pneumothorax – trachea shifts to the *unaffected* side (opposite side of pneumothorax)

b. atelectasis – trachea shifts toward the *affected* side (same side as atelectasis)

E. Breath Sounds

1. Normal Breath Sounds

a. Referred to as vesicular breath sounds

(1) low pitched, soft muffled sound

(2) heard over peripheral lung areas primarily during inspiration

b. bronchovesicular breath sounds

(1) moderate in pitch and intensity
(2) heard around the upper part of the sternum and between the scapulae

c. bronchial (tracheal) breath sounds

(1) high pitched, loud tubular sound
(2) heard over the trachea

2. Adventitious Breath Sounds (abnormal sounds superimposed on normal breath sounds)

a. Crackles (often referred to as *rales*)

(1) Intermittent lung sounds that are often produced by excessive fluid or secretions as air passes through. In this scenario, the crackles are usually coarse and are heard during inspiration and expiration.

Examples where this is observed is in bronchitis or respiratory infections.

(2) Also occur in patients without excess secretions when collapsed alveoli pop open during inspiration. They occur toward the end of inspiration and are referred to *late inspiratory crackles*. This is observed in patients with atelectasis, pneumonia, pulmonary edema or fibrosis.

(3) *Early inspiratory crackles* may be heard as larger proximal airways pop back open. This may occur in patients with emphysema or chronic bronchitis.

b. Wheezes

(1) Used to describe the musical sounds heard from the chest of patients with airway obstruction, such as asthma.

(2) Wheezes are produced by the vibration of the wall of a narrowed or compressed airway as air passes through at a high velocity. The diameter of the airway may be decreased due to bronchospasm, mucosal edema or a

foreign body. The tighter the compression, the higher the pitch of the wheeze.

(3) Sputum in the airway may result in a low-pitched wheeze and can be cleared with coughing.

(4) Wheezes often decrease in pitch and intensity after bronchodilator therapy

c. Stridor

(1) Similar to wheezing and heard primarily over the larynx and trachea during inspiration when an upper airway obstruction is present. It is often heard without the aid of a stethoscope.

(2) Rapid airflow through a narrowed upper airway causes the walls to vibrate and produce a high-pitched sound. This most often results from croup or post-extubation swelling.

(3) Stridor is most often heard during inspiration since the upper airway tends to narrow during the inspiratory phase of the breathing cycle. It may also be heard during expiration if airway obstruction is severe.

(4) Stridor is a life-threatening sign that ventilation is compromised. It is especially a concern if cyanosis is also present. The patient may have to be intubated to maintain a patent airway.

d. Pleural friction rub

(1) a creaking or grating sound that occurs when the pleural surfaces rub against one another during breathing.

(2) heard with pleurisy or other pleural diseases.

e. Diminished breath sounds

(1) Occurs when the intensity of the breath sounds over the larger airways or when the transmission of those sounds is reduced.

(2) Airway secretions, hyperinflated airways (emphysema), obesity, and air or fluid in the pleural space inhibit the normal transmission of sound through the chest wall.

III. **Inspection of the Extremities**

A. **Digital clubbing**

1. Digital clubbing is indicative of longstanding pulmonary disease.

2. It is most commonly observed in patients with COPD, cystic fibrosis and bronchogenic carcinoma.

B. **Pedal edema**

1. When the venous return to the right side of the heart is reduced, peripheral blood vessels engorge, resulting in accumulation of fluid in the subcutaneous tissues of the ankles.

2. Pedal edema often occurs as the result of chronic hypoxemia, which results in pulmonary vasoconstriction causing an increased workload on the right side of the heart (mentioned earlier).

3. The edematous tissues in the ankles pit (indent) when pressed firmly with the fingertips. The severity of edema is characterized by a scale from 1^+ to 4^+ with 1^+ indicating slight and 4^+ indicating severe. The notes in a patient's chart may state, "The patient has 4+ pitting edema."

C. Capillary refill

1. Perfusion to the extremities may be determined by assessing capillary refill.

2. This is performed by compressing the patient's fingernail then releasing it and observing the time it takes for blood flow to return to the nail beds.

3. **Normal refill time is less than three seconds**.

4. Refill times of > 3 seconds indicate decreased cardiac output or poor peripheral perfusion.

Clinical Laboratory Studies

I. **Serum Electrolytes**

A. **Sodium** (Na^+)

1. Normal level: **135 to 145 mEq/L**

2. **Hyponatremia** is an Na^+ level < 135 mEq/L; causes include:

   a. Renal failure
   b. CHF
   c. Excessive fever or sweating
   d. Long-term diuretic administration
   e. Inadequate sodium intake
   f. Excessive water ingestion
   g. Severe burns
   h. GI fluid losses (vomiting, diarrhea)

3. **Clinical symptoms of hyponatremia**

   a. Muscle weakness, making ventilator weaning difficult
   b. Confusion
   c. Muscle twitching progressing to convulsions
   d. Anxiety
   e. Alterations in level of consciousness

4. **Hypernatremia** is an Na^+ level >145 mEq/L; causes include:

   a. Excessive water loss (sweating, diarrhea)
   b. Renal failure
   c. Inadequate fluid intake
   d. Mannitol diuresis
   e. Corticosteroid administration

5. **Clinical symptoms of hypernatremia**

   a. Confusion
   b. CNS dysfunction
   c. Seizure activity
   d. Coma

B. **Potassium** (K^+) **(Most commonly tested electrolyte on the exam!!)**

1. Normal value: **3.5 to 5.0 mEq/L**

2. **Hypokalemia** is a K^+ level < 3.5 mEq/L; causes include:

   a. Diuretic therapy
   b. Adrenocorticosteroid administration
   c. Vomiting, diarrhea
   d. Burns
   e. Severe trauma

3. **Clinical symptoms of hypokalemia**

   a. Muscle weakness leading to paralysis, respiratory failure, and hypotension
   b. Cardiac arrhythmias
   c. PACs and PVCs
   d Atrial and ventricular tachycardia
   e. Asystole
   f. ST segment depression on ECG

4. **Hyperkalemia** is a K^+ level > 5.0 mEq/L; causes include:

   a. Acidosis
   b. Renal insufficiency
   c. Tissue necrosis
   d. Hemorrhage

5. **Clinical symptoms of hyperkalemia**

   a. Paralysis
   b. ECG abnormalities
   c. Cardiac arrhythmias

C. **Chloride** (Cl^-)

1. Normal value: **98 to 107 mEq/L**

2. **Hypochloremia** is a Cl^- level < 98 mEq/L; causes include:

   a. Vomiting, diarrhea
   b. Furosemide (Lasix) diuresis

3. **Clinical symptoms of hypochloremia**

   a. Muscle spasm
   b. Coma (in severe hypochloremia)

4. **Hyperchloremia** is a Cl^- level > 107 mEq/L; causes include:
   a. Respiratory alkalosis
   b. Metabolic acidosis
   c. Dehydration
   d. Administration of excessive amounts of NaCl and K□=

5. **Clinical symptoms of hyperchloremia**

   a. Headache
   b. Malaise
   c. Weakness
   d. Unconsciousness
   e. Coma

Note: The sweat glands of patients with cystic fibrosis don't reabsorb sodium or chloride adequately resulting in a high concentration of these electrolytes in their sweat. Although the "sweat chloride" test is an important diagnostic tool for cystic fibrosis, some cystics have normal sweat chloride levels.

II. Other Chemistries

A. **Blood Urea Nitrogen** (BUN)

1. Urea is a substance produced in the liver; it is carried in the blood to the kidneys, where it is excreted in the urine.

2. If the kidneys fail to remove urea from the blood adequately, the blood urea concentration increases.

3. The normal BUN level is **8 to 23 mg/dL**.

4. **An elevated BUN level is indicative of renal failure.**

B. **Creatinine**

1. Creatinine is a waste product constantly formed within tissue and is filtered out by the kidneys.

2. The normal serum level is **0.7 – 1.3 mg/dL**.

1. Creatinine levels increase in renal disease and is also elevated in muscle diseases.

4. When BUN and creatinine are increased as a result of renal failure, metabolic acidosis is often present because the renal function for acid-base balance is impaired

C. **Glucose**

1. Normal serum level: < **100 mg/dL**

2. Elevated levels observed in diabetic ketoacidosis; patient compensates with alveolar hyperventilation (Kussmaul's breathing)

III. **Hematology Tests**

A. **Red blood cells** (RBCs)

1. The number of red blood cells, also referred to as **erythrocytes,** determine the adequacy of oxygen transport.

2. Normal level: **4 to 6 million/mm^3 of blood.**

3. A decreased RBC count (or anemia) indicates an inadequate oxygen-carrying capacity of the blood. Treatment is a blood transfusion.

4. An increased RBC level is called polycythemia. COPD patients often have elevated RBC levels in response to hypoxemia. This is referred to as *secondary polycythemia*.

B. **Hemoglobin** (Hb)

1. Hemoglobin is the portion of the red blood cell that carries oxygen, so it is an indicator of the oxygen-carrying capacity of the blood.

2. Normal level: **14 to 18.0 g/dL in males; 12 to 15 g/dL in females**

3. A subnormal hemoglobin level indicates inadequate oxygen-carrying capacity in the blood. Treatment is a blood transfusion.

4. Hb is elevated when polycythemia is present.

5. **Hematocrit** (Hct)

a. The hematocrit is the percentage of the total blood volume that is RBCs.

b. Normal levels: 40% to 54% in males; 35% to 49% in females.

c. A decreased hematocrit level indicates inadequate oxygen-carrying capacity in the blood. Treatment is a blood transfusion.

6. **White blood cells** (WBCs)

a. The WBC count determines the presence or absence of infection. WBCs are also referred to as **leukocytes.**

b. Normal Level: **4,000 to 11,000/mm^3 of blood**

c. An elevated WBC count indicates the presence of infection. A chest x-ray film and sputum culture to determine lung involvement should be recommended.

d. An elevated WBC count is called *leukocytosis* and an abnormally low level is referred to as *leukopenia*.

Pulmonary Function Studies

I. LUNG STUDIES

A. Ventilation Studies

1. Tidal volume (V_T)

a. The volume of air (usually in milliliters) that is inhaled or exhaled during a normal breath.

b. The exhaled V_T is usually measured with a respirometer at the bedside or by spirometry.

c. When V_T is measured at the bedside, it is most accurately achieved by the patient being instructed to breathe normally through a mouthpiece connected to a respirometer for 1 full min. The volume reading is then divided by the patient's respiratory rate over that 1 min to obtain the V_T. Nose clips may be used to ensure mouth breathing only.

d. V_T is decreased or normal in restrictive disease and increased or normal in obstructive disease.

e. Normal value is 350 - 600 mL (or approximately 5-8 mL/kg of ideal body weight)

2. Respiratory rate (RR)

a. The number of breaths in 1 min.

b. RR is measured by counting chest excursion for 1 min.

c. RR is increased with hypoxia and hypercapnia and decreased with central respiratory center depression.

d. Normal value is 10/min to 20/min.

3. Minute ventilation (MV, V_E)

a. The total volume of air (in liters) inhaled or exhaled in 1 min. It is calculated by multiplying the respiratory rate times the V_T.

b. V_E is measured by simple spirometry or at bedside with a respirometer.

c. V_E is increased by hypoxia, hypercapnia, acidosis, or decreased lung compliance and decreased by hypocapnia, alkalosis, and increased lung compliance.

d. Normal value is 5 to 10 L/min.

B. **Flow Studies**

1. **Forced expiratory volume ($FEV_{0.5}$, FEV_1, FEV_3)**

a. The volume of air that is exhaled over a specific time interval during the FVC maneuver.

b. It's measured over 0.5, 1, or 3 sec. The FEV_1 is the most common measurement.

c. The severity of airway obstruction may be determined, because it is a measurement at specified time intervals. **FEV is usually decreased in both obstructive and restrictive disease.**

Note: FEV_1 may be decreased in restrictive disease because if the FVC is below normal, then the volume of air exhaled in one second will be decreased. A better indicator of an obstructive or restrictive disorder is determined from the FEV_1/FVC ratio, which compares the FEV to the patient's actual FVC (discussed next).

2. **FEV_1/FVC (ratio)**

a. A ratio of the relationship of FEV to FVC.

b. Normal values are:

50% to 60% of the FVC is exhaled in 0.5 sec
75% to 85% of the FVC is exhaled in 1 sec
94% of the FVC is exhaled in 2 sec
97% of the FVC is exhaled in 3 sec

c. Obstructive disease is indicated by below normal values of FEV/FVC. Patients with restrictive disease have normal or above normal values.

d. Because the FEV_1 is most commonly measured, look for an **FEV_1/FVC of less than 70%** to indicate an obstructive disease.

3. **$FEF_{200–1200}$**

   a. The average flow rate of the exhaled air after the first 200 mL during an FVC maneuver.

   b. It's measured on the spirograph tracing between the 200-mL mark and the 1200-mL mark to determine the average flow rate from the FVC.

   c. It's decreased in obstructive disease.

   d. Normal value is 6 to 7 L/sec (400 L/min).

4. **$FEF_{25\%–75\%}$**

   a. The average flow rate during the middle portion of the FEV.

   b. The 25% and 75% points are marked on the spirographic curve from the FVC.

   c. Values are decreased in obstructive disease.

   d. Normal value is 4 to 5 L/sec.

5. **Peak flow**

   a. The maximum flow rate achieved during an FVC.

   b. It's measured from an FVC or by a peak flowmeter.

Note: When measured with a peak flowmeter at the bedside, the patient should be instructed to take as deep a breath as possible and exhale quickly as hard and fast as possible through the mouthpiece. This test is often done before a bronchodilator is administered and again afterward to determine the drug's effectiveness.

   c. It's decreased in obstructive diseases

   d. Normal value is 400 to 600 L/min (6.5 to 10 L/sec).

6. **Maximum voluntary ventilation (MVV)**

   a. The maximum volume of air moved into and out of the lungs

voluntarily in 10, 12, or 15 sec.

b. This measurement tests for overall lung function, ventilatory reserve capacity, and air-trapping.

c. It's decreased in obstructive disease and decreased or normal in restrictive disease.

d. Normal value is 170 L/min.

II. OBSTRUCTIVE VS. RESTRICTIVE LUNG DISEASES

A. **Obstructive Diseases: These diseases result in decreased flow studies (FEV_1, FEV/FVC, $FEF_{25\%–75\%}$, $FEF_{200–1200}$) and increased FRC, TLC, and RV values.**

1. Emphysema
2. Asthma
3. Bronchitis
4. Cystic fibrosis
5. Bronchiectasis

B. **Restrictive Diseases or Disorders: These diseases result in decreased volumes (FRC, FVC, IC, IRV) and normal FEV/FVC.**

1. Pulmonary fibrosis
2. Chest wall disease
3. Pneumonia
4. Neuromuscular disease
5. Pleural disease
6. Postsurgical situations

C. **Severity of disease (by interpretation of pulmonary function tests)**

Mild: < 70%-74% of predicted value

Moderate: 60%-69% of predicted value

Moderately severe: 50%-59% of predicted value

Severe: 35%-49% of predicted value

Very severe: <35% of predicted value

D. **Predicted values are determined from**

1. Age
2. Gender
3. Height
4. Ideal body weight
5. Race

III. MISCELLANEOUS PULMONARY FUNCTION STUDIES

A. Pre- and Post- Bronchodilator Studies

1. Used to determine the reversibility of lung dysfunction and the effectiveness of the bronchodilator.

2. Patients, most commonly asthmatics, are instructed to perform a peak flow test before administration of a bronchodilator. The value is recorded. The bronchodilator is then administered, followed by another peak flow study.

3. Reversibility of obstructed airways and improved flow rates are considered significant if **the FEV_1 increases by at least 12% or either the FEV_1 or FVC increases 200 mL.**

$$\text{Percent improvement} = \frac{\text{posttreatment value - pretreatment value}}{\text{pretreatment value}} \times 100$$

B. Methacholine Challenge Test

1. Determines the degree of airway reactivity to methacholine, a drug that stimulates bronchoconstriction.

2. May be performed in a before-and-after bronchodilator study or before exercise-induced asthma studies.

3. The objective of the test is to determine the minimum level of methacholine that elicits **a 20% decrease in FEV_1**.

4. A physician should be present during testing, and bronchodilators and resuscitation equipment should be readily available.

C. Measurement of Maximal Inspiratory Pressure (MIP)

1. This measurement is also referred to as negative inspiratory force (NIF).

2. This value represents the maximum amount of negative pressure a patient can generate during inspiration.

3. This is measured with the aneroid manometer which connects to an ET tube via an adaptor. The patient is then instructed to inhale as deeply as possible. The manometer records the negative pressure.

4. An adaptor attached to the manometer, using a one-way valve that allows for exhalation but not for inspiration, is also an effective method for obtaining MIP.

Note: These two methods for determining MIP may cause agitation and anxiety in alert patients. The respiratory therapist should always explain the procedure to the patient before beginning it.

5. An MIP may also be obtained in patients who are not intubated by connecting the manometer to a mouthpiece and placing nose clips on the patient.

6. Normal MIP is approximately -50 to -100 cm H_2O.

7. A patient who cannot generate **at least -20 cm H_2O** of pressure has inadequate respiratory muscle strength. The patient is not capable of generating the necessary negative inspiratory pressures required to cough and maintain a patent airway or to maintain spontaneous ventilation; therefore, mechanical ventilation is most likely indicated.

IV. INTERPRETATION OF CHART SUMMARY

	Disease	
Function	**Obstructive**	**Restrictive**
FVC	Decreased	Decreased
IC	Decreased or normal	Decreased
ERV	Decreased or normal	Decreased
V_T	Increased	Decreased or normal
FRC	Increased	Decreased
RV	Increased	Decreased
RV/TLC	Increased	Decreased
FEV_1	Decreased	Normal or decreased
$FEF_{200–1200}$	Decreased	Normal
$FEF_{25\%-75\%}$	Decreased	Normal
FEV/FVC	Decreased	Normal
MVV	Decreased	Decreased

Airway Management

A. **Oropharyngeal Airway**

1. Lies between the base of the tongue and the posterior wall of the pharynx preventing the tongue from falling back and occluding the airway.

2. **Must be used on unconscious patients only.** A conscious patient would gag with the airway in place leading to the potential of aspiration.

3. The airway should never be taped in placed because if the patient becomes conscious he must be allowed to remove the airway easily to prevent vomiting and aspiration.

4. Proper insertion of the oropharyngeal airway:

   a. Measure the airway from the corner of the lip to the angle of the jaw to ensure proper length.

   b. Remove foreign substances from the mouth.

   c. Hyperextend the neck.

   d. Using the cross-finger technique open the patient's mouth and insert the airway with the tip pointing toward the roof of the mouth.

   e. Observe the airway passing the uvula and rotate 180^{o}.

5. **Hazards of Oropharyngeal Airways**

   a. Gagging or fighting the airway - remove immediately

   b. Base of tongue pushed into the back of the throat obstructing the airway

   c. Pushing the epiglottis into the laryngeal area with too large of an airway

   d. If the airway is too small it could lead to aspiration of the airway or may be ineffective in relieving obstruction.

B. **Nasopharyngeal Airway**

1. Maintains a patent airway by lying between the base of the tongue and the posterior wall of the pharynx.

2. It's constructed of soft pliable rubber and is inserted as follows:

   a. Select the proper size airway by measuring the airway from the tip of the nose to the tragus of the ear. The outside diameter of the airway should be equal to the inside diameter of the patient's internal nares.

   b. Lubricate the airway with a water soluble gel and insert into the patient's nostril.

   c. The flanged end should rest against the nose and the distal tip should rest behind the uvula.

   d. Place tape around the flanged end to secure in place. (May stick a safety pin through the flange and tape pin to the face to prevent aspiration.)

3. This airway is tolerated by the conscious patient.

4. It is most commonly used to facilitate nasotracheal suctioning.

5. **Hazards of Nasopharyngeal Airways**

   a. Aspiration of too small of an airway

   b. Nasal irritation - alternate nostrils daily

C. Esophageal Tracheal Combitube (ETC), also referred to as the Pharyngealtracheal Lumen Airway (PTL airway)

1. The esophageal tracheal combitube (ETC) is similar to an EOA but is a double-lumen tube. The tubes run parallel to each other.

2. Once the tube is inserted, a pharyngeal balloon is inflated which occludes the pharynx to prevent air from leaking out the nose or mouth. Because of this, a mask is not necessary. A cuff is located on the distal end of the tube.

3. Once the airway is advanced beyond the pharynx, it enters into either the trachea or the esophagus. It makes no difference which structure it enters.

4. A balloon at the distal end of the tube is inflated and will seal off either the trachea or the esophagus. If the tube rests in the trachea, that lumen is used to ventilate the patient just like an endotracheal tube. If the tube rests in the esophagus, the patient is ventilated through holes in the upper part of the tube below the pharyngeal cuff, like those on the EOA.

5. To determine which tube to ventilate through, attach the resuscitator bag to tube #1 (esophageal tube) and begin bagging. If the chest rises, breath sounds are auscultated over the lungs and no air is heard over the epigastric region, the ETC is in the esophagus and ventilation is occurring through the holes above the distal cuff. Use of a CO_2 detector is very helpful in determining tube placement.

6. If the chest doesn't rise or sounds are only heard over the epigastrium, the resuscitator bag should be attached to the other tube (#2) and ventilation started. If the ETC is in the trachea, the chest should rise. Confirm the placement by auscultating over the epigastrium and the chest. Use of CO_2 detector is very helpful.

7. **Indications for the ETC**

   a. Difficult face mask fit

   b. Unsuccessful intubation and difficulty ventilating with bag/mask

   c. No one available that has been trained in endotracheal intubation

8. **Contraindications for the ETC**

   a. Patient with an intact gag reflex

   b. Patient with known or suspected esophageal disease

   c. Patient known to have ingested a caustic substance

   d. Suspected upper airway obstruction because of laryngeal foreign body or pathology

   e. Patient less than 4 feet tall

9. **Advantages of the ETC**

   a. Minimal training and retraining required

   b. Visualization of the upper airway or use of special equipment not required for insertion

c. May be useful for patients with suspected neck injury since head doesn't need to be hyperextended

d. Face mask not needed because of the oropharyngeal balloon

e. Can provide a patent airway with either tracheal or esophageal placement

f. If placed in the esophagus, allows suctioning of gastric contents without interruption of ventilation

g. Reduces the risk of aspiration of stomach contents

10. **Disadvantages of the ETC**

a. Proximal port may be occluded with secretions

b. Difficulty in determining proper tube location resulting in ventilation through wrong tube

c. Soft tissue trauma because of rigidity of the tube

d. Can't suction the trachea if the tube is in the esophagus

e. Esophageal trauma from poor insertion technique

D. **King Airway**

1. The King airway is a single use device intended for airway management of the unconscious, apneic patient

2. It is curved tube with ventilation ports between two inflatable cuffs.

3. It is a single-use supraglottic airway that utilizes two cuffs to create a supraglottic ventilation seal, at the pharynx and esophagus, similar to the Combitube.

4. Unlike the Combitube, it has a single ventilation port (15 mm connector) and a single valve and pilot balloon that goes to both the pharyngeal balloon and the esophageal balloon.

E. **Laryngeal Mask Airway (LMA)**

1. The laryngeal mask airway (LMA) is designed to be used as an alternative to a face mask for achieving and maintaining control of the airway during surgery when tracheal intubation is not necessary or in emergency situations when endotracheal intubation cannot be accomplished after several attempts.

2. For the airway to be inserted successfully, the patient must be anesthetized so that the upper airway reflexes are obtunded. Otherwise, laryngospasm may occur.

3. The LMA consists of a tube that is fused to an elliptical, spoon-shaped mask. When inserted, the tube protrudes from the patient's mouth and is connected to a manual resuscitator via a standard 15 mm adapter.

4. The mask resembles a miniature face mask and has an inflatable rim that is filled with air via a pilot valve-balloon system.

5. The tube opens into the middle of the mask through three vertical slits that prevent the tip of the epiglottis from falling back and blocking the lumen of the tube.

6. The LMA is inserted through the mouth and into the pharynx after being lubricated with a water-soluble gel. The device in advanced until resistance is met. Then the mask is inflated, providing a low-pressure seal around the laryngeal inlet. The posterior aspect of the tube is marked with a black line which should be seen midline against the patient's upper lip if airway is placed properly.

7. LMAs are available in all sizes and can be used in patients of all ages, from neonates to adults.

8. **Indications for the LMA**

   a. Difficult face mask fit

   b. Unsuccessful intubation and difficulty ventilating with bag/mask

   c. No one available that has been trained in endotracheal intubation

   d. Elective surgical procedures

9. **Contraindications for the LMA**

   a. Health care provider not trained in the use of the LMA

   b. If risk of aspiration exists

10. **Advantages of the LMA**

    a. Can be quickly inserted to provide ventilation when bag/mask ventilation is not adequate and endotracheal intubation cannot be accomplished

b. Tidal volume delivered may be greater using the LMA rather than bag/mask ventilation

c. Less gastric insufflation than with bag/mask ventilation

d. Simpler training than with endotracheal intubation

e. No risk of esophageal or bronchial intubation

f. Less risk of trauma and bacterial contamination of the lower airway than with ET intubation

h. Less coughing, laryngospasm, sore throat or hoarseness than with ET intubation

11. **Disadvantages of the LMA**

a. Does not provide protection against aspiration of gastric contents

b. Cannot be used if the mouth can't be opened more than 0.6 inches (1.5 cm)

c. May not be effective when airway anatomy is abnormal

d. May be difficult to provide adequate ventilation if high airway pressures are required

12. Using the index finger, the LMA is advanced until resistance is met. The tip of the LMA should rest against the upper esophageal sphincter in the hypopharynx. The cuff should be inflated until no leak is heard. To determine proper position, the lungs should be auscultated bilaterally. Capnography may also be used to confirm a properly placed airway.

13. To determine if mild laryngospasm is present as a result of light anesthesia, the anterolateral neck should be auscultated for the present of wheezing.

14. Since the LMA does not protect the airway from regurgitation, the patient must not eat several hours prior to its insertion.

E . **Endotracheal Tubes**

1. **Indications for Endotracheal Tubes**

a. Relief of upper airway obstruction - resulting from laryngospasm, epiglottitis, or glottic edema

b. Protection of the airway (unconscious or obtunded patients)

c. To facilitate tracheal suctioning

d. To assist manual or mechanical ventilation

2. **Hazards of Endotracheal Tubes**

a. Contamination of the tracheobronchial tree

b. Cough mechanism reduced

c. Damage to the vocal cords

d. Laryngeal or tracheal edema

e. Mucosal damage leading to tracheal stenosis

f. Tube occluded with dried secretions

3. Steps to perform endotracheal intubation

a. Select a laryngoscope with a Miller (straight) blade or a McIntosh (curved) blade. Make sure the light bulb is tight as it won't light if it is loose.

b. Place the patient in the "sniffing position" (head above level of shoulders).

c. Select the proper size endotracheal tube, insert air into the cuff to make sure it holds air and then deflate the cuff.

d. Insert a stylet to make the tube more rigid for easier insertion. Make sure the stylet doesn't extend past the end of the tube.

e. Insert the laryngoscope blade into the right side of the mouth (if laryngoscope is in left hand) and move tongue to the left.

f. Advance the blade forward.

(1) The curved blade (McIntosh) should be inserted between the epiglottis and the base of the tongue (valeculla) and with a forward and upward motion the epiglottis is raised to expose the glottis and vocal cords.

(2) The straight blade (Miller) should be placed under the epiglottis and lifted upward and forward to expose the cords.

NOTE: **Never exceed 15-20 seconds per intubation attempt**. The blade and tube in the back of the throat may stimulate the vagus nerve leading to bradycardia. Remove the blade and tube and bag-mask ventilate should bradycardia occur. Once the patient is stabilized, reattempt intubation.

g. As the cords are observed advance the E-T tube approximately two inches past the cords.

NOTE: If the tube is inserted too far it will enter the right mainstem bronchus.

h. Inflate the cuff and listen for equal and bilateral breath sounds. If louder sounds are heard on the right than the left, the tube probably is in the right mainstem bronchus. Deflate the cuff and withdraw the tube until equal breath sounds are heard.

i. Another method to determine if the tube is in the airway is by exhaled CO_2 analysis or capnometry. If the ET tube is in the airway, CO_2 levels will begin to rise as seen on the capnogram. End- tidal CO_2 levels are generally around 5-6%. If the tube is in the esophagus, the end-tidal CO_2 reading will remain near zero.

NOTE: A capnometry reading of 5-6% does not indicate the tube is necessarily in the proper position, only that it is in the airway. Auscultation will determine proper placement evidenced by bilaterally equal breath sounds.

j. An easier and less expensive method of monitoring exhaled CO_2 levels is with the use of a disposable colorimetric CO_2 detector on the proximal end of the ET tube. The indicator on the detector changes colors, usually purple to yellow, when exposed to increased CO_2 levels, indicating the ET tube is in the airway.

NOTE: The average distance from the teeth to the carina is 27 cm. The ET tube has markings in centimeters indicating the distance to the end of the tube from that point. Generally, the tube should be inserted to the **21-25 cm** mark at the teeth or lip in men, and the **19-21 cm** mark at the teeth or lip in women. This will most likely place the tube at the mid-tracheal level, but must be determined by auscultation.

k. Obtain a stat chest x-ray for tube placement. The carina is x-ray at the 4th rib or 4th thoracic vertebra on x-ray. Therefore, the tip of the ET tube should rest 2-7 cm above the carina.

l. Tape the tube securely.

Proper Endotracheal Tube Sizes by Age

Newborn

< 1000 gm	2.5 mm
1000 - 2000 gm	3.0 mm
2000 - 3000 gm	3.5 mm
>3000 gm	4.0 mm

Children

6 months	3.0 - 4.0 mm
18 months	3.5 - 4.5 mm
2 years	4.0 - 5.0 mm
3-5 years	4.5 - 5.5 mm
6 years	5.5 - 6.0 mm
8 years	6.0 - 6.5 mm
12 years	6.0 - 7.0 mm
16 years	6.5 - 7.5 mm

Adult

Female	7.0 - 8.0 mm
Male	8.0 - 9.0 mm

4. **Nasotracheal Tubes**

a. These are considered non-emergency tubes and are rarely used.

b. **Nasotracheal intubation**

(1) The ET tube should be lubricated with water soluble gel prior to insertion. Lidocaine gel may be used to help lubricate and numb the nasal mucosal.

(2) If the patient is alert and breathing spontaneously, try advancing the tube as patient is taking a deep breath or coughing. This is referred to as blind nasal intubation.

(3) If patient is not cooperative or unconscious the tube is visualized in the mouth and grasped by McGill forceps and guided through the vocal cords upon direct visualization with a laryngoscope.

(4) Tape the tube in place when proper placement is assured.

c. **Complications of Nasotracheal Tubes**

(1) Pressure necrosis of the nasal tissue

(2) Sinus obstruction leading to sinusitis

(3) Obstruction of eustachian tube resulting in middle ear infections
(4) Septal deviation

(5) Bleeding - during intubation or extubation

F. Tracheostomy Tubes

1. Tracheostomy tubes are inserted through an incision (stoma) made between the 2nd and 3rd tracheal rings.

2. The obturator should always be inserted into the outer cannula when the tube is being advanced into the stoma.

3. Once the tube is properly positioned, the obturator is removed and the inner cannula inserted.

4. The cuff is then inflated and tracheostomy ties are used to secure the tube.

5. Some tubes utilize a foam cuff which is deflated during insertion and when the tube is in place is allowed to resume it's normal foam shape which provides an effective seal against the tracheal wall. (Exerts low pressure - 20 mmHg)

6. **Indications for a Tracheostomy**

a. To bypass upper airway obstruction

b. To prevent problems posed by oral or nasal E-T tubes

c. To allow patient to swallow and receive nourishment

d. For long term airway care. (E-T tubes should be left in no longer than 3-4 weeks)

7. Factors to Consider in Switching from an ET tube to tracheostomy

a. The projected time the patient will need an artificial airway

b. The patient's tolerance of the ET tube

c. The patient's overall condition (including nutritional, cardiovascular and infection status)

d. The patient's ability to tolerate a surgical procedure

e. The relative risks of continued ET intubation vs tracheotomy

8. Immediate Complications of Tracheostomy Tubes (occurring within the first 24 hours and are associated with the tracheotomy procedure itself)

a. Pneumothorax

b. Bleeding

c. Air embolism - tearing of pleural vein

d. Subcutaneous emphysema

9. Late Complications of Tracheostomy Tubes (occurring more than 1-2 days after the tracheotomy)

a. Hemorrhage

b. Infection

c. Airway obstruction

d. Tracheoesophageal fistula

e. Interference with swallowing

f. rupture of inominate artery

g. stomal stenosis

h. tracheitis

NOTE: Changing a tracheostomy tube within 48 hours of the tracheotomy is not advisable and should only be changed by a surgeon if it is done. This is because the tracheal rings may recede when the tube is removed making reintubation difficult.

10. **Special Tracheostomy Tubes**

a. Fenestrated Tracheostomy Tube

(1) This tube is used to aid in weaning the patient from a tracheostomy tube and allow for the patient to talk.

(2) With the inner cannula removed air may pass through the hole (fenestration) in the outer cannula allowing for weaning from the tracheostomy tube as well as allowing for talking.

(3) The outer cannula may be plugged with the cap on the proximal end of the tube. With the cuff deflated all air flow will be through the patient's natural airway but still provides a passage for suctioning.

(4) Should ventilation be necessary the inner cannula may be reinserted and the cuff reinflated.

b. **Laryngectomy tube** (Tracheostomy button**)**

(1) This tube is used to wean the patient from the tracheostomy tube while maintaining a patent stoma

(2) Consists of a short hollow tube which is used to replace the tracheostomy tube. It keeps the stoma patent should the tracheostomy tube need to be reinserted.

(3) The patient has complete use of their upper airway.

c. Tracheostomy Speaking Valves

(1) The **Passy-Muir valve** is a commonly used tracheostomy speaking valve.

(2) This valve is placed on the proximal end of the tracheostomy tube (15 mm adaptor). **The cuff must be deflated**. The

patient's inspired air passes through the valve but on exhalation the valve closes directing the air up through the upper airway and vocal cords to allow the patient to talk.

(3) The patient should be suctioned with the cuff deflated prior to attaching the valve so that secretions that have pooled above the cuff won't be aspirated into the airway.

(4) The valves may be used on spontaneously breathing patients or ventilator patients. If attached to ventilator patients, the tidal volume must be increased to compensate for volume loss through the upper airway.

G. ARTIFICIAL AIRWAY EMERGENCIES

1. Cuff leaks

a. Small leaks may be compensated for by increasing the ventilator tidal volume.

b. With larger leaks, the tube must be replaced.

2. Accidental extubation

a. Most common in orally intubated patients.

b. A resuscitator bag must be readily available to manually ventilate the patient prior to reintubation.

3. Obstruction of the tube

a. It is the greatest emergency associated with ET tube care and may be a life-threatening situation.

b. Ways an ET or tracheostomy tube may become obstructed:

(1) kinking of the tube

(a) may be corrected by adjusting the patient's head or neck position or manipulating the tube

(b) most commonly occurs with oral ET tubes

(2) herniated cuff (cuff slipping over end of tube)

(a) corrected by deflating cuff

(b) most commonly occurs after tube position changes or head or neck position changes

(3) mucus plugs within the tube

(a) caused by dried or thick mucus

(b) instill saline and suction - if not relieved, the tube must be replaced immediately

(4) bevel of the tube resting on carina or wall of trachea or bronchus

(a) adjust tube position

**** Steps to take when obstruction is present:**

1. Deflate the cuff.

2. Manipulate the tube.

3. Attempt to pass a suction catheter.

**** If none of these steps are successful in relieving the obstruction, the tube must be removed immediately and the patient ventilated with a manual resuscitator.**

EXAM NOTE: If the patient is in severe distress or the high pressure alarm is activated indicating the patient is not getting ventilated, always extubate the patient and initiate manual ventilation!

EXAM NOTE: If a question indicates the respiratory therapist is called to a patient's room due to the sounding of a ventilator alarm, always remove the patient from the ventilator and manually ventilate FIRST!

H. MAINTENANCE OF ARTIFICIAL AIRWAYS

1. **Cuff Care**

(a) Tubes should employ **high volume, low pressure cuffs only**. These cause less occlusion to tracheal blood flow since they apply less pressure. They are also called "floppy cuffs

(b) In order to ensure that the cuff is exerting the least amount of pressure on the tracheal wall and still providing an adequate seal,

the **minimal occluding volume technique (MOV)** should be employed.

(c) Minimal occluding volume technique: With the stethoscope placed over the larynx, listen for air flow as the cuff is inflated. Inflate the cuff until no air flow is heard..

**** NOTE**: If the peak inspiratory pressure on the ventilator decreases after the MOV has been determined, it should be redone at the lower pressure. For example, the MOV is done when the PIP is 35 cm H_2O. The patient is then suctioned and the PIP drops to 25 cm H_2O. Since the cuff was inflated to MOV at 35 cm H_2O, and the PIP has dropped to 25 cm H_2O, there is now excessive air in the ET tube cuff.

(d) **Cuff pressures should maintained at 20-30 cm H_2O.** Normal capillary perfusion pressure is about 34 cm H_2O and if cuff pressure exceeds this value, ischemic damage to the trachea is possible. Cuff pressures of less than 20 cm H_2O are associated with increased potential of pneumonia resulting from aspiration of supraglottic secretions.

(e) If the cuff is inflated above 30 cm H_2O and a leak is still heard, continue inflating the cuff to MOV. It may be the E-T tube is too small and it's taking more air to inflate the cuff to MOV. In this case the cuff pressure doesn't relate to the pressure on the tracheal wall. **To be safe, the ET tube should be replaced with a larger one.**

NOTE: The minimal leak technique, which allows for a slight leak heard with a stethoscope at peak inspiration, is not recommended since oral secretions drain more easily below the cuff increasing the risk of lower airway bacterial contamination and VAP. **It may still be covered on the exam though.**

2. **Suctioning the Airway**

(a) Technique of suctioning

(1) Pre-oxygenate and deep breathe the patient. Hyperoxygenation is preferred to help prevent hypoxemia which may lead to cardiac arrhythmias.

(2) Adjust proper suction level:

Adult: -100 to -150 mm Hg

Child: -100 to -120 mm Hg

Infant: -80 to -100 mm Hg

Neonate: -60 to -80 mmHg

(3) **Instilling normal saline prior to suctioning is not beneficial in thinning secretions and should not be done. It may also increase the risk of VAP by washing bacteria in the ET tube into the lower airway. If secretions are thick and hard to mobilize, ensure the proximal airway temperature is 35-36^{o}C.**

(4) Insert the catheter without applying suction and advance until patient begins to cough.

(5) Withdraw the catheter applying intermittent suction while rotating the catheter between the thumb and finger. (This decreases mucosal damage)

(6) Once the catheter has been withdrawn into the E-T tube, continuous suction may be applied.

(7) Never leave the catheter in the airway for longer than **15 seconds**.

(8) Upon removal of the catheter, re-oxygenate and deep breathe patient and wait 30 seconds to one minute before entering the airway again.

NOTE: Monitor EKG and pulse oximeter and stop procedure if arrhythmias and/or desaturation occurs. Hyperoxygenate and ventilate (if on ventilator).

(9) Repeat steps until secretions are aspirated and airway sounds clear.

(10) Suctioning the nasal and oral pharynx may now be done, remembering to never re-enter the ET tube with this catheter.

NOTE: When nasotracheal suctioning is performed, the above steps should still be followed as well as adding the following techniques:

(11) Lubricate catheter with water soluble gel.

(12) Instruct patient to take a deep breath or cough as the catheter advances to the oropharynx. This aids in inserting the catheter through the glottic opening. Placing the patient in the “sniff” position may also help facilitate entering the glottic opening.

b. **Selecting the Proper Size Catheter**

(1) The suction catheter should not occupy more than 1/2 of the internal diameter of the ET tube.

(2) Suction catheters are sized in French units in sizes 6.5, 8, 10, 12, 14, 16.

(3) To estimate the proper size suction catheter, multiply the internal diameter of the ET tube by 2 and use the next smallest catheter size.

(4) Example: 8 mm ET tube x 2 = 16. Use a 14 Fr suction catheter.
Example: 6 mm ET tube x 2 = 12. Use a 10 Fr suction catheter.

c. **Yankauer suction device** - used to suction the oropharynx

d. **Coude suction catheter** - angled tip catheter used to suction the **left mainstem bronchus**

e. **Indications for Tracheal Suctioning**

(1) Retained secretions the patient can't mobilize

(2) Maintain patency of artificial airways

(3) Obtain sputum for culture and sensitivity

f. **Hazards of Tracheal Suctioning**

(1) hypoxemia - increase F_IO_2 prior to suctioning!

(2) arrhythmias - due to hypoxemia and vagal nerve stimulation. Vagus nerve is stimulated as catheter irritates the oral/nasal mucosa, tracheal mucosa and carina causing bradycardia.

(3) hypotension - caused by bradycardia and prolonged coughing episode

(4) atelectasis - caused by using too large of a suction catheter or excessive suction pressure

(5) tissue trauma - caused by jabbing catheter during insertion, improper lubrication while nasally suctioning and not applying intermittent suction

** Note: Suctioning may suddenly stop as a result of the following:

(1) kinked suction catheter
(2) mucus plug lodged in catheter
(3) suction collection bottle is full

g. Vacuum Systems/Collection Bottles

(1) The suction catheter is attached to a connecting tube which attaches to the outlet of a collection bottle. This bottle attaches to a DISS connection onto the suction or vacuum regulator which is either a portable pump or a 50 psi vacuum wall outlet at the bedside.

(2) The vacuum regulator supplies the negative pressure necessary to suction the airway.

(3) The secretion collection bottle is generally equipped with a system that will interrupt suction when the bottle becomes full.

(4) Most suction/vacuum systems provide up to -200 mm Hg pressure, but the desired vacuum level can be adjusted by occluding the suction regulator outlet and turning a vacuum control knob on the regulator. Most systems employ locking mechanisms to prevent the excessive suction pressures from being used.

I. ENDOTRACHEAL EXTUBATION

1. **Cuff Leak Test**

a. The cuff leak test is a means of testing for the potential of postextubation swelling that could result in reintubation.

b. Various ways to perform a cuff leak test:

(1) Deflate cuff, occlude the end of the ET tube and listen for an audible leak or feel for air exiting the mouth.

(2) Record the difference between the inspiratory tidal volume and the expiratory tidal volume while the cuff is deflated. A leak of less than 110 mL (average of three values on six consecuitive breaths) indicates a high risk of post-extubation stridor. Treatment with racemic epinephrine or steroids prior to extubation may be required.

c. Calculating "percent cuff leak":

$$\frac{\text{Exhaled Vt before cuff deflation} - \text{exhaled Vt after cuff deflation}}{\text{Exhaled Vt before cuff deflation}} \times 100$$

Patients with a cuff leak of < 10% are at risk for stridor and reintubation.

d. **It's important to recognize that a successful cuff leak test does not guarantee that post-extubation stridor will not occur.**

2**. Procedure of extubation**

a. Explain procedure to the patient.

b. Increase the F_IO_2 level.

c. Suction down the E-T tube.

d. Deflate the cuff and suction down the ET tube again to remove secretions that may have pooled above the level of the cuff.

e. Suction the mouth and back of the throat.

f. Untape the tube and instruct the patient to take a deep breath or deliver a deep breath using a manual resuscitator**. At peak inspiration withdraw the tube.**

3. **Complications of Extubation**

a. Laryngospasm

(1) Spasm of the vocal cords due to irritation of the tube resulting in airway obstruction. This is observed by respiratory difficulty immediately following extubation.

(2) If laryngospasm occurs, administer high F_IO_2 concentration and if it persists for more than 1-2 minutes with respiratory distress

worsening, administration of a muscle relaxant is indicated. Be prepared to bag/mask ventilate or reintubate and manually ventilate since respiratory muscles will be paralyzed as well.

b. Glottic edema

** (1) Inspiratory stridor is the major clinical sign

(2) Caused by:

(a) traumatic intubation
(b) insertion of oversized E-T tube
(c) poor E-T tube maintenance
(d) allergic response to material in the E-T tube

(3) Should be treated with:

**(a) vasoconstrictor - racemic epinephrine with SVN
**(b) steroids - occasionally used to reduce swelling

Medical Gas Therapy

I. Oxygen Therapy

A. Indications for Oxygen Therapy

1. Hypoxemia
2. Increased the work of breathing
3. Increased cardiac work

****Normal PaO_2 level is 80-100 torr****

B. Signs and Symptoms of Hypoxemia

1. tachycardia
2. dyspnea
3. cyanosis
4. slight hyperventilation
5. tachypnea
6. mental disturbance
7. impaired special senses (tunnel vision or blurred vision, loss of coordination)
8. mild to severe hypertension (depending on severity of hypoxemia)
9. headache
10. arrhythmias and hypotension with severe hypoxemia

C. Complications of Oxygen Therapy

1. **Respiratory depression** - most affected is the chronically hypoxemic COPD patient

Traditionally, it has been stated that providing excessive levels of oxygen removes the hypoxic ventilatory drive resulting in hypoventilation (increased $PaCO_2$). This theory is widely debated since the reduction in minute ventilation after O_2 breathing in advanced COPD is not always severe enough to account for the increased $PaCO_2$.

Some research indicates that the increased $PaCO_2$ results from worsening ventilation/perfusion (V/Q) ratio. Some researchers say it's a combination of both. Breathing oxygen worsens the already poor V/Q relationship in COPD patients by resulting in pulmonary vasodilation in poorly ventilated lung regions which draws from the better ventilated areas. Therefore, more blood is directed to poorly ventilated lung regions causing $PaCO_2$ to increase.

Whichever the cause of increasing $PaCO_2$ levels, the board exams still present questions about reducing the ventilatory drive with too much oxygen!

2. **Atelectasis** - high O_2 concentrations in the lung wash out nitrogen and reduce the production of surfactant, both causing atelectasis.

3. **Oxygen toxicity** - high O_2 concentrations result in toxicity to lung tissue due to increased oxygen free radicals. This leads to ARDS.

4. **Retinopathy of prematurity (ROP)** - Caused by high PaO_2 levels in infants causing blindness. **It's more common in premature infants. To reduce the risk of ROP, maintain PaO_2 below 80 torr**. (Normal PaO_2 in premature infants is 50 - 70 torr.)

5. **Reduced muco-ciliary activity** – results in secretion retention

Exam Note: To help prevent the complications of breathing supplemental oxygen, the AARC Clinical Practice Guidelines suggest that F_IO_2 levels should not exceed 0.50. The board exams may allow up to 0.60.

D. **Four Types of Hypoxia**

Hypoxia – deficiency of oxygen at the tissue level

1. **Hypoxemic hypoxia**

   a. Caused by lack of oxygen in the blood as a result of:

      (1) inadequate oxygen in the inspired air - giving O_2 beneficial

      (2) alveolar hypoventilation - O_2 alone may not be beneficial, but responds to oxygen therapy better than right-to left shunts (see below)

      (3) atelectasis - O_2 alone not beneficial

      (4) pulmonary edema - high O_2% may be beneficial but generally responds better to positive pressure

      (5) ventilation/perfusion mismatch - O_2 may be beneficial

      (6) Anatomical right to left shunt - O_2 not beneficial

   b. **If a normal PaO_2 can't be maintained on 50-60% O_2 mask, a large shunt is probable and shouldn't be treated with higher**

O_2 concentrations. CPAP should be administered (if the $PaCO_2$ is normal or below normal). If the $PaCO_2$ is elevated along with hypoxemia, mechanical ventilation should be initiated.

CPAP – continuous positive airway pressure

CPAP is applied to the airway via a face mask or nasal mask. Generally 5-15 cm H_2O is applied to the airway to treat **refractory hypoxemia**. The patient breathes totally on their own with above atmospheric pressures in the airway.

Refractory hypoxemia is a low PaO_2 level that doesn't improve significantly with increases in oxygen concentration. Examples of conditions that cause refractory hypoxemia are atelectasis, pneumonia and pulmonary edema. These are referred to as right-to-left shunts.

When these conditions are present, the normal amount of oxygen is not able to enter the alveoli, therefore oxygen is unable to diffuse into the blood. This results in low PaO_2 levels in spite of increases in oxygen concentration.

CPAP improves PaO_2 in these conditions by opening up collapsed alveoli and stretching alveoli filled with exudative material (pneumonia) and fluid caused by pulmonary edema providing more diffused O_2 to enter the blood. In addition, the positive pressure created by CPAP at the alveolar level helps prevent fluid from pouring across the alveolar-capillary membrane when capillary hydrostatic pressure is increased as a result of left heart failure (cardiogenic pulmonary edema).

CPAP should never be used on patients who experience apnea since CPAP does not ventilate the patient. The exception is sleep apnea, where upper airway obstruction results in apnea. CPAP relieves the obstruction, opening the upper airway preventing decreased inspiratory flows and periods of hypopnea and apnea.

In summary, patients who are ventilating adequately (normal or low $PaCO_2$) but are hypoxemic on 50% O_2 or higher are experiencing refractory hypoxemia. Increasing the F_IO_2 is generally not beneficial, so CPAP should be used. Using CPAP with also allow the use of lower and safer levels of oxygen(less than 50%-60%), reducing the risk of O_2 toxicity.

Example:

pH 7.46
$PaCO_2$ 32 torr
PaO_2 53 torr

If the blood gas above is from a patient on 50% oxygen or higher, and the patient has atelectasis or pulmonary edema, rather than increasing the oxygen to 60% or higher, keep the O_2% at 50% but place the patient on a CPAP mask. The exception is a hypotensive patient where CPAP may further reduce blood pressure. In that case, increase the oxygen concentration.

2. **Anemic hypoxia**

a. The capacity of blood to carry oxygen is decreased as a result of:

(1) **decreased hemoglobin (Hb) level**

(a) normal level is 12-16 g/dL blood

(b) The patient's PaO_2 may be normal but with a diminished capacity of the blood to carry oxygen the tissues may be deprived of oxygen. Hemoglobin value must be determined in order to assess the patient's oxygenation status.

(c) Hemoglobin content may be increased by the administration of red blood cells.

(2) **carbon monoxide poisoning**

(a) Carbon monoxide combines with hemoglobin 200-250 times faster than oxygen does, therefore occupies the iron binding sites on the hemoglobin before oxygen can. This causes tissue hypoxia.

(b) Since hemoglobin will release the CO more readily the higher the PaO_2 is, the patient should immediately be placed on a non-rebreathing mask which delivers close to 100% oxygen. If the patient is experiencing respiratory difficulty and inspiratory stridor resulting from smoke inhalation, intubation and placement on 100% T-piece is indicated.

(c) Increasing the PaO_2 even higher to further increase the dissociation of hemoglobin from CO may be achieved with **hyperbaric oxygen therapy**.

(d) Patients who have been involved in fires or breathing car fumes must be treated immediately for CO inhalation.

(e) PaO_2 and SpO_2 readings may be within a normal range but the patient may be severely hypoxic. SpO_2 will always give a false high reading and should never be measured when CO inhalation is suspected.

(f) The level of carboxyhemoglobin (COHb) may be determined by the use of a CO-oximeter. Normal COHb level is <3%.

(g) The patient's PaO_2 may be > 100 torr since O_2 can't combine with Hb and therefore dissolves in the plasma. SaO_2 levels will be decreased. Do not be tempted to reduce the F_IO_2 with the high PaO_2. Wait until the SaO_2 is in the low-to-mid 90s before reducing the F_IO_2. **For example, if the PaO_2 is 400 torr and the SaO_2 is 55%, the patient is severely hypoxic and the F_IO_2 must not be decreased!**

(3) **excessive blood loss** - treated by giving blood

(4) **methemoglobin** - Results most commonly from nitrite poisoning. Treated by administering ascorbic acid or methylene blue which removes the chemical (nitrite) from the system.

(5) **iron deficiency** - treated by increasing iron intake and giving blood

b. Oxygen is carried in the blood two ways:

(1) bound to hemoglobin (1.34* x Hb x SaO_2)

*1.34 mL of oxygen is capable of combining with 1 gram of Hb

(2) dissolved in plasma (.003* x PaO_2)

*.003 mL of oxygen dissolves in the plasma for 1 mm Hg of oxygen tension (PaO_2)

Note: The sum of these two equals the total arterial O_2 content (CaO_2) in mL/dL.

Total arterial oxygen content is the most effective method for determining a patient's oxygen carrying capacity.

Example: Given the following information calculate the patient's total arterial oxygen content.

ABG results: pH 7.38
PCO_2 36 mm Hg
PO_2 80 mm Hg
SaO_2 96 %
Hb 14 gm/dL

O_2 bound to hemoglobin = 1.34 x 14 x .96 = 18 mL/dL
O_2 dissolved in plasma = .003 x 80 = .24 mL/dL
Total arterial O_2 content (CaO_2) = 18 + .24 = 18.24 mL/dL

Normal arterial oxygen content is 16-20 mL/dL.

EXAM NOTE: If asked to calculate CaO_2 on the exam, it is unnecessary to calculate the amount of O_2 dissolved in the plasma since it's always less than 1. So calculate how much O_2 is bound to Hb and the answer will be the one slightly higher than what you calculated.

3. **Stagnant (circulatory hypoxia)**

   a. the O_2 content and carrying capacity is normal but capillary perfusion is diminished as a result of:

      (1) decreased heart rate
      (2) decreased cardiac output
      (3) shock
      (4) emboli

   b. May be seen as a localized problem as peripheral cyanosis due to exposure to cold weather.

4. **Histotoxic hypoxia**

   a. the oxidative enzyme mechanism of the cell is impaired as a result of:

      (1) cyanide poisoning
      (2) alcohol poisoning

b. Rarely accompanied by hypoxemia, but by increased venous PO_2 levels.

E. **Oxygen Delivery Devices**

1. **Low-Flow devices** - an oxygen delivery device that does not meet the patient's inspiratory flow demands, therefore part of the V_T must be supplied by room air.

** Nasal cannula: 1-6 L/min, 24%-44% (approximately 4% per liter)
** Simple mask: 5-12 L/min, 35%-55% (minimum 5 L/min!)
** Partial Rebreathing mask: 8-15 L/min, 40%-70%
** Non-rebreathing mask: 8-15 L/min, 60%-80%

Note: The reservoir bag on the partial and non-rebreathing masks must be kept 1/3-1/2 full at all times.

**The percentage of oxygen delivered by a low flow device is variable depending upon the patient's tidal volume, respiratory rate, inspiratory time and ventilatory pattern. Therefore, a change in any of these parameters will change the delivered oxygen percentage. In other words, an inconsistent ventilator pattern results in an inconsistent delivered O_2%.

Example: If a patient on a nasal cannula starts to breathe faster, more room air will mix with the oxygen, decreasing the delivered O_2%.

EXAM NOTE: If a question asks you to select the appropriate oxygen delivery device for a patient who has an inconsistent ventilator pattern or has a respiratory rate over 25, select a high-flow device (air-entrainment mask, for example) if the oxygen percent is appropriate. If the F_IO_2 is seems too high, you'll have to go with a low flow device such as a nasal cannula.

Oxygen-conserving reservoir cannulas:

1. Nasal reservoir cannula: The reservoir, which is positioned just below the nose, stores approximately 20 mL of oxygen that the patient inhales during the early part of inspiration. Since the patient receives more oxygen with each breath, the flow needed for a prescribed level of oxygen may be decreased, thus conserving oxygen.

2. Pendant reservoir cannula: Utilizes a pendant- type inflatable reservoir that expands as the patient exhales forcing the stored oxygen out of the pendant and up the cannula tubing to the patient. For this device to

function properly, the patient must exhale through the nose so the exhaled air will pass through the cannula tubing in order to inflate the reservoir.

NOTE: Another oxygen–conserving device is the **pulse-dose oxygen delivery system.** It is typically attached to an oxygen cylinder with the nasal cannula attached to the pulse-dose device. Oxygen is delivered to the patient during inspiration only. It senses the patient's inspiratory effort causing a solenoid valve to open delivering a "pulse" of oxygen at the set flow rate. This type of system results in equivalent oxygenation at lower flows, delivered during inspiration only, thus conserving oxygen

2. **High flow devices** - a device that provides all of the total inspiratory flow required by the patient. They provide relatively accurate and consistent oxygen percentages.

   ** Air entrainment mask: 24%-50%, flow varies according to % setting
   ** Aerosol mask, Tracheostomy collar, T-piece: 21%-100%, flow sufficient so that mist exits mask at peak inspiration. (If mist disappears during inspiration, increase the flow!)

Air/Oxygen entrainment ratios (used to calculate total flow)

Oxygen Percentage	Air/O_2 Entrainment Ratio
24%	25:1
28%	10:1
30%	8:1
35%	5:1
40%	3:1
45%	2:1
50%	1.7:1
60%	1:1

These ratios may be calculated by the following formula:

$$\frac{100 - x}{x - 20^{*}} = \frac{\text{parts air entrained}}{\text{1 part oxygen}}$$

***use 21 on percentages less than 40%**

Example: Calculate the air/O_2 ratio for 30%.

$$\frac{100 - 30}{30 - 21} = \frac{70}{9} = 8 \text{ or } 8{:}1 \text{ ratio}$$

This means that for every liter of oxygen delivered from the flowmeter, 8 liters of air are entrained into the device.

Calculating total flow

If an air entrainment mask is set on 30% (8:1 ratio) with a flowrate of 6 L/min, the total flow delivered would be:

6 L/min. of O_2
+48 L/min. of air (O_2 flow x ratio or 12 x 3)
54 L/min. total flow

****FASTER METHOD**: add the ratio parts together and multiply by the flow.

30% (8:1 air/O_2 ratio)

8 + 1 = 9 9 x 6 L/min = 54 L/min.

Example: An air entrainment mask is set on 24% and a flow of 3 L/min. Calculate the total flow.

$$\frac{100 - 24}{24 - 21} = \frac{76}{3} = \frac{25}{1} = 25{:}1 \text{ air/}O_2 \text{ ratio}$$

3 L/min. of oxygen
+75 L/min. of air
78 L/min. total flow

OR

sum of ratio parts x flow

(25 + 1) = 26 x 3 L/min = 78 L/min

F**. Calculating inspiratory flow**

$$\textbf{Inspiratory flow} = \frac{\text{tidal volume (liters)}}{\text{inspiratory time (sec)}}$$

The flow will be in L/sec, so multiply by 60 to change to L/min.

Example: The physician has ordered oxygen to be set up on a patient with a spontaneous tidal volume of 700 mL and an inspiratory time of 1 second. How much flow must the O_2 device deliver to meet the patient's inspiratory demands?

Patient's inspiratory flow = $\frac{0.7\ L}{1\ sec}$ = 0.7 L/sec x 60 = 42 L/min

In other words, the oxygen delivery device used must be able to deliver a total flow of at least 42 L/min to meet the patient's inspiratory flow demands. Which of the following will achieve this?

A. 40% aerosol mask at 10 L/min (3:1 ratio)
B. 60% aerosol mask at 15 L/min (1:1 ratio)
C. 35% air entrainment mask at 8 L/min (5:1 ratio)
D. 50% air entrainment mask at 15 L/min (1.7:1 ratio)

A. flow = 40 L/min
B. flow = 30 L/min
C. flow = 48 L/min**
D. flow = 41 L/min

Choice "C" exceeds the patient's inspiratory flow demands, therefore is the correct choice.

II. Heliox Therapy

A. Helium is a low density, lightweight gas that when combined with oxygen, will decrease the total density of the gas mixture. This allows the gas to pass through obstructions easier.

B. Common heliox mixtures:

1. 80%/20%

2. 70%/30%

C. Running these gas mixtures through an oxygen flowmeter will give inaccurate readings since the gas is lighter than pure oxygen. A correction factor must be used to make the flow reading accurate.

1. 80/20 mixture - multiply the oxygen flowmeter reading by **1.8** to determine correct flow.

Example: An 80/20 heliox mixture is running through an oxygen flowmeter at 10 L/min. What is the actual flow being delivered to the patient?

1.8 x 10 = 18 L/min

2. Divide the ordered He/O_2 flow by **1.8** to determine what to set the O_2 flowmeter on.

Example: You want to deliver 15 L/min of a 70/30 mixture of He/O_2 to the patient. What must you set the oxygen flowmeter on to deliver this flow?

$$\frac{15}{1.6} = 9.4 \text{ L/min.}$$

NOTE: The flow correction factor for a 70/30 heliox mixture is 1.6

D. He/O_2 mixtures must be delivered in a tightly closed system such as a non-rebreathing mask, ET tube or tracheostomy tube to prevent leakage of this lighter gas.

E. The only side effect of He/O_2 therapy is distortion of the voice.

F. He/O_2 mixtures are safe and may be of benefit in the treatment of:

a. obstruction from secretions, tumors, etc.

b. asthmatics during episode of bronchospasm not reversed with conventional therapy (Also improves distribution of aerosolized medications such as bronchodilators, steroids, etrc.)

III. Assessing Oxygenation

A. Pulse Oximetry

1. Pulse oximeters are devices that measure oxyhemoglobin saturation (SaO_2) by the principle of spectrophotometry.

2. Light from the probe is directed through a capillary bed to be absorbed in different amounts depending on the amount of oxygen bound to hemoglobin. The result is displayed on the monitor as a percent of saturation.

3. The probe is noninvasive and may be attached to the finger, toe or ear.

4. Pulse oximeters are reasonably accurate although some studies show they may be less accurate when used for "spot checks" rather than continuous monitoring.

5. Causes of inaccurate readings

   a. low blood perfusion

   b. carbon monoxide poisoning

   c. severe anemia

   d. hypotension

   e. hypothermia

   f. cardiac arrest

   g. Nail polish, especially blue, green, brown and black may cause lower oximetry readings. Polish should be removed or the oximeter placed on the ear lobe.

   h. Ambient light sources, such as direct sunlight, phototherapy and fluorescent lights affect the accuracy of the pulse reading. Wrapping the sensor sight with a towel or gauze to block the light can eliminate this problem.

   i. Dark skin pigmentation

B. Transcutaneous PO_2 Monitoring ($TcPO_2$, $PtcO_2$)

1. By applying blood gas electrodes over the skin, a neonate's PaO_2 may be monitored continuously without having to perform arterial punctures as frequently.

2. The probe is attached to the skin and warmed to 42°C-44°C, which results in vasodilation and increased perfusion of the dermal layer of the skin. Oxygen diffuses through the skin in concentrations similar to those in arterial blood.

C. Disadvantages of transcutaneous monitoring

1. Burning the skin with the heated probe – The probe location should be changed every 4 hours.

2. Adequate perfusion is necessary – There must be adequate perfusion to the site of the probe for the monitor readings to be accurate. The infant, therefore, should be hemodynamically stable to receive accurate transcutaneous monitor readings.

3. Readings may be inaccurate if the probe is inadequately heated, the monitor is not calibrated properly or the probe becomes loose allowing air to come between the probe and the infant's skin.

D. The transcutaneous monitor is useful for monitoring hyperoxia in neonates who are prone to neonatal retinopathy.

NOTE: Once the heated probe is attached, it takes 10-15 minutes to get a stable, accurate reading. This is because it takes this long for vasodilation to occur.

Bronchopulmonary Hygiene Therapy

I. Postural Drainage and Chest Percussion

A. Goals of chest physiotherapy

1. Prevent the accumulation of pulmonary secretions
2. Improve the mobilization of retained secretions
3. Improve the distribution of ventilation
4. Decrease airway resistance

B. Postural Drainage (see review textbook for various positions)

C. Percussion

1. A means of improving the mobilization of pulmonary secretions by manually striking the chest wall with a cupped hand or placing a mechanical percussor on the chest wall. Both of these techniques are generally performed with the patient in postural drainage positions.
2. Mechanical percussors operate either on compressed air or electricity and are felt to be more effective than manual hand percussion.
3. Percussion should be performed over each specified area for 2-5 minutes.
4. Percussion should not performed over the following areas:
   a. spine
   b. sternum
   c. scapulae
   d. clavicles
   e. surgical sites
   f. areas of trauma

g. bare skin (although some advocate manually percussing over bare skin, it has been shown that the energy wave produced by the air trapped under the hand is not significantly reduced by light covering such as a hospital gown)

h. female breasts

D. Complications of chest physiotherapy

1. Hypoxemia

a. Especially in COPD, cardiac or obese patients

b. Modification of drainage position will make the therapy more tolerable for these patients

c. May be minimized by the administration of a bronchodilator prior to CPT and the delivery of supplemental oxygen during the treatment

2. Rib fractures

a. Caused from too vigorous percussion

b. Most common in neonates and elderly patients

3. Increased airway resistance

a. Patient should be coughed periodically throughout the treatment

b. Suction equipment should be readily available for patients having difficulty expectorating secretions

4. Increased intracranial pressure (ICP)

a. Patients with head trauma should not be placed in the trendelenburg (head down) position

b. Increased ICP may result from prolonged coughing associated with CPT

5. Hemorrhage

6. Decreased cardiac output

a. Often the result of positional hypotension

b. Check heart rate periodically during the treatment

7. Aspiration

a. Caused by vomiting during the treatment

b. CPT should be performed no sooner than one hour following a meal

II. Intrapulmonary Percussive Ventilation (IPV)

A. An airway clearance maneuver that utilizes a pneumatic gas source to deliver a series of small tidal volumes at high frequency (110-225 cycles/min).

B. The length of each percussive cycle is controlled by either the respiratory therapist or patient using a thumb control button.

C. The pressurized bursts of gas are delivered to the patient via a mouthpiece. Bronchodilators or mucolytics may be administered through a pneumatic nebulizer during this 15-20 minute treatment.

D. IPV is an alternative to chest percussion for patients with chest trauma or who don't tolerate percussion.

III. High Frequency Chest Wall Oscillation (HFCWO)

A. An inflatable vest is wrapped around the patient's chest that is attached to an air-pulse generator which intermittently injects small volumes of air into and out of the vest at a high rate. This creates oscillatory movement that increases secretion mobilization.

B. The duration of therapy is usually about 30 minutes, using an oscillation frequency of between 5 and 25 Hz (300 - 1500 cycles/min.)

C. Most commonly used on cystic fibrosis patients.

IV. Positive Expiratory Pressure (PEP) Therapy

A. Positive expiratory pressure (PEP) is a bronchial hygiene therapy used in the management of airway secretions and postoperative atelectasis.

B. It is effective in preventing postoperative atelectasis and secretion mobilization by increasing peak airway pressure.

C. PEP is achieved by having the patient exhale through a mask or mouthpiece with a resistance valve. The valve creates back pressure into the patient's airway. Different size resistors or adjustable resistors are used to increase or decrease the amount of PEP. Generally, PEP levels of 10-20 cm H_2O are used.

D. Contraindications of PEP

1. acute sinusitis
2. ear infection
3. epitaxis (nose bleed)
4. recent facial, oral or skull injury or surgery
5. active hemoptysis

E. Steps in performing PEP mask therapy

1. Assemble equipment, select appropriate expiratory resistor (10-20 cm H_2O)

2. Position patient sitting up with elbows resting on table, with mask applied tightly (to prevent leaks) over the nose and mouth.

3. Instruct patient to inhale a larger than normal volume, but not as deep as possible, then actively exhale, not forcefully, with expiration lasting 2-3 times longer than inspiration.

4. The patient should perform 10-20 of these PEP breaths, then remove the mask and perform 2-3 "huff" coughs. This type of cough, also referred to as the forced expiratory technique (FET), requires forceful exhaling from a mid to low lung volume with an open glottis. This has been proven to be very effective for secretion clearance.

5. Cough normally to mobilize secretions as needed.

6. Repeat steps 1-5 four to six times per session.

7. PEP therapy may be an effective alternative to postural drainage and percussion with the added benefit that the patient can perform this simple task independently with fewer side effects than percussion and postural drainage.

8. PEP therapy may also be combined with aerosolized bronchodilator therapy by attaching a nebulizer or an inhaler to the one-way inspiratory valve of the PEP device.

9. While assessing the patient during PEP therapy, and it appears to be ineffective at the pressure being used, increase the PEP level by 3-5 cm H_2O and continue to monitor.

10. Vibratory PEP devices, such as the flutter valve and Acapella vibrate the airways which aid in secretion mobilization.

V. **Mechanical Insufflation-Exsufflation**

A. This therapy is to assist or replace cough clearance in patients with respiratory muscle weakness or paralysis.

B. The device can generate positive pressures of 30-50 cm H_2O on inspiration for 1-3 seconds. The pressure is then reversed to -10 to -50 cm H_2O during exhalation. This rapid change in pressure during the different phases of breathing (inspiration and expiration) helps make the cough stronger and more effective.

C. Treatments may be administered via face mask or endotracheal tube.

D. Generally, the suggested treatment regimen is 5 breaths followed by coughing or suctioning, and repeated 4-5 times.

Arterial Blood Gas Interpretation

I. Normal ABG values:

pH	7.35–7.45
$Paco_2$	35–45 mm Hg
Pao_2	80–100 mm Hg
HCO_3^-	22–26 mEq/L
Base excess (BE)	−2 to +2 mEq/L

II. Respiratory versus Metabolic Components

A. When the initial pH change is the result of a Pco_2 change, a respiratory disturbance has occurred.

1. An **increased** Pco_2 level (> 45 mm Hg) decreases the pH (< 7.35). This is **respiratory acidemia,** and if the HCO_3^- level is still within normal limits, it is *acute* or *uncompensated*. An example of acute (uncompensated) respiratory acidemia is: pH 7.22; $Paco_2$ 62 mm Hg; HCO_3^- 24 mEq/L

2. A **decreased** Pco_2 level (< 35 mm Hg) increases the pH (> 7.45). This is **respiratory alkalemia,** and if the HCO_3^- level is still within normal limits, it is *acute* or *uncompensated*. An example of acute (uncompensated) respiratory alkalemia is: pH 7.55; $Paco_2$ 26 mm Hg; HCO_3^- 23 mEq/L.

B. When the initial pH change is the result of a HCO_3^- change, a metabolic disturbance has occurred.

1. A **decreased HCO_3 level** (< 22 mEq/L) decreases the pH (< 7.35). This is **metabolic acidemia,** and if the $Paco_2$ level is within normal limits, it is *acute* or *uncompensated*. An example of acute (uncompensated) metabolic acidemia is: pH, 7.25; $Paco_2$,40 mm Hg; HCO_3^-, 15 mEq/L.

2. An **increased HCO_3** (> 26 mEq/L) increases the pH (> 7.45). This is **metabolic alkalemia,** and if the $Paco_2$ level is within normal limits, it is acute or uncompensated. An example of acute (uncompensated) metabolic alkalemia is: pH, 7.52; $Paco_2$, 43 mm Hg; HCO_3^- 35 mEq/L.

C. **pH Compensation**

1. The levels of HCO_3^- and CO_2 always change to keep the pH within the normal range. This is called **compensation.**

2. If the Pco_2 initially changes the pH, the HCO_3^- will change accordingly to return the pH to normal.

Examples:

(A)	pH	7.25	(B)	pH	7.36
	$Paco_2$	59 mm Hg		$Paco_2$	58 mm Hg
	HCO_3^-	32 mEq/L		HCO_3^-	37 mEq/L

The (A) example is a **partially compensated respiratory acidemia.** The elevated $Paco_2$ level caused the initial drop in pH. The HCO_3^- level is increasing to elevate the pH back to normal. Since the pH is approaching normal but is still low, this makes it **partially compensated.**

As the pH returns to normal (B), resulting from the continued increase in the HCO_3^- level, this is called **chronic** or **compensated respiratory acidemia.**

(A)	pH	7.54	(B)	pH	7.44
	$Paco_2$	25 mm Hg		$Paco_2$	26 mm Hg
	HCO_3^-	17 mEq/L		HCO_3^-	13 mEq/L

The (A) example is a **partially compensated respiratory alkalemia.** The decreased $Paco_2$ level caused the initial increase in pH. The HCO_3^- level is decreasing to drop the pH back to normal. Since the pH is approaching normal but is still high, this makes it **partially compensated.**

As the pH returns to normal (B), resulting from the continuing decreasing HCO_3^- level, this is a **chronic or compensated respiratory alkalemia.**

3. If the HCO_3^- level initially changes the pH, the $Paco_2$ level will change accordingly to return the pH to normal.

(A)	pH	7.23	(B)	pH	7.35
	$Paco_2$	24 mm Hg		$Paco_2$	16 mm Hg
	HCO_3^-	13 mEq/L		HCO_3^-	13 mEq/L

The (A) example is a **partially compensated metabolic acidemia.** The decreased HCO_3^- level caused the initial drop in pH. The patient is hyperventilating (decreasing $Paco_2$ levels) to elevate the pH back to

normal. Since the pH is approaching normal but is still low, this is **partially compensated.**

As the pH returns to normal (B), resulting from the continuing drop in $Paco_2$, this is a **compensated metabolic acidemia.**

(A)	pH	7.52	(B)	pH	7.43
	$Paco_2$	52 mm Hg		$Paco_2$	59 mm Hg
	HCO_3^-	30 mEq/L		HCO_3^-	30 mEq/L

The (A) example is a **partially compensated metabolic alkalemia**. The increased HCO_3^- caused the initial increase in pH. The patient is hypoventilating (increasing $Paco_2$ levels) to drop the pH back to normal. Since the pH is approaching normal but still high, this is **partially compensated.**

As the pH returns to normal (B), resulting from the continuing $Paco_2$ retention, this is a **compensated metabolic alkalemia.**

D. Mixed Respiratory and Metabolic Component

1. When both the $Paco_2$ and HCO_3^- cause the pH to move in the same direction, this is called a mixed or combined component.

2. An example of a mixed component is:

pH	7.23
$Paco_2$	54 mm Hg
HCO_3^-	17 mEq/L

This is an example of **mixed respiratory and metabolic acidemia.** An elevated $Paco_2$ and decreased HCO_3^- both contribute to acidemia.

E. Basic Steps to ABG Interpretation

1. Determine the acid-base status by observing the pH.

a. Is the pH acidotic (< 7.35)?

b. Is the pH alkalotic (> 7.45)?

2. Determine if the pH change is the result of $Paco_2$ change or a HCO_3^- change.

   a. When this is determined, observe for signs of compensation. If the $Paco_2$ caused the initial pH change, is the HCO_3^- changing to return the pH back to normal?

   b. Determine oxygenation status by observing Pao_2.

F. ABG Example Problems

pH 7.21
$Paco_2$ 58 mm Hg
Pao_2 80 mm Hg
HCO_3^- 24 mEq/L
BE −1 mEq/L

1. Acid/base status: Acidemia
2. Ventilatory status: Elevated $Paco_2$; hypoventilation resulting in decreased pH
3. Metabolic status: Normal HCO_3 ,no compensation occurring
4. Oxygenation status: Normal Pao_2
5. Interpretation: **Uncompensated (acute) respiratory acidemia**

pH 7.55
$Paco_2$ 26 mm Hg
Pao_2 93 mm Hg
HCO_3^- 23 mEq/L
BE 0 mEq/L

1. Acid/base status: Alkalemia
2. Ventilatory status: Decreased $Paco_2$; hyperventilation resulting in an increased pH
3. Metabolic status: Normal HCO_3; no compensation occurring
4. Oxygenation: Normal Pao_2
5. Interpretation: **Uncompensated (acute) respiratory alkalemia**

pH 7.43
$Paco_2$ 36 mm Hg
Pao_2 55 mm Hg
HCO_3^- 25 mEq/L
BE +1 mEq/L

1. Acid/base status: Normal pH
2. Ventilation status: Normal $Paco_2$

3. Metabolic status: Normal HCO_3
4. Oxygenation status: Moderate hypoxemia
5. Interpretation: **Normal acid/base status with moderate hypoxemia**

pH 7.37
$Paco_2$ 65 mm Hg
Pao_2 59 mm Hg
HCO_3^- 35 mEq/L
BE +10 mEq/L

1. Acid/base status: Normal pH
2. Ventilatory status: Increased $Paco_2$; hypoventilation resulting in decreased pH
3. Metabolic status: Elevated HCO_3; compensating for initial acidemia
4. Oxygenation status: Moderate hypoxemia
5. Interpretation: **Compensated (chronic) respiratory acidemia.**

Since the compensated pH is between 7.35 and 7.40, we must assume this was initially an acidemia caused by an elevated $Paco_2$.

pH 7.27
$Paco_2$ 41 mm Hg
Pao_2 89 mm Hg
HCO_3^- 15 mEq/L
BE −8 mEq/L

1. Acid/base status: Acidemia
2. Ventilatory status: Normal $Paco_2$
3. Metabolic status: Decreased HCO_3, resulting in decreased pH
4. Oxygenation status: Normal Pao_2
5. Interpretation: **Uncompensated metabolic acidemia.** No compensation is occurring, since the $Paco_2$ is normal.

pH 7.22
$Paco_2$ 25 mm Hg
Pao_2 80 mm Hg
HCO_3^- 16 mEq/L
BE −10 mEq/L

1. Acid/base status: Acidemia
2. Ventilatory status: Decreased $Paco_2$; hyperventilation compensating for the initial acidemia
3. Metabolic status: Decreased HCO_3**;** resulting in a decreased pH
4. Oxygenation status: Normal Pao_2

5. Interpretation: **Partially compensated metabolic acidemia.**. **This is an example of a patient with diabetic acidosis (ketoacidosis).**

III. ARTERIAL BLOOD GAS INTERPRETATION CHART

Key for table: N, normal; I, increased; D, decreased.

	pH	Pco_2	HCO_3
Uncompensated (acute)			
Respiratory acidemia	D	I	N
Respiratory alkalemia	I	D	N
Metabolic acidemia	D	N	D
Metabolic alkalemia	I	N	I
Partially compensated			
Respiratory acidemia	D	I	I
Respiratory alkalemia	I	D	D
Metabolic acidemia	D	D	D
Metabolic alkalemia	I	I	I
Fully compensated (chronic)			
Respiratory acidemia	N	I	I
Respiratory alkalemia	N	D	D
Metabolic acidemia	N	D	D
Metabolic alkalemia	N	I	I
Mixed respiratory/metabolic			
Acidemia	D	I	D
Alkalemia	I	D	I

Chest Radiography

I. General Indications for Chest X-Rays

A. Detecting changes in the lung resulting from pathological processes

B. Determining the appropriate therapy

C. Evaluating the effectiveness of treatment

D. Determining the position of tubes and catheters

E. Observing the progression of lung disease

II. Clinical Indications for Chest X-rays

A. Symptoms

1. Unexplained dyspnea
2. Cough, sputum and fever
3. Persistent chest pain
4. Hemoptysis

B. Medical History

1. Recent history of chest trauma
2. History of aspiration of foreign body
3. History of tuberculosis
4. History of COPD
5. Significant smoking history
6. Employment history consistent with inhalation of certain dusts

C. Physical Exam

1. Crackles or wheezes on auscultation
2. Sudden drop in blood pressure during mechanical ventilation
3. Unilateral decrease in breath sounds
4. Excessive use of the accessory muscles during breathing
5. Respiratory rate > 40/min
6. Pedal edema
7. Cardiac murmurs
8. Signs of trauma

D. Arterial Blood Gases

1. Severe hypoxemia
2. Acute hypercarbia

E. Pulmonary Function Tests

1. Evidence of air trapping
2. Marked reduction in expiratory flows or lung volumes
3. Reduced diffusion capacity of lung for carbon monoxide

F. Post Procedure

1. Intubation (endotracheal tube position in the trachea)
2. Central venous pressure or pulmonary artery catheter placement
3. Nasogastric tube placement
4. Chest tube placement

G. Other Clinical Indications

1. Sudden increase in peak airway pressure during mechanical ventilation
2. Following cardiopulmonary resuscitation
3. Routinely for patients on mechanical ventilators
4. Routine screening for infectious disease

III. Useful Terms when Interpreting Chest Films

A. **Consolidation:** well-defined, solid-appearing lung that appears light on the film and is caused by pneumonia.

B. **Radiopaque** describes white areas on the film that indicates fluids and solids; also referred to as opacity or opacification and is caused by pneumonia and pleural effusion, for example.

C. **Infiltrates** are scattered or patchy white areas on the film that are caused by inflammatory processes that indicate atelectasis or disease.

D. **Radiolucency** is a term used to describe dark areas on x-ray film and indicates air; hyperlucency is characteristic of emphysema, asthma, or subcutaneous emphysema.

E. **Silhouette Sign** – used to determine whether a pulmonary infiltrate is in anatomic contact with a heart border. Normally, there is a significant difference in density between the lung tissue and the

heart. This results in a sharply delineated heart borders. If the lung tissue in contact with either heart border becomes consolidated, the corresponding heart border is blurred and is referred to as the *silhouette sign*.

Since the heart is located in the anterior thorax, any infiltrate that obliterates the heart border must be located in the anterior segments of the lungs. Infiltrates that appear to overlap the heart border but do affect its sharpness are located in the posterior lung segments and are not in anatomic contact with the heart.

F. **Air Bronchogram** – is useful in determining whether an abnormality seen on the chest film is located within the lung. Normally the bronchi are not visible on a chest x-ray because they contain air and are surrounded by air-filled alveoli. If the bronchi are surrounded by consolidated alveoli, (white in contrast to dark air in the bronchi) the bronchi will be visible.

Air bronchograms are typically seen in pneumonia and pulmonary edema. Therefore, the presence of air bronchograms confirms that the alveoli are filled with fluid from pneumonia or pulmonary edema.

IV. Chest radiograph positions

A. Posterioanterior (PA)

1. This is the most commonly used position for chest films.

2. The patient is positioned upright with the film taken during a maximal inspiration.

3. The x-ray passes through the chest from back (posterior) to front (anterior) with the film anterior to the patient's chest.

B. Anteroposterior (AP)

1. This position is often used for portable radiographs in the intensive care areas.

2. The x-ray passes through the chest from anterior to posterior.

3. The heart is more easily seen in the position, but the quality of the film is inferior to the PA film.

C. **Lateral**

1. The film is taken from the side with the patient upright and the x-ray passes through the chest laterally.

2. This position allows for visualization of the lung parenchyma behind the heart and the bases of the lungs.

D. **Oblique**

1. This film is taken with the patient turned 45 degrees to either the right or left.

2. This position is used to help differentiate a pulmonary or mediastinal lesion from structures that overlie it. This view is often used when bilateral lesions are present.

3. This position is also used for ventilation-perfusion scanning.

E. **Apical lordotic**

1. In an upright position the patient leans back at a 45-degree angle.

2. This position moves the shadow of the clavicles out of the way for a better visualization of the upper lobes of the lungs.

F. **Lateral decubitus**

1. The film is taken with the patient lying on the side (side-lying position) with the film resting on the posterior surface of the chest.

2. This position is utilized to identify if free fluid (pleural effusion or blood) is present in the chest. Fluid will drain to the dependent area of the lung, the lung the patient is lying on, and create a shadow. So if right-sided fluid is suspected, the patient should be placed on the right side.

3. This view is also helpful in determining the presence of a pneumothorax. Since air rises, the patient should be placed on the left side if a right pneumothorax is suspected.

NOTE: Chest radiographs are usually taken with the patient at maximal inspiration which should show the lungs well aerated and the diaphragm descended to about the level of the 10^{th} rib. A film taken on expiration

may be beneficial to help detect a small pneumothorax that would otherwise be difficult to see on a routine inspiratory film. As the patient exhales, the lung volume is reduced while the pleural air volume remains the same. The pneumothorax now occupies more of the thoracic volume and can be seen better.

V. Evaluating Conditions on Chest x-ray Film

A. Atelectasis

1. Appears lighter than normal lung tissue

2. May be indicated by elevated diaphragm, mediastinal shift (toward area of atelectasis), or increased density and decreased volume of a lung area

B. Pneumonia

1. Appears white on x-ray film

2. Consolidation of entire lobe or more may cause mediastinal shift toward the consolidation.

C. Pneumothorax

1. Air found in the pleural cavity appears dark with no vascular markings in the involved areas.

2. **Tension pneumothorax** may result in mediastinal shift and a tracheal shift away from the side of the pneumothorax.

D. Hyperinflation

1. The most common cause of hyperinflation is obstructive lung disease.

2. Specific findings of hyperinflation on the chest film:

   a. Large lung volumes
   b. Depressed (flattened) diaphragms
   c. Small narrow heart
   d. Enlarged intercostal spaces

E. ET tube placement

1. Tube should rest about **2 to 5 cm above the carina**. On an inspiratory film, the carina is located at the level of the fourth rib or fourth thoracic vertebra.

2. If ET tube is inserted too far, it has a greater tendency to enter the right mainstem bronchus.

3. If right mainstem is inadvertently intubated, diminished breath sounds would be heard on the left and asymmetrical chest movement may be observed.

F. Heart shadow

1. Should appear white in the middle of the chest, with the left heart border easily determined

2. A normal heart should be less than half the width of the chest. Increased heart size may indicate CHF.

G. Diaphragm

1. Should be rounded or dome-shaped

2. Appears white on x-ray film at the level of the 10^{th} rib during a maximal inspiration.

3. Patients with hyperinflated lungs (emphysema) have flattened diaphragms.

4. Both hemidiaphragms should be assessed for height and angle to the chest wall.

5. The dome of the right hemidiaphragm is normally 1 to 2 cm higher than the left because of space needed for the liver.

Assessment of Sleep Disorders

I. **Terminology**

A. **Apnea** – Cessation of airflow for 10 seconds or more

B. **Sleep apnea** – periodic apnea during sleep

C. **Sleep apnea syndrome (SAS)** – a potentially life-threatening disorder characterized by significantly increased incidence of sleep apnea resulting in various clinical consequences, especially snoring and daytime somnolence. Technically defined as the presence of 30 or more apneic episodes per seven hour sleep period.

D. **Obstructive sleep apnea (OSA) -** sleep apnea characterized by > 70% reduction of airflow in the presence of respiratory effort, usually caused by upper airway obstruction (**OSAS**: obstructive sleep apnea syndrome) A common term associated with OSA is **hypopnea**. Hypopnea is defined as a 30% reduction in airflow in the presence of > 4% reduction in SaO_2 during sleep.

E. **Obesity-hypoventilation syndrome (OHS)** – a syndrome involving obesity, obstructive sleep apnea and COPD-like cardiovascular symptoms (hypercarbia, hypoxemia, cor pulmonale and secondary polycythemia. This condition was once referred to as **Pickwickian syndrome**.

F. **Central apnea** – apnea characterized by cessation of respiratory effort. It occurs in **less than 10%** of all cases of adult sleep apnea. It is more often seen in infants and young children. Example: Ondine's curse

G. **Mixed apnea** – an apneic episode which begins as central apnea and changes to obstructive apnea. For example, the episode begins with cessation of respiratory effort but is followed by a period where inspiratory effort resumes but produces no airflow, presumably due to obstruction.

H. **Excessive daytime somnolence (EDS)** – excessive daytime tiredness and/or strong sleep urge at inappropriate times. This is often the symptom which prompts SAS patients to seek treatment.

I. **Apnea-Hypopnea Index (AHI) -** The number of apneic and hypopneic episodes per hour determines the degree of sleep apnea

< 5	normal
5-15	mild
15-30	moderate
> 30	severe

Moderate or severe sleep apnea should be treated with CPAP resulting in an AHI of 0

II. Clinical Manifestations of Sleep Apnea

A. **Snoring** – present in all OSA patients; diagnostic of SAS when coupled with daytime sleepiness

B. **Daytime somnolence** – usually the first complain of SAS patients

C. **Morning headaches and/or confusion**

D. **Abnormal physical movements during sleep** – kicking, restlessness, sleep walking or talking, etc.

E. **Mental changes** – deterioration in intellectual capacity or concentration, personality changes, etc.

F. **Night sweats**

G. **Cardiac arrhythmias**

H. **Pulmonary and systemic hypertension** – seen in about 50% of OSA patients

I. **Congestive heart failure**

III. Sleep studies – polysomnography – the polysomnogram (PSG) is the graphic recording of a variety of physiologic parameters during sleep which include:

A. **Nasal and oral airflow measurements** – flows are generally measured using flow thermistors

B. **Measurement of respiratory efforts** – accomplished by placing electrodes on the upper and lower chest or abdomen to detect movement in these areas.

Note: Measuring both airflow and respiratory effort helps differentiate between obstructive and central sleep apnea.

C. **Electrocardiogram (EKG)** – patients with SAS generally have normal EKGs during the day but have progressive sinus bradycardia during episodes of sleep apnea; once ventilation resumes the heart rate will increase. Some life-threatening arrhythmias may occur with sleep apnea.

D. **Electroencephalogram (EEG) and electrooculogram (EOG)** – the EEG is used to determine sleep stages and the EOG measures eye movements. These tests are performed to determine the patient's level of sleep when the apnea occurs. Two stages of sleep: Rapid-eye movement sleep (REM) and nonrapid eye movement sleep (NREM). REM sleep accounts for 20%-25% of total sleep time. Sleep apnea usually occurs during REM sleep.

E. **Electromyogram (EMG)** – measures muscle tone; muscle tone is at a minimum during REM sleep. The EMG helps confirm the patient is in REM sleep.

F. **Oximetry** – SaO_2 can drop significantly during prolonged apneic episodes; chronic episodes of hypoxemia during sleep can result in both pulmonary and systemic hypertension, cor pulmonale, etc.

   NOTE: If a patient is complaining of daytime sleepiness and has no blood pressure issues, an overnight pulse oximetry study is indicated. If daytime sleepiness is accompanied by increased blood pressure, a sleep study is indicated.

G. **End-tidal CO2 and transcutaneous PCO2** – these parameters are often measured in infants and children

IV. Treatment and management of sleep apnea

A. Avoidance of supine sleeping

B. Weight reduction – can be very effective at reducing OSA, although not all sleep apnea patients are obese

C. Avoidance of alcohol, sedatives and relaxants

D. Pharmacological treatment

   1. antidepressants to reduce REM sleep
   2. respiratory stimulants

E. Nasopharyngeal airway placement during sleep

F. Tongue-retaining devices

G. Surgical treatment – adenoidectomy, tonsillectomy, uvulopalatopharyngo-plasty (UPPP); effective less than 50% of the time

H. Mechanical interventions – primarily for patients with central apnea, measures include diaphragmatic pacing, positive pressure ventilation (BiPAP)

I. **Nasal CPAP (NCPAP) – this is the generally the treatment of choice for OSA.** Applying positive pressure through a nasal mask or full face mask prevents the soft tissue from falling back against the posterior pharyngeal wall obstructing airflow. The amount of pressure used varies from patient to patient. Adverse effects of CPAP are generally mild and are mainly related to comfort.

BRONCHOSCOPY

Bronchoscopy is a technique that utilizes an instrument called a bronchoscope that is used to visualize the tracheobronchial tree for both therapeutic and diagnostic purposes.

I. Fiberoptic bronchoscope

A. It consists of a collection of thin, thread-like glass strands called fiberoptic filaments with a light source projected to its distal end for visualization.

B. Because of its more flexible nature it is better tolerated by patients and therefore more commonly used.

C. Because bronchoscopy is uncomfortable, the patient should be administered a sedative 1-2 hours prior to the procedure. Commonly, Versed is used for this purpose. Sedation should be just enough to allow the patient to follow commands yet still be comfortable. This is referred to as **conscious sedation**.

D. It is also important that the airway be dry during the procedure to aid in visualization. This is usually achieved by the administration of **Atropine 1-2 hours** before the procedure. Atropine will also decrease vagal tone, resulting in decreased potential for bradycardia and hypotension, which can occur during the procedure.

E. The tube may be inserted orally, nasally or through the endotracheal tube. The tube should be lubricated with a water soluble gel for easier nasal insertion. Often xylocaine (Lidocaine) jelly is used both as a lubricant and for its numbing effects. Aerosolized Lidocaine may be administeredprior to the procedure.

F. Biopsy forceps and brushes may be inserted through this bronchoscope to obtain tissue samples.

II. Indications for bronchoscopy

A. Removal of foreign bodies

B. Removal of mucous plugs and thick secretions

1. Normally performed if secretions cannot be remove by routine suctioning techniques.

2. Once the site of the secretions is visualized, normal saline should be instilled prior to suctioning.

C. Atelectasis affecting a lobe or entire lung

D. Pulmonary hemorrhage

1. to locate the area of bleeding

2. to control bleeding by instillation of epinephrine or iced saline lavage at the bleeding site

E. Difficult tracheal intubation as a result of upper airway trauma, obesity, tumors or spinal deformity

1. The endotracheal tube (ET tube) is slipped over the fiberoptic bronchoscope with the scope protruding well past the end of the ET tube.

2. The vocal cords are visualized and the scope is advanced through the cords to the mid-tracheal level where the ET tube is then advanced over the scope to the proper position. The scope is then withdrawn.

F. Biopsy of suspected tumors

G. Obtaining sputum for culture and sensitivity studies

III. Complications of bronchoscopy

A. Hypoxemia

1. monitor oxygen saturation during procedure

2. increase oxygen percentage during procedure

B. Laryngospasm

1. makes advancing the tube more difficult

2. a muscle relaxant should be readily available

C. Bronchospasm

1. a result of irritation to the airway

2. a bronchodilator should be readily available

D. Arrhythmias

1. resulting from vagal stimulation

2. monitor EKG and remove bronchoscope until the patient's cardiac status is stabilized

E. Hemorrhage

1. may occur during insertion of the tube

2. also may occur following biopsy

F. Respiratory depression

1. resulting from sedatives given during the procedure

2. monitor respiratory status closely

G. Hypotension

1. resulting from vagal nerve stimulation

2. may result from sedatives given during the procedure

H. Pneumothorax

1. resulting from inadvertent puncture of the lung

2. monitor respiratory status closely

IV. Respiratory therapist responsibilities during bronchoscopy

A. Prepare the patient and explain the procedure.

B. Administer aerosolized local anesthetic to the patient's upper airway.

C. Conduct patient monitoring throughout the procedure.

1. pulse
2. respiratory rate
3. EKG
4. oxygen saturation

D. Collect sputum and tissue samples that the physician has obtained and prepare them for laboratory analysis.

E. Clean the bronchoscope properly following the procedure. (Soak in liquid disinfectant for 15-30 min)

V. **Specialized bronchoscopy**

A. Electromagnetic navigational bronchoscopy (ENB)

1. ENB is diagnostic tool that combines conventional bronchoscopy with virtual bronchoscopy that allows bronchoscopic instruments to reach peripheral lung areas that traditional fiberoptic bronchscopes can't reach.

2. A low-dose electromagnetic field is created around the patient. A software program creates a three-dimensional virtual bronchial tree that is aligned with the patient's bronchial anatomy that is obtained from CT scan performed prior to ENB.

3. The locatable guide (LG) is then navigated to the point of the lesion where a biopsy can be obtained with a brush, forcep or needle.

4. ENB can successfully diagnose 75%-77% of peripheral lesions where traditional fiberoptic bronchoscopy biopsies were unsuccessful.

5. A pneumothorax is a complication in approximately 3.5% of patients.

B. Endobronchial ultrasound (EBUS)

1. EBUS is a bronchoscope with an ultrasound probe attached to the distal end. A video camera allows visualization for guidance of a needle to sample tissue from the mediastinum and peripheral lung areas where traditional bronchoscopy can't reach.

2. This technique is much more accurate for diagnosing lung tumors (approximately 98%) than positron-emission tomography (PET) or CT chest scans.

3. Lymph nodes below the carina can be more accurately assessed with EBUS than traditional mediastinoscopy.

4. Complications include pneumothorax, pneumomediastinum and bacteremia.

C. Bronchalveolar Lavage (BAL)

1. BAL is the instillation of approximately 100 mL of normal saline through the bronchoscope's suction channel to the affected area. The tip of the scope is positioned into a fourth-generation bronchus and the saline instilled in 20 mL increments five separate times.

2. The saline instilled at this position dilates the distal bronchioles and fills the alveoli, which washes out any cells or microorganisms.

3. The fluid is suctioned back out and collected, being careful not to contaminate the fluid from oral or upper airway secretions.

4. The fluid is sent to the lab for microscopic analysis to determine the type of pneumonia present.

5. BAL is contraindicated in hypoxemic patients and those with reduced pulmonary function, severe cardiovascular disease or serious electrolyte abnormalities.

Noninvasive Positive Pressure Ventilation (NPPV)

I. Characteristics of NPPV

A. NPPV is a type of ventilatory technique used on nonintubated patients. It is utilized in the acute care setting to “buy time” for specific patients to get past the initial ventilatory crisis and avoid intubation and ventilation.

II. Indications for NPPV

A. Patients with acute exacerbation of COPD

B..Management of acute cardiogenic pulmonary edema and CHF

C. Ventilator patients who have been extubated too soon, to avoid reintubation

D. Home management of sleep apnea and patients with neuromuscular dysfunction

E. Acute respiratory failure to prevent endotracheal intubation

II. Contraindications of NPPV

A. Intolerance to nasal or oral mask

B. Secretion problems

C. Hypotension (patient should be hemodynamically stable)

D. Severe hypoxemia

E. Upper airway obstruction

F. Severe acidemia

G. Patients prone to aspiration

III. Advantages of NPPV

A. Avoidance of intubation and associated complications

B. Patient comfort

C. Utilization of natural airway defenses

D. Able to speak and swallow

E. Less need for sedation

IV. Disadvantages of NPPV

A. Need cooperative patient

B. Limited access to airway and suctioning

C. Mask discomfort

D. Facial ulcers, eye irritation, rhinitis and dry nose

E. Air leak (most BiPAP units compensate for leaks)

F. PIP limited to 20-30 cm H_2O

V. NPPV Set Up

A. NPPV may be time-cycled or patient-cycled. Once inspiration begins, a preset inspiratory positive airway pressure (IPAP) is reached. Expiratory positive airway pressure (EPAP) should be preset to avoid CO_2 buildup in the nasal mask. EPAP is the equivalent of PEEP.

B. The initial IPAP setting is usually 10-15 cm H_2O, and the EPAP setting is 4-5 cm H_2O. The difference between the IPAP and EPAP settings is the pressure support. IPAP settings range from 2 to 25 cm H_2O and EPAP ranges from 2 to 20 cm H_2O.

C. A frequency control determines the timed breath rate and is adjustable from 6 to 30 cycles/min. The % IPAP control is set to determine the time spent in inspiration and functions as the I/E ratio control.

D. An IPAP should be used that results in an exhaled V_T of 6 to 8 mL/kg of ideal body weight.

Ventilator Management

I. Volume-control ventilation (VC)

A. V_T is constant, PIP varies with changes in compliance and resistance.

B. If the PIP increases, whether it resulted from an increased airway resistance or a decreased lung compliance (increased plateau pressure), the V_T is still delivered, unless the high pressure limit is reached.

C. It the high pressure limit is reached, inspiration ends delivering less volume to the patient.

D. The high pressure limit should be set 10 cm H_2O above the PIP.

E. If $PaCO_2$ is *increased*, increase the V_T or RR.

1. Regardless of what the PaO_2 is, if the $PaCO_2$ is increased, correct it first!

2. DO NOT increase the RR when AC mode is used, unless the patient is not assisting above the set rate, for example, patients who are sedated or paralyzed who are not breathing above the set rate. In other words, the patient may be in the AC mode and rate of 10/min with a total rate of 15/min. Increasing the rate to 15/min will not be effective in reducing the $PaCO_2$.

3. Increasing the RR when SIMV mode is used will decrease the $PaCO_2$.

F. If $PaCO_2$ is *decreased*, DO NOT automatically recommend decreasing the V_T or RR. YOU MUST look at the PaO_2 to determine the correct recommendation.

1. If the $PaCO_2$ is decreased and the PaO_2 is normal, decrease V_T or RR. Again, decreasing the RR when AC mode is used will not be helpful unless the patient is sedated or paralyzed and not breathing above the set rate.

2. If the $PaCO_2$ is decreased and PaO_2 is decreased, increase either the F_IO_2 or the PEEP, since the patient's hypoxemia has resulted in hyperventilation and will be corrected by increasing the PaO_2.

3. Decreasing the RR when SIMV mode is used will increase the $PaCO_2$.

II. Pressure-control ventilation (PC)

A. PIP remains constant, V_T varies with changes in compliance and resistance.

B. If lung compliance decreases or airway resistance increases (which would result in an increased PIP), the V_T will decrease since the PIP can't increase in PC.

C. Conversely, if lung compliance increases or airway resistance decreases, the V_T will increase.

Example: Over the past 3 hours, the patient's exhaled V_T has decreased from 600 mL to 400 mL. The PIP has been maintained at 30 cm H_2O. This indicates that either the compliance has decreased or airway resistance has increased. If it's an airway resistance issue, suction the patient or recommend a bronchodilator.

D. When PIP is increased, V_T increases. When PIP is decreased, V_T decreases.

E. If $PaCO_2$ is *increased*, increase the PIP or RR. Think of the PIP control as the same as the V_T control on VC ventilation.

F. If $PaCO_2$ is *decreased*, decrease the PIP or RR. Again, the PaO_2 must be evaluated to determine the most appropriate change (see under Volume-Control Ventilation on previous page.)

G. Changing the PEEP affects the V_T.

1. Since the PIP stays constant in PC, when the PEEP is increased, PIP doesn't increase, so V_T will decrease.

2. When PEEP is decreased, V_T will increase.

3. If you want to maintain the same V_T after PEEP is increased, increase the PIP by the same amount.

F. PIP should be set to achieve an exhaled V_T of 6-8 mL/kg

NOTE: Questions are still asked occasionally about IPPB therapy on the exams. The material above regarding PC holds true for IPPB, but the exhaled V_T for IPPB should be 12-15 mL/kg.

III. High-frequency oscillation ventilation (HFOV)

A. Used primarily on infants.

B. If $PaCO_2$ is *increased*, increase the amplitude.

C. If $PaCO_2$ is *decreased*, decrease the amplitude.

IV. Setting initial ventilator settings

Mode – AC or SIMV

V_T – **6-8 mL/kg IBW** (may be slightly higher than 8 mL/kg but < 10 mL/kg)

4-6 mL/kg IBW for ARDS

RR – 10-16/min

F_IO_2 – generally the same F_IO_2 prior to initiation of ventilation

PEEP – 4-5 cm H_2O

Pressure support (PS) - 5-10 cm H_2O to augment spontaneous V_T on SIMV mode

Flowrate – 40-60 L/min

Exam Note: You may not have a choice that meets all of these criteria, so pick the best choice, which will be the one that is closest to these initial settings.

V. Treatment of hypoxemia and hyperoxemia (F_IO_2 or PEEP?)

A. If hypoxemia is present with the patient breathing 50%-60% O_2 or higher, *increase* the PEEP first. If the question states the patient has atelectasis or pulmonary edema on 50% oxygen, increase the PEEP, which will be more effective in increasing the PaO_2 than increasing the F_IO_2 in this instance.

B. If hypoxemia is present with the patient breathing less than 60% O_2, increase the F_IO_2, but don't exceed 60%.

C. If hyperoxemia is present with the patient breathing 60% O_2 or higher, de*crease* the F_IO_2 first.

D. If hyperoxemia is present with the patient breathing 60% or less, de*crease* the PEEP first. *Exception: ARDS or pulmonary edema present, maintain the PEEP level and decrease the F_IO_2.*

Note: The statements above are true for infants, pediatrics and adults

E. *Avoid increasing PEEP level above 5-8 cm H_2O on patients with increased intracranial pressure (ICP), hypotension or decreased cardiac output. Instead, increase the F_IO_2, even above 60% if necessary.*

VI. Calculating ideal body weight (IBW) to determine V_T setting

In pounds:

IBW (males) = 106 + 6 (height in inches – 60)

IBW (females) = 105 + 5 (height in inches -60)

Example: 5'4" male weighing 130 kg (286 lb)

106 + 6 (64 – 60) (always subtract the height -60 first!)

106 + (6x4) = 106 + 24 = 130 lb

Change 130 to kg: 130/2.2 = 59 kg

Select V_T of 360-500 mL

I

Calculating ideal body wt (in kgs) :

Males: 50 kg + 2.3 kg (ht in inches – 60)

Females: 45 kg + 2.3 kg (ht in inches – 60)

VII. Ventilating the ARDS patient

A. Use V_T of 4-6 mL/kg IBW

B. According to ARDS protocols, PEEP may be increased to as high as 24 cm H_2O, provided the PIP is not excessive (> 40 cm H_2O)

C. **Plateau pressure should not exceed 30 cm H_2O**.

D. Permissive hypercapnia is permissible on the exams by using lower V_T or PIP levels.

E. If a question indicates $PaCO_2$ levels need to be decreased, *increase the RR*, not the V_T or PIP! Rates as high as 35/min may be used

F. Acceptable PaO_2 for ARDS patients is 55-80 torr.

VIII. Indications for mechanical ventilation

A. MIP > 20 cm H_2O (-15 cm H_2O for example)

B. VC < 10-15 mL/kg

C. V_D/V_T > 0.60

D. $PaCO_2$ > 50 torr and rising

IX. Weaning parameters

A. MIP at least -20 cm H_2O

B. VC > 15 mL/kg

C. PaO_2/F_IO_2 > 200

D. RSBI < 105

E. V_E < 10-15 L/min

F. V_T > 4-6 mL/kg

G. $P(A\text{-}a)O_2$ < 350 on 100% O_2

Equations to Know for the Exams

Note: The equations listed below are the most common ones asked about on the TMC examination. There are typically only 3-4 math questions on the exam.

1. Lung compliance:

$$C_L = \frac{V_T}{\text{Plateau pressure} - \text{PEEP}}$$

2. Total flow from high-flow O_2 delivery device (AEM, aerosol mask):

air/O_2 ratio parts added together x flowrate

3. Time left in an O_2 cylinder:

$$\frac{\text{cylinder pressure} \times \text{cylinder factor}}{\text{flowrate}}$$

H cylinder factor: 3.14 L/psig (3)
E cylinder factor: .28 L/psig (.3)

4. Time left in liquid O_2 tank:

$$\frac{\text{lbs of liquid } O_2 \times 860}{2.5 \text{ lb/L}} = \text{liters of gaseous } O_2$$

Shortcut: 344 x lbs of liquid O_2 = liters of gaseous O_2

$$\text{Time left} = \frac{\text{liters of gaseous } O_2}{\text{liter flow}}$$

5. V_D/V_T ratio:

$$\frac{PaCO_2 - PECO_2}{PaCO_2}$$

6. Alveolar V_E (alveolar minute ventilation):

   $(V_T – V_D) \times RR$

   V_D = 1 mL/lb of IBW (nonintubated patient)

   V_D = 1 mL/kg of IBW (tracheostomized patient)

7. V_E (minute ventilation):

   $V_T \times RR$

8. $P(A\text{-}a)O_2$:

   Shortcut for exam:

   $P_AO_2 = (7 \times O_2\%) – PaCO_2 + 10)$

   $P_AO_2 – PaO_2$

9. **Calculating ideal body wt (in lbs) :**

   Males: 106 lb + 6 lb (ht in inches – 60)

   Females: 105 lb + 5 lb (ht in inches – 60)

   Calculating ideal body wt (in kgs) :

   Males: 50 kg + 2.3 kg (ht in inches – 60)

   Females: 4.5 kg + 2.3 kg (ht in inches – 60)

10. Airway resistance (Raw)

$$\frac{\text{PIP – plateau pressure}}{\text{flowrate}}$$

11. Desired ventilator V_T:

$$\frac{V_T \text{ (current setting)} \times PaCO_2 \text{ (current value)}}{PaCO_2 \text{ (desired)}}$$

Note: When calculating desired V_E or respiratory rate, substitute those values into the above equation.

12. **Desired F_IO_2**:

$$\frac{PaO_2 \text{ (desired)} \times F_IO_2 \text{ (current level)}}{PaO_2 \text{ (current value)}}$$

13. **CaO_2 (total O_2 content):**

$(1.34 \times Hb \times SaO_2) + (0.003 \times PaO_2)$

Since the number for dissolved O_2 (0.003 x PaO2) is always less than 1, just calculate the O_2 bound to Hb (1.34 x Hb x SaO2) and pick the closest selection just higher than your answer and you'll get it right.

Note: Use the fractional concentration of the SaO_2; 0.95 instead of 95%.

14. **Heliox flow correction**

1. 80/20 mixture - multiply the oxygen flowmeter reading by **1.8** to determine correct flow.

Example: An 80/20 heliox mixture is running through an oxygen flowmeter at 10 L/min. What is the actual flow being delivered to the patient?

1.8 x 10 = 18 L/min

2. Divide the ordered He/O_2 flow by **1.8** to determine what to set the O_2 flowmeter on.

Example: You want to deliver 15 L/min of a 70/30 mixture of He/O_2 to the patient. What must you set the oxygen flowmeter on to deliver this flow?

$$\frac{15}{1.6} = 9.4 \text{ L/min.}$$

NOTE: The flow correction factor for a 70/30 heliox mixture is 1.6

Exam Note: As of January, 2020, the NBRC allows the use calculators on the exams. But be aware there is very little math on the TMC and Clinical Simulation exams.

Test-Taking Strategies

1. Multiple true-false questions (Only one or two of these on the exam)

Example: While assessing a patient's chest radiograph the respiratory therapist observes an area of hyperlucency. This may be the result of which of the following?

1. hyperinflation
2. atelectasis
3. emphysema
4. pneumothorax

A. 1 and 3 only
B. 2 and 3 only
C. 1, 3 and 4 only
D. 2, 3 and 4 only

Students are often intimidated by these types of questions, but you can answer these questions correctly without knowing whether all the selections are right or wrong. For instance, if you know selection #1 is true and selection # 2 is false, select answer that has a 1 without a 2. That can often rule out two or even three choices. In this question, you know that answers B and D cannot be the correct answer since both have a 2 in the answer. This gives you a 50/50 chance of answering this question correctly. Don't get flustered with these questions. Go with what you know, and pick an answer that fits what you know to be correct, even if it's only two of the four selections. The correct answer is C.

2. Look for answers that are stating the same thing.

Time	peak pressure ($cm H_2O$)	plateau pressure ($cm H_2O$)
1 PM	38	18
2 PM	42	23
3 PM	46	26

Which of the following statements regarding these data are true?

A. Lung compliance is decreasing.
B. Airway resistance is decreasing.
C. The lungs are becoming easier to ventilate.
D. Lung compliance is increasing.

Notice that choices C and D are stating the same thing. When lung compliance increases, the lungs are becoming easier to ventilate. Therefore, neither of these answers can be correct. That leaves choices A and B. You may know that B is incorrect, leaving only A, which is the correct answer. Using the process of elimination can help you get answers right when you don't actually know the right answer.

3. Group similar answers together to eliminate them.

The following PFT values have been obtained on a 57-year-old male.

	Actual	Predicted	%Predicted
FEV_1	1.4 L	3.0 L	47%
FEV/FVC	48%	70%	
VC	2.1 L	3.8 L	55%
TLC	6.4 L	4.8 L	133%
FRC	3.4 L	2.5 L	136%

Which of the following pulmonary disorders is consistent with these findings?

A. pulmonary fibrosis
B. pneumonia
C. atelectasis
D. emphysema

Notice choices A, B and C are restrictive lung conditions, meaning that the PFT results can't indicate a restrictive disorder. The answer has to be an obstructive disorder. The answer has to be D. So if you got confused on the PFT results, you can still answer the question correctly by simply ruling out those you know *can't* be correct.

Preparing for the NBRC Examinations

You've finally completed and graduated from your respiratory care program and are now focusing on taking the NBRC Therapist Multiple-Choice (TMC) Exam and Clinical Simulation Exam.

If you're like many graduates, you feel overwhelmed with all the material you have learned over the past 2-4 years of your respiratory care education, and hardly know where to start in your preparation and study for your exams. This section provides some suggestions on how to make the best use of your study time as well as studying techniques.

1. **Familiarize yourself with what material the exam covers.**

   The National Board for Respiratory Care (NBRC) provides a detailed content outline of the subject matter they test over on every exam they administer. It's referred to as the Content Outline and it lists by three detailed content categories what topics you may appear on the exam. You can go to the NBRC website at nbrc.org and print off the "Detailed Content Outline" for the exam you are preparing to take. The matrix is quite detailed and even indicates how many questions on the exam will come from each category. It's essential that you become familiar with what you will be tested over so you know where to focus your area of study.

   Taking the NBRC exams on a routine basis, I know from experience there is little math on the exam. So often, math may be our weakest area and we feel the need to study all the math equations we have done throughout our respiratory care education and then some. If you focus a great deal of your study time on math, you are wasting time. There are generally only three or four math problems at the most on the TMC Exam. I'm not suggesting avoiding studying math all together, but by going through the Detailed Content Outline you'll get a good idea of the math problems with which you need to be familiar.

   Print the Clinical Simulation content outline from their website to familiarize yourself with topics covered on this branching-logic exam. There are 22 clinical simulations, two which are not counted in the final score. Each simulation will consist of 4-6 sections. The patient is assessed in the information-gathering sections, which are then evaluated and used to make decisions (decision-making sections) regarding the appropriate care of the patient.

2. Take as many practice exams as possible.

The more NBRC-type questions you see, the better. The NBRC provides a free TMC exam on their website that is much like the actual exam. After taking the exam you get a score report letting you know your score along with an answer key that also indicates your answer and from which exam content area each question comes. Therefore, you are able to see which questions you answered correctly and incorrectly. Pay close attention to the questions you missed so you can determine on which areas you need to focus your study. It's important to take these exams in one sitting. In other words, don't answer thirty questions, stop, and come back and do twenty more, etc. You need to get the feel and timing for a 3-hour test. You want to learn to pace yourself so you don't run out of time before answering all the questions.

You can also purchase TMC and Clinical Simulation self-assessment exams (SAE) from the NBRC that are very helpful for exam preparation. They provide explanations for each selection.

My 17-chapter exam review textbook*, Respiratory Care Exam Review*, 5th edition, 2020, Elsevier Publishers, has two practice TMC exams with an answer key and explanations for all the correct answers. It also has 20 practice clinical simulations with explanations for all selections. Reviewing the explanations after taking these exams will give you a good understanding of why you missed specific questions.

Do not memorize questions! Review the explanations to get a better understanding of the material.

3. Don't spend too much time on one question.

The TMC Exam consists of 160 questions, which includes 20 pre-test questions that don't figure into your final score. There is a 3-hour time limit to complete the exam, meaning you have a little over one minute per question. It's very important that you don't spend too much time on questions or you the risk the possibility of not completing the exam within the specified time limit.

Pace yourself, so that you are on at least question **60 by the end of the first hour**. If you feel you are spending too much time on a question, make a note on the scratch paper you are provided to come back and look at the question again after you have completed the exam. **But don't leave the question blank**. Mark an answer in case you don't have time to return to the question. Therefore you

have a chance of getting the answer correct. But if left blank, it rules out that possibility.

Also, if you realize you are about to run out of time, for example, you're on question 151 with only three minutes left, answer the last ten questions without even reading the questions but selecting the same choice for each question. For example, select "A" for each question. This way you will get at least a couple questions correct, maybe more, since some of those answers will be an "A" choice.Then return to question 151, and read the last ten questions more carefully and answer them to the best of your ability. Following this suggestion will ensure that every question gets answered and gives you a chance of getting them correct. If time runs out with questions not answered, obviously you will not get those questions right.

4. Plan a study schedule.

The last thing you want to do is cram for these exams by studying for only a couple days prior to your test date. Try to set aside a certain amount of time each day to study for your exam. Begin studying at least 2-3 weeks prior to your exam date. Plan on studying around 1-2 hours each day, with special focus on your areas of weakness that you have determined from practice exams, or those areas you know have given you the most trouble in school.

When you find your mind drifting off the material or you seem to be just looking at the words and not absorbing the material, stop studying. Take a break and come back to it later.

Study up to within two days of the exam and ***don't study the night before the exam.*** If you have followed a good study schedule for the past 2-3 weeks or more, one more night is not going to make a difference. Take a break from studying and you'll feel fresh the next day to take the exam.

5. Find a good exam review textbook.

With all the material you have learned while in school using several different textbooks, an exam review textbook can be a wise investment. These review books filter out material that isn't that necessary to know for the NBRC exams and focus on what is important for exam purposes by utilizing the detailed content outline provided by the NBRC.

My textbook*, Respiratory Care Exam Review*, 5th edition, 2020 published by Elsevier publishers, is a good example. You can

purchase my textbook from the publisher by going to my website, www.respiratoryreviewworkshops.com, and click on the “Contact” link. A picture of the textbook is on the contact page. Click on the picture of the book and you will be sent to the publisher’s website where you can purchase the book. Or you can go directly to Elsevier.com to purchase the book.

This isn’t to say that other textbooks are not important to use in your studies. They should be used to supplement the review textbook that you find may not go into as much detail as you would like.

6. Test Anxiety

Some students find they suffer from text anxiety, getting so nervous prior to and during the exam, that it clouds their thinking, resulting in a lack of confidence while taking the exam. This leads to second guessing themselves on questions they most likely know. The best remedy for test anxiety is knowing that you have prepared yourself well for the exam. Knowing you have studied hard and are truly prepared should give you a level of confidence, not over-confidence, that you are ready to take the exam.

It’s easy to get frustrated taking either exam, but especially the Clinical Simulation exam. Remember, you don’t have to achieve a perfect score. You can make mistakes, in fact, quite a few and still pass.

I believe in the power of prayer! If you do, pray for a peace as you prepare for the exam and while taking the exam. It’s amazing the calmness He can provide in times of stress like this.

I hope this section has provided you beneficial tips for getting yourself prepared for these important exams. Best wishes!!