Pulmonary/Cardiac/Cancer Rehabilitation

Priscila Gonzalez, M.D., Sara Cuccurullo, M.D., Iqbal Jafri, M.D., and Lisa Luciano, D.O.

Pulmonary

Priscila Gonzalez, M.D. and Sara Cuccurullo, M.D.

Cardiac

Iqbal Jafri, M.D.

Cancer

Lisa Luciano, D.O. and Priscila Gonzalez, M.D.

Pulmonary Rehabilitation

Goals of Pulmonary Rehabilitation

- Improvement in cardiopulmonary function
- Prevention and treatment of complications
- Increased understanding of the disease
- Increased patient responsibility for self-care and compliance with medical treatment
- Improvement in level of activity and quality of life, return to work

Benefits of Pulmonary Rehabilitation

- Improvement in exercise tolerance, symptom-limited oxygen consumption, work output, mechanical efficiency, and vital capacity
- Exercise increases arterial venous oxygen (AVO_2) difference, increasing oxygen extraction from arterial circulation
- Reduction in dyspnea and respiratory rate
- Improvement in general quality of life; decreased anxiety and depression, improvement in Activities of Daily Living (ADLs)
- Improvement in ambulation capacity
- Decreased hospitalization rates
- Focus on conditioning peripheral musculature in order to improve their efficiency and reduce stress on the heart and lungs (Alba 1996)

Candidates for Pulmonary Rehabilation

Motivated nonsmokers or patients who have quit smoking and whose activities are limited because of dyspnea are good candidates for a pulmonary rehabilitation program.

- Functional evaluation to assess pulmonary disability is recommended prior to starting the program:

  Classification of functional pulmonary disability—Moser Classification

  1. Normal at rest—dyspnea on strenuous exertion
  2. Normal ADL performance—dyspnea on stairs/inclines
  3. Dyspnea with certain ADLs, able to walk one block at slow pace
  4. Dependent with some ADLs; dyspnea with minimal exertion

     Note: 1—4 have no dyspnea at rest

  5. Housebound— dyspnea at rest, assistance with most ADLs
- Patients who benefit the most from a pulmonary rehabilitation program have at least one of the following:
  - Respiratory limitation of exercise at 75% of predicted maximum O_2 consumption
  - Irreversible airway obstruction with a Forced Expiratory Volume in one second (FEV_1) < 2000 ml or an FEV_1/FVC ratio of less than 60% (See Lung Volume Definitions below)
  - Restrictive lung disease or pulmonary vascular disease with carbon monoxide diffusion capacity <80% of predicted value (Bach, 1993)

Quick Review of Pulmonary Physiology

Central control of respiratory function

- Voluntary control of respiration originates in the cortex and descends through the spinal cord to the respiratory muscles

The medullary respiratory center—serves to integrate different chemoreceptors

- Central chemoreceptors (stimulated by hypercarbia)

  Peripheral chemoreceptors (stimulated by hypoxia) located in the carotid and aortic bodies

Muscles of respiration

Inspiratory muscles

- Accessory muscles of respiration—sternocleidomastoid, trapezius, pectoralis major
- Diaphragm—innervated by the phrenic nerve. Works at rest. Primary muscle of respiration
- External intercostals—act during exercise

Expiratory

- Abdominal muscles—primary expiratory muscles
- Internal intercostals

Muscles of the upper airway

- Keep the upper airway open
- Include muscles of the mouth, tongue, uvula, palate, and larynx

Acute ventilatory failure may result from

- Severe respiratory infections
- Pulmonary edema
- Diffuse parenchymal injury
- ARDS (Acute Respiratory Distress Syndrome)
- Acute pulmonary circulatory failure (i.e., acute pulmonary embolism)
- Head trauma or medications that can cause dysfunction of respiratory drive
- Patients with SCI with lesions above C3 present with diaphragmatic failure

Note: Chronic respiratory failure—considered when ventilatory failure exceeds 30 days

Pulmonary function evaluation

- The magnitude of functional impairment can be assessed through the use of pulmonary function tests
- Respiratory excursions during normal breathing and during maximal inspiration and expiration are observed
- Evaluation of lung volume changes can be used to classify respiratory dysfunction into obstructive and restrictive pulmonary disease

Lung Volume Definitions (Figure 9-1)

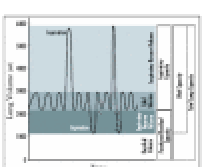


Figure 9-1

Illustration of respiratory excursions during: Normal (more...)

Vital capacity (VC): the greatest volume of air that can be exhaled from the lungs after maximum inspiration

Forced vital capacity (FVC): vital capacity measured with the subject exhaling as rapidly as possible

Total lung capacity (TLC): amount of gas within the lungs at the end of maximal inspiration

Tidal volume (TV): amount of gas moved in normal inspiratory effort

Functional residual capacity (FRC): amount of gas in the lungs at the end of normal expiration

Residual volume (RV): amount of gas in the lungs at the end of maximal expiration

Forced expiratory volume in one second (FEV1): amount of air expelled in the first second of FVC

Maximal mid expiratory flow rate (MMEF): average flow rate, between 25% to 50% of FVC

Maximal voluntary ventilation (MVV): the maximum volume of air exhaled in a 12-second period in liters per second

Maximal static inspiratory pressure (PI max): static pressure measured near RV after maximal expiration

Maximal static expiratory pressure (PE max): static pressure measured near TLC after maximal inspiration **Minute volume:** tidal volume × rate of breathing per minute

Other important definitions

Maximal Oxygen consumption

Expired gases during maximal exercise are collected and analyzed for oxygen content.

VO_2 max-volume of consumed O_2. Can be calculated using the Fick equation:

VO_2 max = (HR × SV) × AVO_2 difference (Note: SV=Stroke Volume; HR=Heart Rate)

- Individual VO_2 max is dependent on body weight, age (peak is reached at approximately 20 years of age), sex (values for females are approximately 70% those of males), and natural endowment (the most important)
- Training or the presence of pathological conditions can affect this potential
- Endurance exercise training increases VO_2 maximum, cardiac output, and physical work capacity of untrained healthy individuals

Classification of Respiratory Dysfunction

Obstructive Pulmonary Disease (OPD)—Intrinsic Lung Disease

- Characterized by increased airway resistance due to bronchospasm resulting in air trapping, low maximum midexpiratory flow rate, and normal to increased compliance
- Impaired blood oxygenation secondary to perfusion-ventilation mismatching. Gas exchange surface of the lung is decreased as a result of air trapping. With decreased diffusion, hypoxia is present with normal or increased ventilation
- Usually eucapnic or hypocapnic, despite severe hypoxia. Hypercapnia occurs in acute respiratory failure or end-stage disease
- Flattening of the diaphragm, with increased airway resistance, expiratory effort, respiratory muscle fatigue

Incidence: 10% to 40% of all Americans

Fifth leading cause of death in the United States

Fifty percent have limitations in activity level and 25% are limited to bed activities.

Caused by a combination of factors

- Genetic predisposition
- Respiratory infections
- Chemical inflammation (cigarette smoke, asbestos)

  Cigarette smoke is the most common cause of chronic bronchitis and emphysema.

Causes chronic inflammation and decreased mucociliary clearance

Smokers are more likely to die from COPD than nonsmokers (3.5 to 25 times more likely)

Smoking cessation is linked to improvement in the following:

- Improvement in symptoms
- Improvement in pulmonary function
- Decreased risk of respiratory tract infection
- Decreased reduction in rate of loss of FEV_1, (long term)

- Allergic processes (asthma)
- Metabolic deficiencies (Alpha 1-antitrypsin deficiency)

Causes of Chronic Obstructive Pulmonary Disease (COPD)

REMEMBER ALL FORMS OF COPD INVOLVE AIR TRAPPING

- Chronic bronchitis
- Emphysema
- Cystic fibrosis
- Asthma

Chronic Bronchitis

- Chronic mucous hypersecretion and respiratory infections as a result of tracheobronchial mucous gland enlargement.
- Production of >100 ml of sputum/day for >3 mo., for at least two consecutive years.

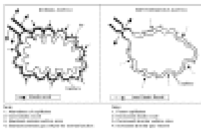


Figure 9-2

Normal Single Alveoli as Compared to Emphysematous (more...)

Emphysema (Figure 9-2)

- Distention of air spaces distal to the terminal nonrespiratory bronchioles with destruction of alveolar walls. This is secondary to the unimpeded action of neutrophil derived elastase
- Loss of lung recoil, excessive airway collapse on exhalation, and chronic airflow obstruction
- Decreased gas exchange surface of the lung, arterial PO_2 decrease
- Increase in pulmonary vascular resistance in the presence of pulmonary tissue hypoxia, leading to severe pulmonary artery hypertension and right ventricular failure

Cystic Fibrosis (CF)

- Generalized disease of the exocrine glands. Respiratory involvement is caused by failure to adequately remove secretions from the bronchioles, resulting in widespread bronchiolar obstruction and subsequent bronchiectasis, overinflation, and infection

- Aerobic exercise for cystic fibrosis patients helps to increased sputum expectoration. Patients have increased ciliary beat with improved mucous transport
- Aerobic exercise also improves exercise capacity, respiratory muscle endurance, and reduces airway resistance

Asthma

- Hypertrophy of bronchial muscle, mucosal edema, and infiltration with eosinophils and mononuclear cells, which cause changes in the basement membrane. Chronic bronchitis can result from asthma
- Episodic widespread narrowing of airways, and paroxysmal expiratory dyspnea at night

The magnitude of functional impairment in COPD patients can be assessed using Pulmonary Function Tests (PFTs)

- When the predicted FEV_1 is close to 4 liters, the patient should not have a history of significant exercise impairment
- Impairment develops when FEV_1 falls below 3 liters per second
- Between 2 to 3 liters the patient may experience mild exercise limitation (able to walk significant distances, but not at high speed)
- FEV_1 between 1 to 2 liters, the patient may experience moderate degree of exercise impairment (intermittent rest periods are required to walk significant distances or to climb stairs)
- FEV_1 < 1 liter, severe exercise impairment (very short distance ambulation)

Restrictive Pulmonary Disease—Mechanical Dysfunction

- Impaired lung ventilation as a result of mechanical dysfunction of the lungs or the chest wall, with respiratory muscle dysfunction. Stiffness of the chest wall or the lung tissue itself
- Hypercapnia precedes hypoxia, causing oxygenation abnormalities
- Almost all lung volumes are decreased

Causes of Restrictive Pulmonary Disease

- Chest Wall Disease (increased stiffness of chest wall)
  - Neuromuscular disease (e.g., Duchenne's muscular dystrophy)
  - Thoracic deformities (e.g., kyphoscoliosis)
  - If scoliotic angle is >90 degrees, patients have dyspnea; with >120 degrees patients present with hypoventilation and may have cor pulmonale
  - Ankylosing spondylitis (limited expansion of the chest wall)
  - Cervical spinal cord injury
- Intrinsic Lung Disease (increased stiffness of lung tissue)
  - Interstitial lung disease
  - Pleural disease
  - Surgical removal of lung tissue

  Note: Intrinsic lung disease can lead to pulmonary HTN, Right Ventricular Hypertrophy, and cor pulmonale

Examples of Chest Wall Disease

Neuromuscular Disease

- Weakness of respiratory muscles impairs the bellows activity of the chest wall, limiting ventilatory capacity and causing hypoventilation
- Respiratory muscle weakness causes impaired cough
- Examples: Duchenne's Muscular Dystrophy (DMD), Amyotrophic Lateral Sclerosis (ALS), Guillain-Barré Syndrome (GBS), Myasthenia Gravis (MG)

Duchenne's Muscular Dystrophy—sex-linked recessive

- Patients present with several respiratory complications including:
  - Atelectasis
  - Pneumonia
  - Chronic alveolar hypoventilation (CAH) with hypoxemia
  - Ventilatory failure
- About 73% of the patients die from severe carbon dioxide retention due to CAH
- DMD patients develop progressive scoliosis, which limits expansion of the chest wall and interferes with respiration

Amyotrophic Lateral Sclerosis

- Most common form of motor neuron disease that causes respiratory failure. Respiratory failure usually develops late in the disease and is the most common cause of death
- Respiratory muscle weakness causes ventilatory limitation and impaired cough

- If symptoms begin with limb weakness the disorder may progress to respiratory failure in 2–5 years

Thoracic Deformities (i.e., Kyphoscoliosis)

- Severe Kyphoscoliosis limits expansion of chest wall, reduces lung volumes, and compromises respiratory muscle efficiency
- If scoliotic angle is > 90 degrees, patients suffer dyspnea
- If scoliotic angle is > 120 degrees, patients suffer hypoventilation and cor pulmonale

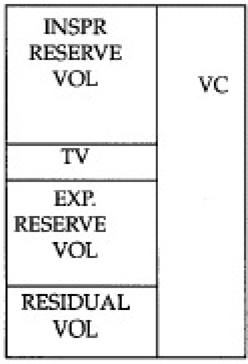
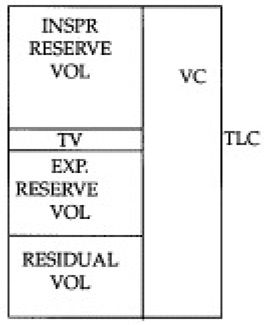
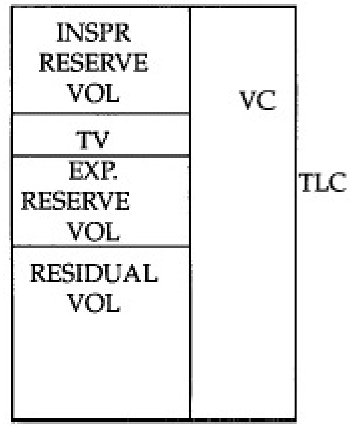
Ankylosing Spondylitis

- There is limited expansion of chest wall secondary to the ankylosing process.

Cervical Cord Injury

- Diaphragm is innervated by the phrenic nerve (at C3–C5)
- Spinal cord trauma sparing phrenic nerve innervation leaves diaphragm function intact and adequate ventilation can be sustained
- Although lower cervical and high thoracic cord lesions leave diaphragm function intact, they eliminate intercostal and abdominal muscle function, severely impairing cough mechanism
    - These patients have difficulty clearing secretions and ventilatory failure ensues
- Lesions above C3 eliminate all but accessory muscles of breath
- RV increases in C-spine injury

Pulmonary Function Evaluation

Normal lung volumes	Restrictive lung disease	Obstructive disease (COPD)
		
Normal changes noted with aging	**Key point:** **All volumes are decreased**	**Key point:** **Air trapping occurs**
• Decreases in VC MVV FEV_1 PO_2 • **FEV_1 decreased at a rate of 30cc/yr** • **No changes in** TLC PCO_2 • **Increases in** RV FRC	**Increased stiffness of chest wall** Ankylosing spondylitis Cervical SCI Neuromuscular disease including: DMD, ALS, MG, GBS Kyphoscoliosis **Increased stiffness of lung** Pulmonary edema Interstitial lung disease • **Decreases in** VC TLC RV FRC FVC MVV (decreases in severity) All volumes are decreased, this is distinctive for restrictive lung disease • FEV_1 is normal Note: RV increases in C-spine injury	**Limitation in expiration before air is fully expired** Emphysema Cystic fibrosis Asthma Chronic bronchitis **Flattening of the diaphragm** Increased: Airway resistance Expiratory effort Respiratory muscle fatigue Impaired gas exchange as a result of air trapping leads to resp. muscle fatigue. • **Decreases in:** VC FEV_1 MVV FVC • FEV_1 decreases 45 to 75 cc/yr. in COPD patients • **Increases in:** RV FRC TLC

Key: Refer to lung volume definitions for abbreviations.
Note: MVV decreases in most pathological states and aging.

Lung Volume Changes Present in Different Conditions

Tobacco use with normal aging

The rate of decrease in FEV_1 is approximately 30cc/year

- In smokers this can increase to 2–3 times this value. Smokers with an age < 35 years can increase lung function if they quit smoking. If patient is > 35 years of age and quits smoking, the rate of decline of lung function slows to the normal rate associated with aging

Cervical spinal cord injury

Cervical spinal cord injured patients have restrictive lung disease.

Pulmonary changes seen in C5 quadriplegics

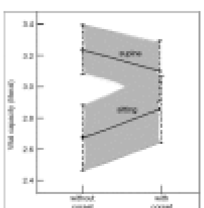


Figure 9-3

Comparison chart of actual vital capacities with and (more...)

- Diaphragm remains intact and the expiratory muscles are paralyzed

- Patients retain approximately 60% of their inspiratory capacity and ventilate well, but have weak cough and difficulty clearing secretions during respiratory infections
- All volumes are greatly reduced because of limited expansion of the chest wall
- Decreased TLC and VC
- Increased RV
- In patients with spinal cord injury, the abdominal contents may sag due to the greater strength of the diaphragm relative to the weakness of the abdominal wall muscles. This decreases diaphragmatic excursion and the vital capacity in the sitting position.
- The reduction in vital capacity is most severe in quadriplegics with cervical cord injury and during the acute injury period. Severity of reduction increases with higher level of injury. A study by Maloney reported that in the sitting position the use of an abdominal binder improved vital capacity. (Figure 9-3) (Maloney, 1979)
- The goal of pulmonary rehabilitation of the SCI patient is to:
    - Increase vital capacity
    - Maintain good pulmonary hygiene
    - Subjectively improve dyspnea as it relates to patient functional mobility and self-care
    - Reduce average number of hospital stays

Duchenne's muscular dystrophy

- Vital capacity plateaus between 1,100 and 2,800 ml between 10 and 15 years of age

- Independent of chest deformity, the vital capacity is then lost at a rate of 200 to 250 ml/year. The rate of loss tapers below 400 ml

No clear guidelines have been established for determining the point at which ventilatory support should be instituted in patients with Duchenne's muscular dystrophy, but various studies suggest the following:

- Dyspnea at rest
- Vital capacity, 45% predicted
- Maximal inspiratory pressure < 30% predicted
- Hypercapnia

Amyotrophic lateral sclerosis (ALS)

- Routine pulmonary function tests, including functional vital capacity, should be monitored closely in ALS
- The earliest changes noted are decreases in maximum inspiratory and expiratory muscle pressures, followed by reduced vital capacity and maximum breathing capacity
- When VC falls to 25 ml/kg of body weight, the ability to cough is impaired, increasing the risk of aspiration pneumonia
- Functional vital capacity is the best prognostic indicator for noninvasive ventilation in patients with ALS. Patients may lose VC at a rate 1,000 ml or more per year.
- Blood gases remain normal until the patient is near respiratory arrest (Bach 1996)

Rehabilitation of the Patient with Copd

1. Evaluate Nutritional State

- Respiratory muscle weakness is associated with metabolic deficits
- Decreased magnesium, calcium, potassium, and hypophosphatemia are associated with respiratory muscle weakness which is reversible after replacement
- Serum albumin level correlates better with hypoxia than spirometric values. Indicates visceral protein depletion and is a good predictor of rehabilitation potential
- Impaired nutritional status is associated with increased morbidity and mortality
    - More frequent infections: Impaired cell-mediated immunity
    - Decreased macrophage action in the pulmonary alveolar region
    - Increased bacterial adherence and colonization in upper and lower airways
    - Pseudomonas species commonly colonize in patients with poor nutrition
- Poor nutritional state affects lung repair mechanisms, including surfactant synthesis Can lead to generalized weakness, affecting respiratory function, and finally, hypercapnic respiratory failure, and problems with weaning from mechanical ventilation

2. Optimize Pharmacologic Treatments Prior to Starting the Rehabilitation Program

- For reversible bronchospasm
    - methylxanthines
    - Beta-2 agonists

- Anticholinergics—e.g., Atrovent® or Ipratropium®, can be used alone or added to a regimen, including beta-2 agonists. Block smooth muscle muscarinic receptors

- Theophylline—has a bronchodilator effect, decreases diaphragm fatigue; increases cardiac output, and improves mucociliary clearance in COPD
- Young patients with moderate asthma, who have tried B-2 agonists during exercise, may benefit from theophylline use
- Systemic steroid inhalers. Important to instruct inhaler use with the patients—>60% of COPD patients use them incorrectly
- Expectorants and mucolytics may be used for secretion management
- Increase fluid intake
- Low flow nasal supplemental O_2 can be used during therapy to reduce dyspnea and improve exercise performance, especially in patients with documented Coronary Artery Disease (CAD)
- O_2 is recommended for patients who desaturate during exercise. The most accepted guideline for O_2 use during exercise is if the patient exhibits an exercise induced SaO_2 below 90%
- Inspiratory phase or pulsed oxygen therapy, especially if provided transtracheally, decreases mucosal drying and discomfort. O_2 delivery is of 0.25 to 0.4 L/min. compared to 2–4 L/min. via face mask or nasal cannula
- Supplemental O_2 use is also recommended for patients with a continuous PO_2 of 55 to 60 mm Hg

Benefits of home oxygen use include:

1. Reduction in polycythemia

2. Improvement in pulmonary hypertension
3. Reduction of the perceived effort during exercise
4. Prolongation of life expectancy
5. Improvement in cognitive function
6. Reduction in hospital needs

- Cessation of smoking should be emphasized

3. Train in Controlled Breathing Techniques

- COPD patients exhibit an altered pattern of respiratory muscle use. The rib cage inspiratory muscles generate more pressure than the diaphragm. Expiratory muscles are also involved
- Controlled breathing techniques are used to reduce dyspnea, reduce the work of breathing, improve respiratory muscle function and pulmonary function parameters. Different types may be used in patients with obstructive pulmonary disease and restrictive disease

Techniques to Improve Pulmonary Function Parameters

Diaphragmatic breathing

- Used to reverse altered pattern of respiratory muscle recruitment in COPD patients.
- Patient uses the diaphragm, relaxes abdominal muscles during inspiration:

  Lying down, or at 15% to 25% head-down position, the patient places one hand over the thorax below the clavicle to stabilize the chest wall, and the other over the abdomen. The patient takes a deep breath, and expands the abdomen using the diaphragm. Feedback of abdominal and rib cage movement is obtained through hand placement as described previously

Benefits: increased tidal volume, decreased functional residual capacity, and increase in maximum oxygen uptake.

Segmental breathing

- Obstructions, such as tumors and mucous plugs, should be cleared prior to practicing this technique
- The patient is asked to inspire while the clinician applies pressure to the thoracic cage to resist respiratory excursion in a segment of the lung. As the clinician feels the local expansion, the hand resistance is decreased to allow inhalation. This facilitates the expansion of adjacent regions of the thoracic cavity that may have decreased ventilation

Techniques to Reduce Dyspnea and the Work of Breathing

Pursed-lip breathing

Patient inhales through the nose for a few seconds with the mouth closed, then exhales slowly for 4–6 seconds through pursed lips. By forming a wide, thin slit with the lips, the patient creates an obstruction to exhalation, slowing the velocity of exhalation and increasing mouth pressure. Expiration lasts 2–3 times as long as inspiration.

Benefits: Prevents air trapping due to small airway collapse during exhalation and promotes greater gas exchange in the alveoli. Increases tidal volume, reduces dyspnea and work of breathing in COPD patients. When added to diaphragmatic breathing, reduces the respiratory rate and can improve blood ABGs. (Bach, 1996)

4. Maintain an Adequate Airway Secretion Management Program

Airway clearance techniques (Controlled cough, Huffing)

Controlled cough

The patient assumes an upright sitting position, inhales deeply, holds the breath for several seconds, contracts the abdominal muscles ("bears down" increasing intrathoracic pressure), then opens the glottis and rapidly and forcefully exhales while contracting the abdominal muscles and leaning slightly forward.

This is repeated two or three times and followed by normal breaths for several minutes before attempting controlled cough.

Coughing generates high expulsive forces promoting secretion retention and may exacerbate air trapping; also leads to fatigue if the cough is weak.

Huffing

An alternative is huffing—following a deep inhalation, the patient attempts short, frequent exhalations by contracting the abdominal muscles and saying "ha, ha, ha".

The glottis remains open during huffing, and does not increase intrathoracic pressure, therefore, in COPD patients where airways can collapse. This is a more efficient means of secretion removal.

Secretion Mobilization Techniques (Postural Drainage, Percussion, Vibration)

Indications: Sputum production >30 ml/day

Aspiration

Atelectasis

Moderate sputum production in debilitated patients that are unable to raise their own secretions

Postural Drainage

Use gravity-assisted positioning to improve the flow of mucous secretions out of the airways. The affected lung segment is placed uppermost to increase oxygenation and drainage. Best done after awakening in the morning (secretions accumulate at night) and one to two hours after meals to avoid gastroesophageal reflux.

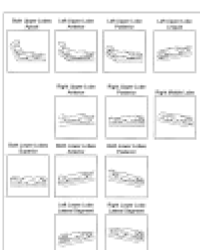


Figure 9-4

Postural Drainage Positions.

Positions for postural drainage (Figure 9-4)

A common position is the Trendelenburg or head-down posture, which can be done with the patient supine or prone, and different postural variations such as side lying or trunk bending.

To drain the upper lobes:

Patient is positioned sitting up

Exceptions:

- Right anterior segment—Patient supine
- Lingular—Patient in lateral decubital Trendelenburg
- Both posterior segments—Prone

To drain the right middle lobe and lower lobes:

Patient is positioned in the lateral decubital Trendelenburg

Exceptions:

- Superior segment of the lower lobe—Patient prone with buttocks elevated
- Posterior lower segment—Patient in prone Trendelenburg position with buttocks elevated
- Anterior segment—supine Trendelenburg

Precautions for postural drainage:

- Head-down—Trendelenburg
- Head-down tilt can range from 10° to 45°. COPD patients can tolerate up to 25° tilt.
- Avoid in: Pulmonary edema

CHF

HTN

Dyspnea

Abdominal problems—hiatal hernia, obesity, recent food ingestion, abdominal distention.

- Side-lying position

  Contraindications: Axillofemoral bypass graft

  Musculoskeletal pain—e.g., rib fractures

Postural Changes

Postural changes not only help with secretion mobilization but affect the work of breathing by changing the mechanical load on the respiratory muscles and the oxygen supply and consumption in these areas

1. Mechanical load—Pressure changes related to position

- Upright position—Abdominal contents remain in low position due to gravity; diaphragm can compress them easily
- Supine position—Redistributes abdominal contents. Diaphragm is in a slightly longer resting position further up into the thorax
- Head-down Trendelenburg—Diaphragm at its longer resting position, displaced by the weight of the abdominal contents into the thorax

With progression from the sitting to the Trendelenburg position, the diaphragmatic work of breathing is increased (the abdominal content load increases). The diaphragm will accommodate to the increase in load by increasing its contraction.

In obesity, the external load of the abdominal muscles may be greater than the muscle's capacity of contraction.

In neuromuscular disease, the muscles may not be able to generate tension against the abdominal content load, requiring changes in posture to assist in breathing. This is also valid for COPD patients where postural changes can affect the diaphragmatic mechanical response.

The weight of the pulmonary tissue also contributes to overall pressure on the most dependent alveoli. The dependent alveoli expand in size when changing from sitting to supine position, increasing ventilation at the base of the lung.

2. Blood flow—gravity dependent

Maximum flow is greatest at the most gravity dependent portions of the lung.

Figure 9-5

3 Zone Model of the Lung: The difference in blood (more...)

Figure 9-6

A:Perfusion of the lung is dependent on posture. (more...)

- Upright sitting—Ventilation/Perfusion (V/Q) mismatch, most effective at the middle lung fields Blood flow is more at the lower fields, while gas distribution is initially distributed through the apices. With inspiration, the fall in pressure will draw the greatest gas volume to the more dependent areas of the lung.
- In some patients changing from supine to prone positioning displaces the weight of the abdominal contents, reversing blood flow distribution to the anterior segments
    - The difference in blood flow distribution is based on the pressure affecting the capillaries: (Figure 9-5)
    - The pressure of the surrounding tissues can influence the resistance to blood flow through the capillaries
    - Blood flow depends on pulmonary artery pressure, alveolar pressure, and pulmonary venous pressure
- The perfusion of the lung is dependent on posture.
- The perfusion of the 3-zone model of the lung in the upright position is described below. (Figure 9-6A)

Zone 1: Ventilation occurs in excess of perfusion

Zone 2: Perfusion and ventilation are fairly equal

Zone 3: Is the most gravity dependent region of the lung where

Pulmonary Artery Pressure > Pulmonary Venous Pressure, which is > Alveolar Pressure

- When changing from a sitting to supine position, venous pressure increases in relation to the arterial pressure in dependent areas of the lung
- Blood flow is governed by the pulmonary arterial to venous difference
- When supine, the apical blood flow increases, but the bases remain virtually unchanged. There is an almost uniform blood flow throughout the lung. However, posterior segment flow will exceed anterior segment perfusion in this position.
- The normal ratio of ventilation/perfusion is 0.8. Areas of low ratios (perfusion > ventilation) act as a shunt. Areas of high ratios act as dead space.

Percussion

Mechanical percussor or a cupped hand can be used to rhythmically strike the thoracic cage during the entire respiratory cycle to loosen mucus within the lungs.

Delivered at a frequency of 5 Hz for 1 to 5 minutes or longer over the chest area desired to be drained.

Used on patients who are unable to mobilize and expectorate excess secretions, or to help expand areas of atelectasis.

Precautions:

Coagulation disorders

Anticoagulation therapy

Platelet count below 50,000

Fractured ribs

Flail chest

Severe osteoporosis

Contraindications:

Cardiovascular instability or failure

Aortic aneurysm

Increased intracranial pressure

Increased intraocular pressure

Cannot do percussion over a tumor

Vibration

Rapid shaking back and forth, (not downward) on the thorax over a segment of the lung, causing mucus to move toward the trachea. Applied to the thorax or airway to facilitate secretion elimination.

Can be applied manually or through the use of a mechanical vibrator.

Mechanically:

Vibrator can be used at frequencies ranging from 10–15 Hz up to 170 Hz

Most animal studies favor the 10–15 Hz frequency range

- Uses very little or no pressure on the thorax, and constitutes an alternative in cases where percussion is contraindicated
- The effects of mechanical chest percussion and vibration are frequency dependent
- Side effects of percussion and vibration can include increased obstruction to airflow in COPD patients

Preoperative and Postoperative Chest Therapy Program

Airway clearance and secretion mobilization techniques can be applied prior to surgery, and after the procedure

A preoperative and postoperative chest therapy program has the following advantages:

- Decreases the incidence of pneumonia
- Reduces the probability of developing postoperative atelectasis following thoracic and abdominal surgery

Pre-operative Program: The patient is taught standard postoperative treatment.

Deep breathing—Taught with the patient in the semi-Fowler position, in which the abdominal muscles are on slack. This allows greater diaphragmatic excursion. Most important modality of postoperative pulmonary hygiene.

Rolling—Allows patient mobility and minimizes trunk movement

Coughing—Decreased cough effectiveness can be a result of anesthesia

Two-stage cough, preceded by a deep diaphragmatic breath. First cough raises the secretions, second cough facilitates expectoration. May use splinting techniques for coughing, splinting the surgical incision with the use of a pillow or hands.

Huffing

Incentive spirometry—Provides the patient with visual feedback of the air volume inspired during a deep breath. Patients practice deep inspiration every hour in addition to their chest physical therapy sessions.

Post-operative Treatment

Most therapy programs start one day postoperatively. Diaphragmatic and segmental breathing are used to assist the ventilator.

Breathing exercises are provided.

Secretion management techniques include postural drainage, vibration and percussion. If the patient underwent abdominal surgery, one hand is placed between the incision site and the area to be percussed to decrease discomfort during the treatment. A pillow over the incision may also be used.

Vibration is preferred post operatively because it is less traumatic.

These treatments are contraindicated in patients with cardiac or hemodynamic instability or in cases of pneumothorax.

5. Provide Therapeutic Exercises

Used to improve respiratory muscle endurance, strength, and efficiency

Inspiratory resistive loading

- Uses an inspiratory muscle trainer. The patient inhales through its inspiratory orifices, which progressively decrease in size. Exhalation is performed without resistance
- Treatment is provided 1 to 2 times per day for approximately 15 to 30 minutes, with a rate of 10 to 20 breaths per minute. If the patient is able to tolerate 30-minute sessions, the intensity is increased by varying the orifice size. To increase endurance and orifice size that allows a longer exercise duration is chosen

Threshold inspiratory muscle training

A threshold loading device allows inspiration only after a predetermined mouth pressure is reached. Produces inspiratory resistance without relying on inspiratory flow rates. Benefits include increased ventilatory strength and endurance.

- Inspiratory muscle training has been proven beneficial in patients with cystic fibrosis, where FVC, TLC, and inspiratory muscle strength have been improved
- Inspiratory muscle training has appeared to prevent the weakness associated with steroid use in patients with this type of medication, as documented in one controlled study
- In patients with asthma, a reduction in asthma symptoms has been noted in addition to the documented improvement in the inspiratory muscle strength and endurance. A reduction in hospitalizations and emergency room visits, increase in school and work attendance, and reduction in medication use has also been found.

6. Instruct In Reconditioning Exercises

This type of exercise allows the patient to increase the ability to perform ADLs. The patient is engaged in a progressive program for which he or she is made responsible.

- Activities may include: aerobic conditioning (bicycle, pool exercise program, walking, stair climbing, calisthenics), ROM exercises (coordinated with diaphragmatic breathing) and upper extremity strengthening exercises
- A daily 12-minute walk with a record of time spent and distance achieved; and 15 minutes a day of inspiratory training is also advised. The 12-minute walk can be used to estimate exercise tolerance
- Pulse parameters include: increase of at least 20% to 30% during the activity with a return to baseline within 5 to 10 minutes after exercise
- The program is reevaluated weekly for 10 to 12 weeks, and modifications are made along with patient education
- Upper extremity exercise reduces the metabolic demand and increased ventilation associated with arm elevation, and dyspnea
- Unsupported upper extremity activities produced the most benefits, including decreased O_2consumption. These type of activities include self-care, lifting, reaching, carrying, and athletic activities
- All exercises should be performed to tolerance (symptom limited, subjective dyspnea)
- Should hold exercise for a HR >120 beats/minute
- Hold exercise if the patient has premature beats > 6/minute
- Hold exercise for oxygen saturation less than 92%. If the patient desaturates during exercise (<90%) may use

supplemental O_2 to enhance exercise performance and protect patients with CAD from dysrhythmia

Aerobic exercise in patients with cystic fibrosis may include:

- Exercises involving the trunk muscles such as sit-ups
- Swimming
- Jogging

- Patients with CF that participate in a structured running program show significant improvements in exercise capacity, respiratory muscle endurance, and a reduction in airway resistance. In addition, studies in children with CF have found increased sputum expectoration and an improvement in lung function after several weeks of strenuous regular aerobic exercise.

7. Muscle Rest Periods Should Be Added to the Exercise Program

Monitor hypercapnia as an indicator for the need of a rest period.

Ventilatory assistance provides relief to tired respiratory muscles decreasing their energy expenditure. Diaphragm rest can be achieved by assisting ventilation noninvasively with the use of body ventilators, mouthpiece, or nasal intermittent positive pressure ventilation (IPPV) or tracheostomy IPPV.

Although assisting ventilation can exacerbate air trapping in COPD patients, the benefits of resting respiratory muscles and decreasing oxygen consumption may outweigh this in importance

Two groups of COPD patients may benefit from ventilatory assistance

1. Medically and psychologically stable patients who require assistance around the clock, usually by tracheostomy route
2. Patients with need of nocturnal assistance only

   The nocturnal use of ventilators supports weak respiratory muscles
   Potential benefits include:

   - increased vital capacity, respiratory muscle strength and endurance, and decreased need for hospitalizations

Ventilatory assistance for COPD patients includes Positive Pressure Airway Ventilators and Negative Pressure Body Ventilators

Positive Pressure Airway Ventilation can be intermittent (IPPV), continuous (CPAP), or bilevel (BiPAP).

- Intermittent Positive Pressure Ventilation (IPPV) is the most common method of noninvasive support

  For mouthpiece IPPV, a mouthpiece is set up near the mouth, where the patient can easily grab it up to 6 to 8 times a minute for full ventilatory support. It is an ideal inspiratory muscle aid for day time use.

  For nocturnal use, nasal IPPV with CPAP mask (adequate seal is a problem) or mouthpiece IPPV with lip seal retention (seal is adequate, but patient cannot talk).

- Continuous Positive Airway Pressure ventilation (CPAP) may be used to help maintain patent airways in patients with sleep disordered breathing (obstructive sleep apnea). It produces splinting of the pharyngeal airway with positive pressure delivered through a nose mask. This method prevents desaturation.

- Bilevel positive airway pressure (BiPAP) permits independent adjustment of inspiratory (IPAP) and expiratory positive airway pressure (EPAP)

Negative Pressure Body Ventilators (NPBV) used during the day or night have provided the following benefits:

- Improved respiratory endurance with decrease in dyspnea
- Improved in quality of life, 12-minute walking distance
- Improved transdiaphragmatic pressure, and maximum inspiratory and expiratory pressures

NPBV ventilators assist respiratory muscles by creating atmospheric pressure around the thorax and abdomen

NPBV are also an alternative to intubation and tracheostomy for patients with acute respiratory failure (Bach 1998)

Rehabilitation of the Patient with Restrictive Lung Disease

Respiratory complications are the most common causes of death in advanced restrictive lung disease. The major cause of acute respiratory failure for these patients is impaired secretion clearance. Rehabilitation of the patient with restrictive lung disease is based on prevention of complications and assistance with secretion management.

1. Patient Education

- Prevents development of pneumonia, respiratory failure, and subsequent intubation and mechanical ventilation
- Importance of vaccinations should be stressed:

  Influenza, pneumococcal, and the possible use of antiviral agents

- Avoid crowded areas or exposure to respiratory tract pathogens
- Avoid sedatives at night and the risk of possible aspiration
- Avoid oxygen therapy. Central ventilatory drive can be suppressed, exacerbation of carbon dioxide can occur, and the risk of respiratory failure can be increased

  Studies indicate that O_2 therapy can prolong hypopneas and apneas by 33% during rapid eye movement (REM) and by 19% otherwise, even in patients with mild neuromuscular disease

- Avoid obesity and heavy meals
- Develop goals and start planning for the future

2. Keep A Good Nutritional State

- Respiratory muscle insufficiency can be exacerbated by hypokalemia
- Patients with Duchenne muscular dystrophy have decreased total body potassium, and commonly develop hypokalemia during acute illnesses

3. Instruct In Controlled Breathing Techniques

Glossopharyngeal breathing

- This is a noninvasive method to support ventilation, and it can be used in the event of ventilator equipment failure
- The patient takes a deep breath, and uses the pistoning action of the tongue and pharyngeal muscles to project air boluses into the lungs. Rhythmic opening and closing of the vocal cords occurs with each air bolus
- Each breath usually consists of 6 to 9 air boluses (or up to 65), with each bolus consisting of 30 to 150 ml of air (usually 60 to 200 ml.)
- Requires intact oropharyngeal muscle strength, and the patient should not be tracheostomized

Other uses of glossopharyngeal breathing

- Enables the patient to breathe without mechanical ventilation (up to 4 or more hours if the lungs are normal; if lungs are affected may only tolerate minutes). This time off the ventilator can be used to transfer to different types of aids
- Improves the volume of the voice and the rhythm of speech, allowing the patient to shout
- Helps prevent micro-atelectasis
- Allows the patient to take deeper breaths for more effective cough
- Improves or maintains pulmonary compliance

Use deep breathing and insufflations

- A program of air stacking hyperinflations 2 to 4 times a day with progressively increasing volumes helps prevent atelectasis and can benefit VC

- Regular maximal insufflations can be provided with manual resuscitators, portable ventilators, and mechanical insufflators-exsufflators. A mouthpiece may be used, or a nosepiece may be provided for larger volumes and when patients have weak oral muscles

4. Use Adequate Secretion-Management Techniques

Manually assisted cough

- The clinician's or the assisting person's heel of the hand or arm is placed at various sites along the anterior chest or abdomen to provide pressure, and is coordinated with the patient's coughing or expiratory effort
- Location of the areas of pressure:
    - Heimlich-type or abdominal thrust assist—Patient in the side-lying position, pressure is applied at the navel while pushing up the diaphragm
    - Costophrenic assist—Patient in any position, pressure applied to the costophrenic angles
    - Anterior chest compression assist—Patient lying on the side or the three-quarter supine position, pressure applied to the upper and lower anterior chest
    - Counter rotation assist—Pressure is applied to the pelvis or shoulder during inspiration followed by reversing the pressure direction to compress the thorax in all planes to facilitate expulsion

Suctioning

- Should be done in conjunction with other secretion clearing techniques, or when other techniques fail to remove secretions appropriately
- May lead to complications such as: airway membrane irritation, airway edema and wheezing, hypoxemia, bradycardia or tachycardia, hyper- and hypotension, increased intracranial pressure
- ONLY suction as you withdraw the catheter

Chest percussion, postural drainage may also be used.

Mechanical insufflator-exsufflator

- Most effective method of mechanical assistance for secretion clearance in paralyzed patients
- A deep inspiration (positive-pressure insufflation) is provided via a mask or through the tracheal tube, followed by rapid controlled suction (negative pressure exsufflation)
- Insufflation and exsufflation can be independently adjusted
- A desired decrease in pressure from insufflation to exsufflation is approximately 80 cm H_2O. This may be sustained for 2 to 3 seconds. The duration of exsufflation is longer than with other methods of assistance
- The decrease in pressure creates flows of approximately 7 to 11 L/second, helping to bring secretions to the upper airways where those can be suctioned
- It can be used in patients with scoliosis, dysphagia , impaired glottis function, and severe upper respiratory tract infections

- Allows continued ventilatory support without tracheostomy, and improves pulmonary volumes and SaO_2

5. Use Noninvasive Ventilation

Mechanically assisted ventilation provides respiratory muscle rest, decreasing the energy expenditure of the respiratory muscles.

Body ventilation—includes positive, negative/positive, and negative pressure ventilation

Positive pressure body ventilators

Provide positive pressure on the abdomen to assist diaphragmatic cephalad movement, promoting expiration. Passive inspiration occurs after removing the abdominal pressure.

- **Intermittent abdominal pressure ventilator (IAPV)**

  Examples: Pneumobelt, Exsufflation belt.

  - Abdominal corset containing a battery operated rubber air sac. It helps to create forced expiration by moving the diaphragm cephalad. When deflated, the diaphragm and the abdominal contents fall to resting position, resulting in passive inspiration
  - Worn from the xiphoid to above the pelvic arch. Cycles are 40% inspiration and 60% expiration. Approximately 250 to 1,200 ml of tidal volume can be provided

- Depends on gravity to assist inspiration, and is only effective when the patient is in the sitting position. A trunk angle of 75° from the horizontal is optimal but may be used with 45° in some cases
- This is the most useful mode of ventilation for wheelchair-bound patients with less than 1 hour of ventilator-free time during the day. Benefits also include liberating the mouth and hands for other activities
- Contraindicated in severe scoliosis and severe obesity. The patient should have a mobile abdomen
- Not useful in patients with decreased pulmonary compliance or increased airway resistance
- Most beneficial when used during the day in addition to nocturnal noninvasive IPPV. Inspiration may be supplemented by the use of available inspiratory muscles and or glossopharyngeal breathing

Negative and positive pressure body ventilator

Rocking bed

Rocks the patient along a vertical axis (15 to 30 degrees from the horizontal) utilizing the force of gravity to assist ventilation.

- When the head of the bed is up, inspiration is assisted by using gravity to pull the diaphragm down. This creates a negative pressure
- With the head down, exhalation assist is obtained. Cephalad movement of the abdominal contents pushes the diaphragm up with production of positive pressure
- It is used in patients with diaphragm paralysis with some accessory muscle function
- Benefits: prevents venous stasis, improves clearance of bronchial secretions, weight shifting prevents development of pressure ulcers, benefits bowel motility. It is easy to apply
- Disadvantages: heavy (not portable); not effective in patients with poor lung or chest wall compliance or in those with increased airway resistance

External oscillation ventilator (Hayek oscillator)

- Flexible chest enclosure (cuirass) with external oscillating ventilator
- Pressure change is developed between the cuirass and the chest wall. Negative pressure helps chest wall expansion and inspiration. Positive pressure causes chest compression and aides expiration
- Inspiratory pressure is always negative, but the expiratory pressure can be adjusted to positive, zero or subatmospheric, and negative
- By increasing the number of oscillations per minute it may be used for secretion clearance
- Patients with decreased lung compliance may use this type of assistance

Negative pressure ventilators

- Create intermittent extrathoracic pressure over the chest wall and abdomen, helping inspiration
- Main use is at night
- Provides rest to fatigued respiratory muscles
- Cor pulmonale may be prevented
- The patient may be able to function during the day without respiratory assistance
- Contraindicated in upper airway obstruction cases, where it may increase the frequency and severity of airway collapse and obstruction during the night. This may lead to obstructive apnea and desaturation
- Not useful in children < 3 years old due to recurrent pneumonias and atelectasis
- Not useful in patients with excessive airway secretions

Tank Ventilators (Emerson iron lung, LifeCare Porta-lung)

- Patient's entire body is enclosed in a chamber that produces intermittent subatmospheric pressure (Iron lung) or has a separate negative pressure generator (Porta-lung).
- Uses: Management of acute respiratory failure patients

  Ventilatory support in patients with decreased pulmonary compliance, significant scoliosis, and severe infections

Wrap Ventilators (Poncho, Pneumosuit)

- Plastic grid that covers abdomen and thorax. The wrap is sealed around the patient's wrists, neck and abdomen, or legs. A

negative pressure ventilator creates subatmospheric pressure under the grid and wrap
- Provides greater volumes
- Only used with nocturnal assisted ventilation

Uses: In patients with scoliosis or with sensory deficits

Disadvantages: Difficult to don, decreased access to the body by the medical personnel; difficult to turn the patient

Cuirass or Chest Shell Ventilators

- Firm shell that covers the chest and abdomen attached to a negative pressure ventilator that generates a sub-atmospheric pressure under the shell
- It is the only Negative Pressure Body Ventilator (NPBV) that can be used during the day for ventilatory support in the seated position

Advantages: The patient can get on and off without assistance

Disadvantages: In insensate patients can cause pressure ulcers around the area anterior to the axilla

Not effective in: Patients with complete respiratory paralysis

Impairment of pulmonary compliance

Patients with apnea

Patients with intrinsic lung disease

Severe back deformity

Morbid obesity

Management of Sleep Disordered Breathing

- Weight reduction can improve obstructive sleep apnea for obese patients
- Use of independently varying inspiratory positive airway pressure and expiratory positive airway pressure ventilators is very effective in patients with hypercapnia. The greater the difference between Inspiratory Positive Airway Pressure (IPAP) and Expiratory Positive Airway Pressure (EPAP), the greater the inspiratory muscle assistance
- To allow for an adequate fit, custom molded nasal interfaces may be provided
- Portable volume ventilators may be used in morbidly obese patients or patients who require high peak ventilators pressures
- An orthodontic splint that brings the mandible and tongue forward is helpful to maintain the hypopharynx open, as a long-term resource

Invasive Ventilatory Support

Invasive ventilation is used when noninvasive methods fail or are inadequate

Tracheal intubation or tracheostomy is indicated when the ABGs show $PaO_2 < 55$ mm Hg, or $PCO_2 > 50$ mm Hg.

COPD and restrictive lung disease patients may need intubation for other reasons:

- Noninvasive mechanical ventilator does not deliver O_2 adequately due to poor access to oral or nasal routes, i.e., orthopedic conditions (osteogenesis imperfecta, inadequate bite or mouthpiece entry), presence of NGT, or upper airway obstruction
- Severe intrinsic pulmonary disease requiring high Frequency of Inspired Oxygen (FiO_2)
- Inadequate oropharyngeal muscle strength
- Uncontrolled seizures or substance abuse
- Assisted peak cough flow < 160 L/minute
- When mechanical exsufflator is not available or contraindicated
- Unreliable access to assisted coughing
- Depressed cognitive status

Tracheal intubation with tracheostomy tube

The choice of tracheostomy tube depends upon the patient and the duration of use

Types of tracheostomy tubes

Metal (e.g. Jackson, Holinger)

- Cuffless, reusable tubes made of stainless steel or silver
- Cause less local irritation, and tissue reaction as compared to plastic
- May be left in place longer
- Help to keep the tracheostomy stoma open until the tracheostomy is not needed, in patients who breathe spontaneously

Plastic (e.g., Bivona, Shiley, Portex)

- Disposable, made of PVC, nylon, silicone, and Teflon
- Available single or double cannulated, with/without cuff

Cuff inflated versus uncuffed

Cuff-inflated Tracheostomy Tubes

- Provide a good air seal, protects lower airways from aspiration, and prevents air leaking through the upper airway. Creates the least positive pressure against the tracheal wall.
- Patients cannot speak with cuff-inflated tracheostomy tube.
- Two types: High pressure/low volume
    - Low pressure/high volume-conform more to the shape of the trachea and inflate more uniformly

Uncuffed Tracheal Tubes

- Some patients may be able to talk while on mechanical ventilation
- Should not be used in patients at risk for aspiration because it provides a loose fit
- Used after tracheostomy, when a looser fit of the tube on the stoma is needed, or to prevent subcutaneous emphysema
- Used in patients with increased secretions
- Should not be used in patients known to aspirate

Fenestrated versus nonfenestrated tubes

Fenestrated

This tracheostomy tube is good for patients who are able speak and require only intermittent ventilatory assistance.

- A continuous inner cannula can be used with an outer fenestrated cannula. The fenestrations should lie within the lumen of the trachea, and should not touch the tracheal wall (may develop granulation tissue around the holes and become clogged with secretions)
- The inner cannula can be attached to a positive pressure ventilator
- When the inner cannula is out and the tube is plugged, the patient can breath through the fenestrations and is able to phonate. This is possible because the air is directed though the upper respiratory tract

Nonfenestrated

- Used in patients who require continuous mechanical ventilation, or are unable to protect the airway during swallowing
- If the patient wants to talk, a one-way talking valve may be used on the tracheostomy tube. These devices open on inhalation and close during exhalation to produce phonation

Talking tubes (TT) versus speaking valves

Speaking Tracheostomy Tubes (e.g., Portex "Talk" tube, Bivona Fome-cuff with side-port airway connector, Communi-trach)

- Used in alert and motivated patients, who require an inflated cuff for ventilation and who have intact vocal cords and the ability to mouth words

- Airflow is through the glottis, supporting vocalization with airflow over the vocal cords while maintaining a closed system for ventilation
- Talking trachs supply pressurized gas mixtures through a cannula that travels through the wall of the talking tube, then enters the trachea through small holes above the inflated tube cuff so the patient can use the larynx to speak while the cuff is inflated (thus leaving mechanical ventilation undisturbed)
- The quality of speech is altered (e.g., lower pitch, coarser). Patients need to speak short sentences (because constant flow through the vocal cords can cause the voice to fade away)
- The patient requires some manual dexterity and minimal strength to occlude the external port

One-way speaking valves (e.g., Passy-Muir speaking valve, Olympic Trach-Talk)

- Passy-Muir valve is the only valve that has a biased, closed position; opens only on inspiration
- All the other valves are open at all times until they are actively closed during expiration (when enough force is placed)
- The air is directed into the trachea and up through the vocal cords, creating speech as air passes through the oral and nasal chambers
- Requires less work—opening and closing the valve is not needed
- Do not use the speaking valves with COPD patients because the lung has lost elasticity and the patient cannot force air out due to lack of lung compliance

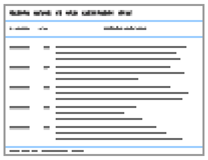


Table 9-1

Characteristics Of One-Way Speaking Valves

Guidelines for Decannulation

- Patients are ready for decannulation when they no longer need mechanical ventilation and can adequately clear airway secretions
- Patient should be evaluated for aspiration risk
- Should be able to cough secretions out of the tracheal tube
- Gradual cuff deflation allows weaning from cuffed to uncuffed TT. The cuffless TT is down sized to a smaller size and the patient evaluated for ability to cough secretions
- When the patient does not need excessive suctioning and the outer diameter of the TT is 8 mm., you may discontinue the TT or place a tracheal button temporarily

Tracheal buttons—extend only to the inner surface of the anterior tracheal wall without causing tracheal lumen obstruction. They are used when there is doubt about the success of the tracheostomy weaning. When plugged, the patient may breathe through the upper airway without resistance from the tracheostomy tube.

Another means of invasive ventilatory support is electrophrenic respiration with the use of a diaphragmatic pacer, used in patients with intact phrenic nerves and diaphragm. This is discussed in detail in the spinal cord injury chapter.

Cardiac Rehabilitation

Definition

Cardiac rehabilitation is the process by which persons with cardiovascular disease (including but not limited to patients with coronary heart disease) are restored to and maintained at their optimal physiological, psychological, social, vocational, and emotional status.

(American Association of Cardiovascular and Pulmonary Rehabilitation–AACPR)

Goals

The goal is to improve or maintain a good level of cardiovascular fitness, thereby returning the individual to a normal and productive life.

- For those able to return to work:
    1. Return to productive employment as soon as possible
    2. Improve and maintain as good cardiovascular fitness
- For those not able to return to work:
    1. Maintain as active a life as possible

2. Establish new areas of interest to improve quality of life

- Patient Education and Reduction of Coronary Risk Factors

Risk Factors for Coronary Artery Disease (CAD)	
Irreversible	**Reversible**
Age	Hypertension
Male gender	Cigarette Smoking
Family history of CAD	Hypercholesterolemia
Past history of CAD, PVD, CVA	Hypertriglyceridemia
	Diabetes Mellitus
	Obesity
	Sedentary lifestyle
	Type A personality

Epidemiology

- Cardiovascular disease is the leading cause of morbidity and mortality in the United States, accounting for almost 50% of all deaths
- Coronary Heart Disease (CHD) with its clinical manifestations of stable angina pectoris, unstable angina, acute myocardial

infarction (MI), and sudden death affects about 13.5 million Americans. Nearly 1.5 million Americans sustain myocardial infarction each year, of which almost 500,000 episodes are fatal

- 50% of MI occurs in people under age 65
- Annually, 1 million survivors of MI and more than 7 million patients with stable angina pectoris are candidates for cardiac rehabilitation, as are patients following coronary artery bypass graft (CABG) (309,000 patients in 1993), and a similar number will require angioplasty
- Although several million patients with CHD are candidates for cardiac rehabilitation services, only 11% to 20% have participated in cardiac rehab programs
- The mortality rate for CAD has fallen 47% since 1963; 30% of that decrease occurring from 1979–1989
- The Framingham study credits three factors as playing possible roles in this marked decrease in those with CAD. (Wilson et al., 1987)
    1. The modification of risk factors in those with CAD:
        - Lower cholesterol
        - Lower blood pressure
        - Better hypertension management
        - Reduced cigarette smoking
    2. Improved treatment methods
    3. Improved prevention

Phases of Cardiac Rehab

Phase I	During acute inpatient hospitalization
Phase II	Supervised ambulatory outpatient lasting 3 to 6 months
Phase III	Maintenance phase in which physical fitness and risk factor reduction are accomplished in a minimally supervised or unsupervised setting

Phase I (Inpatient Period)

This stage of rehabilitation can last from as short as one day to as long as 14 days for cardiovascular patients undergoing invasive procedures or suffering from acute events

Phase II (Immediate Outpatient Period)

This period is the convalescent stage following a hospital discharge. The length is partly determined by risk satisfaction and monitoring need. By definition this period is the most closely monitored phase of rehabilitation.

Phase III and Phase IV (Intermediate and Maintenance Periods)

The third stage of recovery is an extended outpatient period that may be divided into two components, intermediate and maintenance. The intermediate stage follows immediate out-patient cardiac rehabilitation, that is, when the patient is not intensely monitored and/or supervised but is still involved in regular endurance exercise training and lifestyle change. The transition to Phase IV varies according to the individual outcomes and medical needs.

Exercise Physiology

- Total Oxygen Consumption (VO_2) represents the oxygen consumption of the whole body, therefore it mainly represents the work of the peripheral skeletal muscles rather than myocardial muscles.
- Aerobic capacity (VO_2 max) is a term used to measure the work capacity of an individual. As the individual increases the workload (exercise) the VO_2 increases in a linear fashion until it levels off and reaches a plateau, despite further increases in the workload. This is the aerobic capacity of the individual. It is usually expressed in the millimeters of O_2 consumed per kilogram of body weight per minute.
- Myocardial Oxygen Consumption (MVO_2) is the actual oxygen consumption of the heart. It can be measured directly with cardiac catheterization. In a clinical setting, however, the rate pressure product (RPP) can be used since the heart rate and systolic blood pressure correlates well with the MVO_2.
- Double Product, also called Rate Pressure Product (RPP) refers to the work required of the heart, which closely parallels the systolic blood pressure (SBP) × heart rate (HR).
- Rate Pressure Product (RPP) = SBP × HR
- Cardiac Output (CO) = HR × stroke volume
- Metabolic equivalent (met): Resting metabolic unit—1 met = 3.5 ml O_2 consumed per kilogram of body weight per minute (Pashkow, 1993)

Outcomes of Cardiac Rehabilitation Services

The results of cardiac rehabilitation services, based on reports in the scientific literature. The most substantial benefits:

Improvement in Exercise Tolerance

Cardiac rehabilitation exercise training improves objective measures of exercise tolerance in both men and women, including elderly patients with CHD and heart failure.

Improvement in Symptoms

Cardiac rehabilitation exercise training decreases symptoms of angina pectoris in patients with CHD and decreases symptoms of heart failure in patients with left ventricular systolic dysfunction. Improvement in clinical measures of myocardial ischemia, as identified by ECG and nuclear cardiology techniques, following exercise rehabilitation.

Improvement in Blood Lipid Levels

Multifactorial cardiac rehabilitation in patients with CHD, including exercise training and education, results in improved lipid and lipoprotein levels. Exercise training as a sole intervention has not effected consistent improvement in lipid profiles. Optimal lipid management requires specifically directed dietary and, when medically indicated, pharmacological management as a component of multifactorial cardiac rehabilitation.

Reduction of Cigarette Smoking

Education, counseling, and behavioral intervention are beneficial for smoking cessation.

Improvement in Psychosocial Well-being and Stress Reduction

Improvement in psychological status and functioning, including measures of emotional stress and reduction of the Type A behavior pattern

Reduction in Mortality

Multifactorial cardiac rehabilitation service can reduce cardiovascular mortality in patients following myocardial infarction.

Safety

The safety of exercise is established by the very low rate of occurrence of myocardial infarction and cardiovascular complications during exercise training.

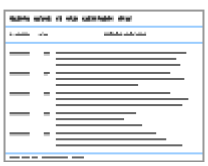


Table 9-2

Absolute Contraindications for Entry into Inpatient(more...)

Candidates for Inpatient Cardiac Rehabilitation

- Patients who have had myocardial infarction
- Coronary artery bypass surgery (CABG) or angioplasty patients

- Coronary patients with or without residual ischemia
- Heart failure and arrhythmias
- Patients with dilated cardiomyopathy
- A variety of patients with nonischemic heart disease
- Patients with concomitant pulmonary disease
- Patients who have received a pacemaker or an automatic implanted cardioverter-defibrillator
- Patients who have had heart-valve repair or replacement
- Aneurysm, aneurysm resection, organ transplantation

Modified from "Exercise Prescription for Cardiac Patients" In ACSM Guidelines for Exercise Testing and Prescription (5th ed) p.179, Philadelphia; Lea & Febiger, 1995, with permission.

Reprinted from Froehlicher VF. Exercise and the Heart. Clinical Concepts p.15, Year Book Medical Publishers, Inc. Chicago 1987., with permission.

Inpatient Versus Outpatient Rehabilitation

1. Inpatient program: Strictly supervised inpatient hospitalization lasting 1–2 weeks (phase I)
2. Structured outpatient program: Supervised ambulatory out-patient program lasting 3–6 months (phase II)
3. Maintenance program: Minimally supervised or unsupervised setting (phase III/IV)

Inpatient Program 7–14 Days

Acute Period—CCU (Coronary Care Unit):

- Activities of very low intensity (1–2 mets)

Passive ROM (1.5 mets)

Upper extremity ROM (1.7 mets)

Lower extremity ROM (2.0 mets)

Avoid: isometrics (increases heart rate), valsalva (promotes arrhythmia), raising the legs above the heart (can increase preload)

- Use protective chair posture—can reduce the cardiac output by 10%
- Bedside commode (3.6 mets) versus bedpan (4.7 mets)

The goal of an inpatient rehabilitation program is to provide a coordinated, multifaceted program designed to assist and direct patients and their families early in the recovery process following an acute cardiovascular event. The focus is on the medical care, physical activity, education, and psychological issues.

Subacute Period—Physical program can vary among institutions. Transfer from the CCU to either a telemetry unit or to the medical ward.

- Activities or exercises of intensity (3–4 mets)

Calisthenics of known energy cost

ROM exercise: intensity can be gradually increased by increasing the speed and/or duration; may add mild resistance or low (1–2 lbs.) weight

Early ambulation: starting in the room and then corridors of the ward, treadmill walking at 0% grade starting at 1 mph and gradually increasing to 1.5 mph, 2 mph, 2.5 mph as tolerated

- Energy cost of low grade ambulation:

  1 mph (slow stroll) = 1.5–2 mets

  2 mph (regular slow walk) = 2–3 mets

  Propelling wheelchair = 2–3 mets

- Serial progression of the self-care activities should parallel to the intensity of the monitored program, particularly with earlier hospital discharge

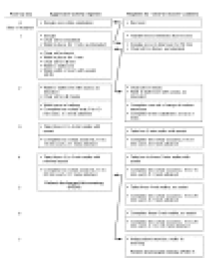


Figure 9-7

Activity regime for patients recovering from bypass (more...)

Bypass Surgery—Rehabilitation regime is differentiated into Aggressive vs. Slow to Recover Fig. 9-7).

Exercise Testing

Graded Exercise Testing

Graded exercise stress tests (GXTs) assess the patient's ability to tolerate increased physical stress. The GXT may be used for diagnostic, prognostic, and therapeutic application, with or without addition of radionuclide or echocardiography assessment.

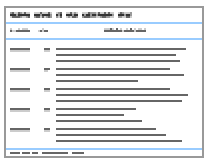


Table 9-7

Borg Scale of Rate Perceived Exertion

- The cardiac rehabilitation health professionals usually use GXTs as a functional rather than diagnostic tool
- GXTs also provide useful information when applied to risk stratification models. GXTs also allow the establishment of appropriate limits and guidelines for exercise therapy and the assessment of functional change over time
- Submaximal GXT is recommended for inpatients and prior to outpatient cardiac rehabilation programs
- GXTs may be submaximal or maximal relative to patient effort in addition to common indications for stopping the exercise test (see Contraindications to Exercise Testing). Endpoint criteria for submaximal testing may include heart rate limits, perceived exertion, and predetermined met levels

- Most of the activities of daily living in the home environment require less than 4 mets (*Guidelines for Cardiac Rehabilitation* 2nd ed. 1995)
- The American Heart Association suggests a heart rate limit of 140 and 130 beats per minute for patients not on beta-blocking agents, or Borg rating of perceived exertion (RPE) of 13–15 (Table 9-7), as additional end point criteria for low-level testing
- The low-level test provided sufficient data to permit most activities of daily living and serve as a baseline for ambulatory exercise therapy.
- The frequency of the test should be relative to the patients clinical course rather than a fixed schedule.

Exercise Testing Protocols

A variety of exercise testing protocols are available, whether the test is conducted using treadmill, cycle, or arm ergometer.

- Amputee patients use arm ergometer
- Treadmill testing provides a more common form of physiologic stress, (i.e., walking), in which subjects are more likely to attain a slightly higher VO_2 maximum and peak heart rate
- The cycle ergometer has the advantage of requiring less space and generally is less costly than the treadmill. Minimized movements of the arm and thorax facilitates better quality EKG recording and blood pressure monitoring. (*Guidelines for Cardiac Rehabilitation* 2nd ed. 1995)
- To perform a stress test in an above-knee amputee, an upper extremity ergometer is used

- Balke-Ware protocols that increase metabolic demands by 1 met per stage are appropriate for high-risk patients with functional capacity of less than 7 mets

Bruce Protocol

Metabolic demands of > 2 mets per stage may be appropriate for low to intermediate risk patients with functional capacity greater than 7 mets

The widely used Bruce Protocol of 2–3 mets per stage is useful with stable patients with functional capacities of 10 mets.

Pharmacological testing in debilitated patients for whom exercise testing cannot be performed, has been used to evaluate ischemia. The data from pharmacologic testing cannot be used in exercise presumption. (Froehlicher, 1987)

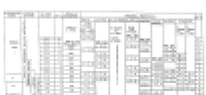


Figure 9-3

Approximate met Costs for Sample Exercise Testing (more...)

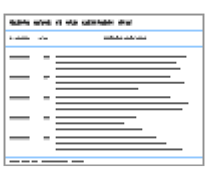


Table 9-4

Contraindications to Exercise Testing

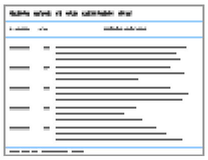


Table 9-5

Indications for Stopping an Exercise Test

Additional Criteria for Stopping Low-level/Hospital Discharge Exercise Test
1. Exercise heart rate > 130 bpm 2. Borg RPE (Rate perceived exertion) 15 (15 grade scale) (Table 9-7)
Suggested Endpoint Criteria for a Submaximal Exercise Progress Evaluation
1. Appearance of any criteria that indicate ending an exercise test 2. Exercise heart rate in excess of previous GTX peak heart rate RPE = Rate Perceived Exertion > 16 (Borg 15 grade scale) (Elaboration of Borg Scale—see below)

Modified from "Guidelines for Exercise Test Administration" ACSM Guidelines for Exercise Testing and Prescription (5th ed) p. 78 Philadelphia: Lea & Febiger, 1995, with permission and from Fletcher GF, Hartley, LH, Haskell WL, Pollock ML. "Exercise Standards, a Statement for Health Professionals from the American Heart Association" Circulation 1990; 82: 2297.

Structured Outpatient Program/Maintenance Program

Traditionally, outpatient cardiac rehabilitation has been divided into three phases:

Phase II (immediate)

Phase III (intermediate)

Phase IV (maintenance)

Phase II (immediate) will define the stage of cardiac rehabilitation that occurs immediately after discharge, in which higher levels of surveillance, monitoring of ECGs, and intensive risk factor modification occurs

Phase III (intermediate) is the period of rehabilitation when ECG monitoring occurs only if signs and symptoms warrant, although endurance training and risk factor modification continue

Phase IV (maintenance) is the stage in the program that is structured for patients who have plateaued in exercise endurance and achieved stable risk factor management

Physical Activity Program

Slow walk	2 mph	2–3 mets
Regular speed walk	3 mph	3–4 mets

Brisk walk	3–5 mph	4–5 mets
Very brisk walk	4 mph	5–6 mets
Sexual intercourse*		3–4 mets
Outdoor work—shovel snow, spade soil		7 mets
Jog, walk	5 mph	9 mets
Mop floor		2–4 mets
Push power lawn mower		4 mets

*** Note:** met level for sexual intercourse varies depending upon reference source. Tardif (1989) states that patients who reach 5–6 mets on stress-testing without ischemia or arrhythmias can, in all likelihood, resume their normal sexual activities without any risk.

The goal is the improvement of the cardiovascular capacity through physical exercise training whether in a minimally supervised or unsupervised setting.

Types of Physical Activities

- Begin with the last exercise program performed during the supervised cardiac exercise program
- Aerobically trained, clinically stable candidates may participate in resistive or circuit training. An overall lifestyle that includes proper diet, weight control, stress management, and smoking cessation should be maintained along with good physical fitness

- Active participation, within prescribed limits, in sport activity is encouraged

Sport Activity	Energy Cost in Mets
Golf	2–5
Bowling	4–5
Volleyball	3–4
Ping pong	3–6
Tennis	4–7
Roller-skating	5–6

From Goldman L., Hashimoto B., Cook EF., Loscalzo A. Comparative reproducibility and validity of systems for assessing cardiovascular functional class: advantages of a new specific activity scale. *Circulation 1981* Dec; 64(6): 1227–37 © American Heart Association, with permission.

Cardiac Functional Classification

Class I

- NY Heart Association—Patient's cardiac disease does not limit physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, dyspnea, or anginal pain.
- Specific Activity Scale

Patients can perform to completion any activity requiring > or = 7 mets:

Can carry 24 lbs. up 8 steps

Can carry objects that weigh 80 lbs.

Do outdoor work (shovel snow, spade soil)

Do recreational activities (skiing, basketball, squash, handball, jog at 5 mph)

Class II

- NY Heart Association—Patient's cardiac disease results in slight limitation on physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnea, or anginal pain.
- Specific Activity Scale

  Patient can perform to completion any activity requiring > or = 5 mets, but cannot and does not perform to completion of activities requiring > or = to 7 mets:

  Sexual intercourse to completion without interruption

  Garden, rake, weed

  Roller-skate, walk at 4 mph on level ground

Class III

- NY Heart Association—Patient's cardiac disease results in marked limitation of physical activity. They are comfortable at rest. Less than ordinary physical activity causes fatigue, palpitation, dyspnea, or anginal pain.

- Specific Activity Scale

  Patient can perform to completion any activity that requires > or = 2 mets and < 5 mets:

  Shower without interruption

  Strip and make bed

  Clean windows

  Walk 2.5 mph

  Bowl, golf

  Dress without stopping

Class IV

- NY Heart Association—Patient's cardiac disease results in inability to carry on any physical activity without discomfort. Symptoms of cardiac insufficiency or of the angina syndrome may be present even at rest. If any physical activity is undertaken, discomfort is increased.
- Specific Activity Scale

  Patient cannot or does not perform to completion activities requiring > or = 2 mets. Cannot carry out activities in Class I – III.

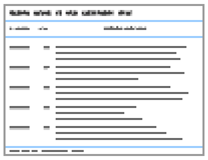


Table 9-6

Criteria for Determination of the Specific Activity(more...)

Contraindications to Exercise Testing

Exercise Prescription

Exercise for the cardiac patient should specify the type of exercise, the intensity, duration and frequency

Type of Exercise

Exercise for cardiovascular conditioning should be isotonic, rhythmic, and aerobic; should use large muscle masses and should not involve a large isometric component

- Sessions of exercise should incorporate aerobic activity such as walking/jogging, stationary cycling or water aerobics. Sessions should also incorporate warm-up and cool-down periods. In addition to aerobic activity, resistance exercise (using light weights) may be added on an individual basis
- Resistance exercises have been shown to be a safe and effective method for improving strength and cardiovascular endurance in low-risk patients. Surgical and myocardial infarction

patients should wait three to six weeks before beginning resistance training. Patients diagnosed with the following conditions should be excluded from resistance training:

CHF

Uncontrolled arrhythmias

Severe vascular disease

Uncontrolled hypertension

Systolic blood pressure > 160 mm/Hg, or diastolic blood pressure > 100 mm/Hg

Aerobic capacity less than 5 mets

- Results in increase in aerobic capacity of all muscle fibers exercised: both type I and type II fibers. Type I fibers continue to show approximately five times the aerobic capacity of type II fibers, as before exercise. (Flores and Zohman, 1993)

Exercise Intensity

- Exercise intensity is usually prescribed as some percentage of the maximum capacity obtained on exercise testing, (i.e., O_2 consumption, heart rate workload and/or degree of exertion)

O_2 Consumption

Threshold	40–50% max VO_2	60% max HR

Optimum	55–65% max VO_2	70% max HR
Ceiling	80–90% max VO_2	90% max HR

For the deconditioned cardiac patient, exercise even at 40% to 50% of max VO_2 will result in improvement

Target Heart Rate (THR)

Exercise intensity is based on target heart rate

Note: Clearance Heart Rate (HR) is the clinical maximum HR attained on stress test.

Target HR is the following range:

Clearance HR × .7 = beginning range

Clearance HR × .85 = end range

1. For the cardiac patient, 70% of the maximum HR attained on the exercise stress test
2. For the healthy patient, 70% to 85% of the predicted age-adjusted maximum HR: Average maximum = 220 − age
3. Karvonen formula—useful for those on chronic beta blockade or with abnormally high resting heart rate

    - The age-predicted formula of (220 − age = HR maximum) has the potential for over- and underestimating the actual exercise intensity and, therefore, places patients with heart disease at risk for exercise-induced cardiovascular complications

- The percent HR maximum reserve method of establishing a target HR uses the subject's potential heart-rate increase and assumes that the resting heart rate represents zero intensity. Thus, this method corrects for the nonzero value of resting heart rate associated with the percent HR maximum method

  Karvonen Method:

  THR range = 0.7 to 0.85 (HR maximum − resting HR) + resting HR

  Example: Patient is a 60 year old with a HR maximum of 160 and a resting HR of 60.

  (160 − 60) × 0.7 + 60 = 130 for lower limit

  (160 − 60) × 0.85 + 60 = 145 for upper limit

  Therefore, the target HR (THR) range = 130–145

  Age Predicted Method:

  THR range = 0.7 (220 – age) to 0.85 (220 – age)

  Example: same as previous patient

  (220 − 60) × 0.7 to (220 − 60) × 0.85

  THR range = 112–136

Perceived Exertion Method

1. Borg RPE scale (Table 9-7): A linear scale of rating from 6–20. This scale is a valid indication of physical exertion and correlates linearly

with HR, ventricular O_2 consumption, and lactate levels. The new exerciser can proceed with exercise to level 13, (somewhat hard) provided he has been given clearance to do so from his exercise stress test.

2. Conversational exercise level: Patient should be able to talk while exercising (Talk Test) The conversational level is of adequate intensity to induce a training effect but allows the exerciser to talk without becoming excessively out of breath while exercising at the same time

The American Heart Association suggest a heart rate limit of 130–140 beats per minute (b/min) for patients not on beta-blocking agents, or Borg rating of perceived exertion (RPE) of 13–15 as an additional point criteria for low-level testing

Duration and Frequency of Exercise

- The duration depends on the level of fitness of the individual and the intensity of the exercise
- The usual duration when exercise is at 70% of maximum heart rate is 20–30 minutes at conditioning level
- In the poorly conditioned individual, daily exercise as low as 3–5 minutes can bring about improvement. For the conditioned individual who prefers to exercise at higher intensities, duration of exercise may be reduced to 10–15 minutes

Format of an Exercise Session

- There should be a warm-up phase before and a cool-down phase after the period of training

- The warm-up period is usually at the lower intensity levels of exercise to be performed, gradually increasing to the prescribed intensity
- At the cool-down period, there is gradual reduction in exercise intensity to allow the gradual redistribution of blood from the extremities to other tissue and to prevent sudden reduction in venous return, thereby reducing the possibility of postexercise hypotension or even syncope. (*Guidelines for Cardiac Rehibilitation* 2nd ed. 1995)

Predicted Age-Adjusted Maximum Heart Rate

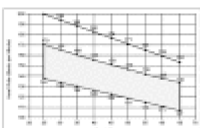


Figure 9-8

Exercise intensity based on the predicted age-adjusted (more...)

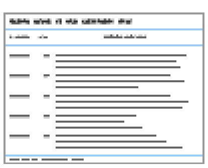


Table 9-8

Patient Rating Scales: Angina, Dyspnea, Intermittent(more...)

Cardiac Rehabilitation of Special Groups

Heart Transplantation

Pathophysiology

The heart is denervated (loss of vagal inhibition to the SA node), therefore, physiologic response is somewhat different then the one seen in a post-CABG patient.

1. High resting heart rate
2. Lower peak exercise heart rate
3. Postexercise recovery rate—slow return to resting level
    - At maximum effort—the work capacity, cardiac output, systolic BP, and the total O_2consumption (VO_2) are lower
    - Pretransplantation, rehabilitative strength training may enhance pre-operative and operative recovery
    - Five- and ten-year survival is about 82% to 74% respectively
    - Accelerated arthrosclerosis occurs following transplantation

Exercise Prescription

1. Heart-rate guidelines are not used
2. Intensity of exercise is based on the following:
    - Borg RPE scale 11 to 14 (Table 9-7)

- Percentage of maximum oxygen consumption or maximum workload performed on stress test
- Anaerobic threshold
- Duration frequency and types of exercise follow the same principles as those with other types of cardiac problems
- During exercise testing, ischemia is not presented as angina, therefore, ECG changes and other symptoms should be followed

Outcome

Generally favorable, typically reporting increased work output and improved exercise tolerance.

Most Common Major Physical Disabilities That Often Exist with Coronary Artery Disease

1. Amputation
2. Stroke

1. Amputee

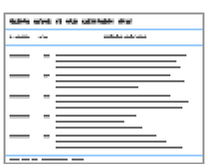


Table 9-9

Energy Cost of Ambulation for the Amputee

- The atherosclerotic vascular disease that affects the cardiovascular system also predisposes these patients to limb loss (dysvascular lower extremity amputation)
- Diabetes, in addition to causing accelerated atherosclerotic vascular disease, is a major risk factor for amputation. It has been estimated that 50% to 70% of all amputations are the result of complications of diabetes
- **Energy Cost of Ambulation for the Amputee** is based on percentage increase above the cost of normal ambulation at 3 mets (Table 9-9)

Amputee Exercise Test

- Pharmacological stress testing using dipyridamole—for patients that are unable to perform any exercise stress test
- Upper extremity cycle ergometer stress test—first determine the safety and ability of mobility
- Telemetry monitoring of ambulation training:
    1. Preprosthetic period
    2. Prosthetic period
    3. Postprosthetic period

2. Stroke

- Acute MI and acute stroke
- CABG and acute stroke
- According to the studies, as much as 77% of stroke patients have some form of co-existing cardiac disease
- Roth et al., showed the overall incidence of cardiac complications of 27% to 34% during inpatient rehabilitation. The incidence was higher in patients with known CAD

- Complications include:

  Hypertension

  Angina

  Myocardial infarction

  CHF

  Rhythm disturbances

Stroke Exercise Testing Modality

- Treadmill ambulation, if tolerated
- Stationary bicycle/ergometer modified for involved leg (ace wrap)
- Portable leg ergometers that allow for seating in a wheelchair or arm chair
- Arm ergometer modified for involved hand or using one-handed arm ergometer
- Telemetry monitoring of level surface ambulation or general conditioning classes

Hemiplegic Ambulation Compared to Normal Ambulation

- Speed—40% to 45% slower
- Energy cost—50% to 65% higher

Cardiovascular Conditioning of the Physically Impaired

Choice of Modalities Used for Assessment Depends on Number of Variables

- Upper extremity cycle ergometer—impaired lower extremity with normal upper extremity
- Air dyne arm—leg cycle ergometer for lower extremity weakness
- Hemiparetic—strap the affected extremity to foot pedal and/or handle bar
- Wheelchair bound—extra wide treadmills that can accommodate a wheelchair

Evaluation for Return to Employment

- Evaluation of the patient
- Evaluation of the job
- Matching the patient and the job
- Other conditions

Evaluation of the Patient

- Clinical Evaluation – Functional Cardiac Classification

  Class I—can perform 7 mets or greater

  Class II—can perform 5 mets or greater but not 7 mets

  Class III—can perform 2 mets or greater but not 5 mets

  Class IV—cannot perform 2 mets or greater

- Functional Exercise Stress Test

  Recommendations are made based on the maximum work load performance.

  > 7 mets—can return to work to most jobs in the USA

> 5, but < 7 mets—can return to sedentary job and household chores

3–4 mets—not suitable to return to employment (Flores and Zohman, 1998)

Evaluation of the Job

- Physical Task Performed

  Regular work or steady activity not to exceed endurance limits

  Peak activity – not to exceed prescribed maximum intensity

  Duration of each task

- Environmental Conditions at Areas of Work

  Temperature and humidity

  Hot and humid environment can increase the energy cost of work two to three times

  Air pollution

  High altitude

  Motivation and emotional attitude of patients

  Transportation to and from work

  Household chores after work

Matching the Patient and the Job

- Matching the cardiac functional class and/or result of stress test to the requirement of the job
- Simulated job monitoring
- Monitoring the actual tasks at the job site

Other Conditions

- Emotional Disorders
- Alcoholism
- Financial compensation (security gain)
- Retirement age
- Legal aspect
- Strenuous job requirements
- Patient motivation

American Heart Association Diet

Step 1 Diet

On this diet you should eat:

8% to 10% of the day's total calories form saturated fat

30% or less of the day's total calories from fat

Less than 300 mg of dietary cholesterol a day

Just enough calories to achieve and maintain a healthy weight

Step 2 Diet

If you do not lower your cholesterol enough on Step 1 diet or if you are at a high risk for heart disease or already have heart disease:

Less than 7% of the day's total calories from saturated fat

30% or less of the day's total calories from fat

Less than 200 mg of dietary cholesterol a day

Just enough calories to achieve and maintain a healthy weight

Benefits Derived from Long-Term Outpatient Cardiac Rehabilitation

- Increased oxygen extraction and wider AVO_2 difference. Skeletal muscles take up more oxygen from entering blood supply so that the venous return carries less back to the heart. The heart is thus doing less work to bring adequate oxygen to the tissue
- Improved utilization of oxygen by active muscles resulting from increased oxidative enzymes and number of mitochondria in the muscles
- Increased maximal oxygen consumption (VO_2 max) or aerobic capacity and physical work capacity
- The conditioned patient generally has a slower pulse and low blood pressure and lower rate pressure product; RPP = HR × SBP. Because RPP is a good indicator for the myocardial oxygen demand (MVO_2), the trained cardiac patients function at a lower myocardial oxygen demand. Thus, an angina patient may be below the angina threshold in daily life and is

able to perform certain activities without angina or silent ischemia

  - Decreased MVO_2 at rest and any submaximal workload
  - Increased cardiac output at maximal exercise; cardiac output remains the same at rest and at submaximal exercise
  - Cardiac output = Heart rate × stroke volume
  - Fick equation $VO_{2\,max}$ = (HR × stroke volume) × AVO_2 difference
  - Fick equation measures cardiac output × AVO_2 difference
  - Increased stroke volume at rest, submaximal and maximum work. This increase is due mostly to a combination of increased blood volume and prolonged diastolic filling time. (Flores and Zohman, 1993; Garden and Gillis, 1996)
  - Exercise training, combined with intensive dietary intervention, with and without lipid-lowering drugs results in regression or limitation of progression of angiographically documented coronary atherosclerosis
  - Cardiac rehabilitation exercise training decreases myocardial ischemia as measured by exercise, ECG, and radionuclide perfusion imaging
  - Cardiac rehabilitation exercise has no apparent effect on development of a coronary collateral

circulation and produces no consistent changes in cardiac hemodynamic measurement at cardiac catheterization

- Exercise training in patients with heart failure and decreased ventricular systolic function resulted in documented improvement in functional capacity. Data reinforces that the favorable training effects in these patients are due predominantly to adaptation in the peripheral circulation and skeletal muscles rather than adaptation in the cardiac musculature. (Cardiac Rehabilitation: Clinical Practice Guidelines Number 17; 1995)

Cancer Rehabilitation

Goals of Rehabilitation

The general rehabilitation goals of patients with cancer are similar to the general goals of patients with disabilities caused by other diseases.

Rehabilitation of the patient with cancer should begin when disability is anticipated, rather than after it has occurred. The number of individuals surviving five years or more with a history of cancer continues to grow. Survivors may face significant physical and psychosocial problems that affect their quality of life. Rehabilitation goals can be appropriately assessed according to the different stages of the disease manifestation.

In **preventative rehabilitation therapy** the goal is to achieve maximal function in patients considered to be cured or in remission.

Supportive rehabilitation therapy is geared for those patients whose cancer is progressing; the goals of supportive rehabilitation therapy include providing adaptive self-care equipment in an attempt to offset what can be a steady decline in a patient's functional skills. Range of motion and bed mobility can be taught to patients hospitalized or confined to bedrest to prevent the adverse effects of immobility.

In **palliative rehabilitation therapy** the goals are to improve or maintain comfort and function during the terminal stage of the disease

Through retrospective analysis and observation, over 1/2 of all cancer patients had some form of difficulty addressable by physical medicine and rehabilitation. Physical medicine problems occur for patients with all tumor types. In patients with Central Nervous System (CNS), breast, lung, head and neck tumors, physical medicine problems may occur in over 70%. Often, there is a gap in rehabilitative patient care which is changed dramatically by introducing a physiatrist to the oncologic management team.

There is little literature studying the effectiveness of cancer rehabilitation. In a study published by Marciniak (Garden, 1994), comprehensive inpatient rehabilitation resulted in significant functional gains in patients who suffered from cancer or its treatment, regardless of metastases or cancer type. Other studies report improvement in functional independence and productivity in patients suffering from brain injury after post acute outpatient rehabilitation. (Marciniak, 1996)

Epidemiology

- Approximately 1,268,000 new cases were expected to be diagnosed in 2001

- Since 1990 approximately 15 million new cancer cases have been diagnosed
- The National Cancer Institute estimates that approximately 8.4 million Americans alive today have a history of cancer
- The five-year relative survival rate for these cancers is approximately 60% (American Cancer Society, 2002)
- The most common rehabilitation problems for the patient with cancer were described in a study by Lehman including a sample of 805 patients: general weakness 35%, ADL deficits 30%, pain 30%, difficulty with ambulation 25%. Other problems include: speech, swallowing, respiratory, neurologic impairments, skin problems, nutritional deficiencies, lymphedema, skeletal disease, and psychological disorders. (Lehman, 1978)

Causes and Management of Disability Associated with Cancer

Immobility and Related Problems

These complications are pertinent in the cancer patient secondary to longer time periods of illness, treatment, and recovery

Immobility may predispose patients to

- Muscle Atrophy
- Decreased Endurance
- Joint Contractures
- Orthostatic Intolerance
- Protein Loss

- Deep Venous Thrombosis (DVT)
- Pulmonary Embolism (PE)
- Impaired Glucose Tolerance
- Pressure Ulcers
- Difficulty Voiding
- Constipation
- Compression Neuropathies
- Sleep Disturbance
- Depression
- Dysphagia

Traditional rehabilitation intervention may allow patients to maintain independence and AVOID complications associated with bedrest or immobility associated with prolonged hospitalization and medical treatment. Traditional rehabilitation intervention is geared toward countering the effects of bedrest and maximizing ADLs and functional mobility. The following apply:

- Patients may perform strengthening exercises using an elastic band or mild resistive exercises against gravity while in bed
- Bed mobility and frequent repositioning with cushions or pillows is employed to avoid skin breakdown and joint contractures
- Evaluation for an air mattress for those patients at high risk for the presence of skin breakdown
- AROM exercises are performed in the upper and lower extremity and are initiated whenever possible
- The tilt table may be used to facilitate weight bearing and gradual upright positioning in those patients with orthostatic hypotension
- OT and PT evaluations are necessary for equipment assessment, transfers, balance, ROM, bed mobility, and to maximize

independence in ADLs and ambulation, as well as for patient and family education

- A high index of suspicion for swallowing disorders should be maintained. Swallowing disorders may result from a variety of reasons in patients with cancer. Swallowing difficulty can be associated with cognitive impairment, central nervous system involvement, radiation treatment, and in patients with generalized deconditioning secondary to bedrest. When aspiration is suspected, a dysphagia evaluation is performed. A follow-up barium swallow may be required. If silent aspiration is suspected a barium swallow is necessary. Calorie counts should also be performed to ensure adequate nutrition. A gastrostomy may be required for long-term nutritional management in some patients
- A high index of suspicion should be maintained for metastatic involvement of the extremities and spine. Complaints of bony pain or discomfort warrant further investigation prior to initiating a skilled rehabilitation program. Extremities with possible tumor involvement should be positioned for non-weight bearing and ROM withheld until a workup is completed
- Patient-specific cardiac and pulmonary precautions should be ordered along with any skilled rehabilitation program (Lehman, 1978)

Central Nervous System Involvement in Cancer

Brain Tumors

Primary tumors in adults—gliomas comprise approximately 60% of all primary CNS tumors Cerebellar astrocytoma is the most common primary CNS solid tumors in young adults

Primary brain tumors in children

Brain tumors (17%) are only second to leukemia (25%) as the most prevalent malignancy in childhood.

- Cerebellar astrocytoma is the most common posterior fossa tumor in childhood and has the best prognosis
- Medulloblastoma is the next most common posterior fossa tumor in childhood and is the most prevalent brain tumor in children less than 7 years of age
- Brain stem gliomas are the third most frequent posterior fossa tumor in children

Brain metastasis

- Brain metastasis occurs in approximately 25% of patients with cancer

  Lungs, gastrointestinal, and urinary tract tumors account for most brain metastasis in men

  Breast, lung, gastrointestinal, and melanoma account for most brain metastasis in women

  Rehabilitation of patients with primary brain tumors or metastatic lesions is based on the location of the lesion and resultant neurological deficits. (Takakura et al., 1982)

Some of the presenting signs and symptoms of brain involvement are headaches, weakness, seizures, and cognitive impairment.

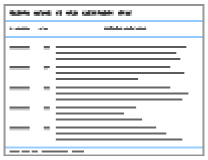


Table 9-10

Chemotherapeutic Agents and Side Effects

- Headaches are the most common symptom
- Weakness is the most common focal sign
- Seizures are frequently the first presenting sign of CNS involvement
- Contrast CT or MRI is the best diagnostic test
- Cognitive impairment, aphasia, dysarthria, and dysphagia require intervention through speech therapy, communicative evaluations, and dysphagia management. Deficits usually reflect the specific location of the lesion
- Chemotherapy and radiation may produce neurologic deficits including impaired visual perceptual skills, memory, and judgment. (Table 9-10)
- Rehabilitation efforts are also geared towards the prevention of skin pressure breakdown through effective bed mobility, progressive ambulation and mobilization, maximizing ADLs, safety and equipment assessment, and family training to improve the patient's quality of life

Spinal Cord Involvement

Tumors

Tumors of the spinal cord are rare. The majority of tumors are extradural (95%) and arise from the vertebral body. Approximately 70% of metastatic tumors are in the thoracic cord.

Radiation effects

Radiation therapy may also damage the spinal cord.

Induced Transient Myelopathy

The most common form of radiation damage is referred to as **induced transient myelopathy**. The syndrome develops after 1–30 months, with a peak onset at 4–6 months. There is transient demyelination of sensory neurons in the posterior column and lateral spinothalamic tract. Patients may report symmetrical paresthesias that radiate to the extremities. CT scans are normal and induced transient myelopathy usually resolves over a period of 1–9 months.

Delayed Radiation Myelopathy

Delayed radiation myelopathy is irreversible. The symptoms begin at 9–18 mo. after radiation treatment. Most cases occur within 30 mo. Symptoms begin with lower extremity paresthesias followed by bowel dysfunction and weakness. Midback pain may also be associated with radiation myelopathy. Resultant deficits depend on the level of neurological involvement. (Takakura et al., 1982)

Involvement of the Peripheral Nerve

- Peripheral neuropathy can occur due to tumor or from chemotherapeutic agents
- Peripheral polyneuropathy has been associated with lung cancer, multiple myeloma, and breast and colon cancer
    - Polyneuropathy is associated with inflammation and degeneration of the dorsal root ganglia

      Symptoms include gait dysfunction, paresthesias, sensory loss, with sparing of the face, bowel, and bladder

- EMG reveals fibrillation potentials, and polyphasic motor unit potential
- Subacute motor neuropathy usually occurs with lymphoma. Anterior horn cells degenerate, resulting in weakness; however, stabilization occurs with gradual improvement

Treatment

Treatment for involvement of the peripheral nervous system usually focuses on treatment of the underlying malignancy, treatment of pain or paresthesias, and supportive rehabilitation, intervention including orthotics, assistive and adaptive equipment, endurance, energy conservation, ROM, skin protection, and maintenance of strength.

Chemotherapy (<u>Table 9-10</u>)

- Chemotherapy can cause a peripheral or plexus neuropathy that is generally distal and symmetrical and is commonly associated with vincristine. Vincristine may also cause distal axonal degeneration, severe neuropathic pain, and in rare cases motor involvement may lead to quadriparesis

- Cisplatin and vincristine may also cause autonomic neuropathies resulting in fluctuating blood pressure or heart rate

Radiation

- Radiation may cause peripheral nerve damage due to effects on the nerve itself, or by involvement of the surrounding connective tissue and vascular supply. Symptoms include muscle atrophy, hyperesthesia, paresthesias, decreased strength and decreased range of motion
- Brachial Plexopathy is uncommon; however, it can occur as a result of radiation treatment or through direct tumor extension
    - Direct extension must be excluded especially in the presence of severe pain. In 90% of patients with direct tumor extension, pain is the initial symptom
    - In postradiation plexopathy, numbness and paresthesias are the usual initial symptom. The upper trunk is predominately involved with radiation plexitis and the lower trunk is predominately involved in 75% of patients with invasive tumor
    - One example of tumor extension is seen in Pancoast's syndrome, which is caused by a lesion in the superior pulmonary sulcus. It produces pain in the C8, T1, T2 nerves as well as Horner's syndrome. Patients report pain beginning in the shoulder and vertebral border

of the scapula. Radiation and surgery are the usual treatment. (O'Young et al., 1997)

  - Myokymia on EMG is pathognomonic of radiation plexitis
  - An MRI may be used to reveal invasive lesions but is not 100% sensitive in tumors resulting in a plexopathy. A CT reveals focal lesions in over 90% of the cases

Radiation Therapy Side Effects

- Cognitive effects of radiation are probably dose related. Young children are at higher risk than adults as myelin is developing rapidly and, therefore, is susceptible to CNS insult. It usually presents slowly, in delayed fashion, and can be difficult to distinguish from tumor recurrence.
- It is estimated in approximately 34% after radiation therapy, especially if combined with chemotherapy.
- Fibrosis and contractures—maintain patient on a prophylactic stretching program, and continue therapeutic stretching after surgery.
- Postradiation osteonecrosis—uncommon; may lead to pathologic fractures

Myopathy: Paraneoplastic Polymyositis and Dermatomyositis

- These are well-recognized syndromes that can be associated with malignancies of the breast and lung

- Rehabilitation treatment includes traditional rehabilitation, intervention, stretching, isometric exercises, assistive devices, energy conservation, bracing, as well as social and vocational counseling. Specific attention must be paid to avoid exercise to fatigue
    - Carcinomatous Myopathy—A syndrome seen in metastatic disease that is consistent with muscle necrosis and presents with proximal muscle weakness
    - Carcinomatous neuropathy affects peripheral nerves as well as muscle. Signs and symptoms include distal motor and sensory loss, proximal muscle weakness, decreased reflexes and sensation. It most often occurs with lung cancer. Type II muscle atrophy is present as well as a distal peripheral polyneuropathy. Rehabilitative measures focus on supportive intervention including adaptive equipment, orthosis and functional mobility
    - Chemotherapy-related myopathies, such as steroid myopathy, result from atrophy of type II muscle fibers in the proximal musculature
    - Isometrics may be used to improve muscle metabolism and enhance strength and recovery

Breast Cancer Rehabilitation

Lymphedema

Lymphedema is a frequent complication of breast cancer management and is manifested by upper extremity swelling associated with a sense of arm fullness. It usually develops over an extended period of time, postmastectomy or lumpectomy in up to one-third of women.

Lymphedema is a result of damage or blockage of the lymphatic system in which an accumulation of protein occurs in the interstitium. This changes the colloidal pressure and detracts fluid into the interstitial space.

Lymphedema is described in three grades:

Grade 1 Pitting edema that is reversed by elevation

Grade 2: Nonpitting edema. The skin may now become hardened secondary to the development of fibrotic tissue as a result of chronic excess protein in the interstitial spaces and deposition of adipose tissue. Appears as brawny edema unresponsive to elevation.

Grade 3: Swelling of the involved extremity described as lymphostatic elephantiasis. Cartilage-like.

Without intervention the limb enlargement progresses and continues, which may result in significant social, physical, and psychological disability.

Intervention focuses on prevention by not interfering with lymph outflow by constricting the arm, protecting the arm from infection, excess scarring, and avoidance of vasodilation from extreme heat exposure.

Treatment

Treatment involves elevation, retrograde massage or manual lymph drainage, isometric external compression garment.

- Compression therapy by sequential graded pumps has been shown to be effective in reabsorption of water form the interstitium into the venous capillaries. The downfall to this is that large protein molecules remain interstitial, continuing to change the colloidal pressure. If a pneumatic or graded pump is used, it must be used daily (2–6 hours) followed by placement of a compression garment to prevent re-accumulation of fluid. This must be done daily for the remainder of the patient's life
- Precautions should be taken when using a compression pump and its use should proceed after manual lymph drainage has been performed.

When initiating the compression pump, patients with cardiovascular compromise should be monitored closely for shortness of breath, increasing heart rate, fluctuation of blood pressure, or complaints of increasing pain

Caution should be taken in the presence of residual tumors

Pumping should be discontinued if edema increases above the pump's sleeve

Pumps should not be used in the presence of infection

Pumps are contraindicated in bilateral mastectomy patients because truncal edema may result

- When more than one lymphedematous area is involved there is no place for fluid resolution and other areas may become edematous
- Following mastectomy, immediate postoperative therapies can safely consist of hand pumping, hand and elbow ROM exercises, positioning techniques, postural exercises, and

shoulder ROM exercises to 40 degrees of flexion and abduction. Active assistive exercises can be initiated when the surgical drains have been removed.

- Additional management includes antibiotic treatment as needed for cellulitis or dermatolymphangitis.

Metastatic Bone Involvement

In Patients with Metastatic Bone Disease

- 75% have breast, lung or prostate cancer

  25% have renal, thyroid, or other cancer

  60% of all bone metastasis in males are secondary to prostate cancer, and approximately > 90% of patients with advanced prostate cancer will develop bone metastases

  50% to 85% of bone metastasis in females are secondary to breast cancer

- More than 50% of all patients with breast, lung, or prostate cancer will eventually develop bone metastasis. Skeletal metastasis arise through hematogenous spread. Bone is the third most common site for metastasis
- The most consistent symptom is pain, which is most severe at night or upon weight-bearing. In patients with spinal involvement, pain may be worse lying down and improves with sitting

- Metastatic Bone Disease causes pain, pathological fractures, neurologic injury, and functional disability. Pathological fractures occur in 10% to 30% of patients with bone lesions
- Skeletal metastases are rarely solitary. The metastasis usually involves the axial skeleton, proximal femur, and humerus. 70% of spinal metastases occur in the thoracic spine. 95% are extradural in origin and involve the vertebral body anterior to the spinal canal

Evaluation of Metastatic Bone Disease

- Bone scan is done usually at the time of diagnosis with correlation of involved areas on bone scan with X-rays. Most patients with high risk for conus medullaris involvement are followed serially with bone scans to detect bony involvement before physical manifestation is present.
- Complaints of pain warrant X-rays and a bone scan at any time during the disease
- If the clinician suspects metastatic involvement, the patient is placed non-weight bearing on the involved extremity until a full evaluation and work-up is completed.
- Bone scans usually pick up metastatic disease early. Up to one-third of patients with positive bone scans have no X-ray changes on plain films. If a patient complains of persistent back pain and radiographs are normal, an MRI is indicated. Not all lesions are painful. Bone scans are highly sensitive but not highly specific for tumor involvement. False negatives occur in the setting of bone destruction without ongoing repair or bone metabolism.

Involvement of the Upper Extremity

More than 90% of upper extremity metastases involve the humerus.

- In the upper extremity the majority of symptomatic lesions are from:
    1. Breast Cancer (Ca)
    2. Multiple Myeloma
    3. Renal Ca

Involvement of the Lower Extremity

Most metastases of the lower extremity involve the hip and femur.

- In the lower extremity the majority of symptomatic lesions are from:

HIP	FEMUR
Prostate Ca	Breast Ca
Breast Ca	Renal Ca
Lung Ca	Multiple Myeloma
Lymphoma	Prostate Ca

Note: It is possible to have a negative bone scan with positive X-rays (Any complaint of pain warrants a bone scan and plain film)

Treatment Once Bony Involvement is Identified

- Once metastatic bone disease is identified, treatment may consist of radiation, chemotherapy, immobilization, splinting, bracing, and/or surgical intervention. If an unstable lesion is identified or suspected a surgical opinion should be sought

Immobilization—Relieves pain and assists with prevention of pathological fractures. Different types of immobilization consist of:

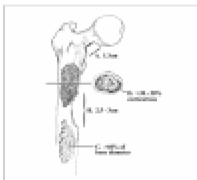
- Slings, splinting and/or concommitant weight-bearing precautions with appropriate assistive devices
- Spinal orthosis: halo bracing, cervical bracing, Philadelphia collars, sternal-occipital-mandibular immobilizers (SOMI brace)
- Body jackets such as the plastic molded body jackets (TLSO—thoracolumbar sacral orthosis) can be used for lesions involving the cervical and thoracic regions. A thoracic extension can connect a SOMI or Philadelphia collar to a custom molded body jacket

General Indications for Surgical Treatment of Metastatic Bone Disease

1. Intractable pain
2. Impending pathological fracture
3. Fracture has occurred

Surgical Intervention Is Indicated When:

	Size of Lesion	**Amount Cortex Involved**

	Size of Lesion	Amount Cortex Involved
• Upper Extremity	> 3 cm	> 50%
•  **Figure 9-9** Lytic lesions of the femur that meet criteria for (more...) Lower Extremity (Fig. 9-9)	> 2.5 cm	> 30% to 50%
• Femoral Neck	> 1.3 cm	> 1.3 cm in axial length
• Surgical intervention is indicated if greater than 50% to 60% of medullary cross-sectional diameter is involved • This determination is enhanced by CT sections		

(Gerber and Vargo, 1998)

- Lytic lesions are generally considered to be more prone to fracture than blastic lesions Lytic lesions typically occur in tumors of the:

- Breast
- Lung
- Kidney
- Thyroid
- Gastrointestinal tumors
- Neuroblastoma
- Lymphoma
- Melanoma

- Blastic lesions typically occur in prostate cancer

Involvement of the Axial Skeleton

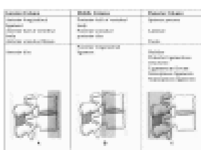


Figure 9-10

Three Column Model of Spine Stability. **A.**Anterior (more...)

- Requires evaluation of the extent of metastatic involvement of the vertebral column. An MRI will clearly delineate epidural vertebral involvement even if radiographs are normal
- Denis (1984) described stability of thoracic and lumbar injuries by utilizing the three-column model described as (Figure 9-10):
    - The spine is considered stable when only one column is involved except if it is the middle column

- The spine is considered unstable when two or more columns are involved or the middle column is severely involved
- The spine is also considered unstable if greater than 20 degrees of angulation is present
- These basic principles can be applied in evaluating metastatic bony involvement of the spine.

Primary Bone Tumors

- Metastatic cancer to the skeletal system is more common.
- Primary bone tumors consist of 0.5% of all cancers in the United States each year

Osteosarcomas

Most common primary malignant tumor of bone in children. (Garden and Gillis, 1996)

- Occur in adolescence and commonly involve the knee and proximal humerus
- Five-year survival has increased to nearly 80%
- **Tx.** Involves surgical intervention through amputation or limb salvage. Amputee and prosthetic management—see Prostheties and Orthotics

Multiple Myeloma

- Represents 10% to 25% of patients with pathologic fractures

- Characterized by presence of cells resembling plasma cells originating in the bone marrow. This abnormal protein leads to termination of cells
- Occurs most commonly in patients 50 to 70 year old males > female
- Usually progresses with gradual development of pain
- Frequently involves the lumbar spine, pelvis/sacrum, chest, skull, and ribs
- Often, there may be no early findings and pathologic fracture may be the presenting manifestation of the disease
- Course of disease is insidious and eventually leads to extensive marrow replacement, anemia, thrombocytopenia, and hemorrhages

Complications:

- Renal failure occurs as a result of tubular blockage by protein cast deposition
- Bone involvement on roentgenograph reveals diffuse osteoporosis and multiple lytic lesions
- Early films are often negative
- Bone scans may be normal. However, a skeletal survey may reveal diffuse "punched out" lytic lesions with black sclerotic borders
- Amyloid deposits may also infiltrate peripheral nerves causing a peripheral neuropathy

Treatment:

- Radiotherapy
- Chemotherapy

- Intramedullary fixation – may be difficult or impossible because of the remaining abnormal bone
- Rehabilitation concerns are similar to those for patients with metastatic involvement or other primary malignancies. A high index of suspicion is necessary to identify patients at risk for pathologic fractures

Rehabilitation of Patients with Oncologic Bone Disease

- Goals are to protect the affected bone and promote strength and mobility
- Intervention includes:
    - Crutches, walkers, wheelchairs, and required assistive devices and equipment to provide safety, joint protection, and function
    - Orthosis for patients with spinal instability—Corsets may be beneficial for pain relief and support when spinal stability is not a concern
    - Exercise programs should avoid high impact, torsion, and manual resistive exercises Isometric and nonresistive isotonic exercises: swimming, walking, or stationary biking are recommended within reason of each patient's current limitation. Exercises should improve endurance and strength
    - Fall prevention and proper body mechanics are also components of the rehabilitation program
    - Physical modalities used to relieve pain—soft tissue massage, electrical stimulation (TENS)

- Heat modalities, such as ultrasound, diathermy, microwave therapy—considered contraindicated in the presence of malignancy

Cancer Pain

Cancer pain may result from direct tumor invasion, chemotherapy, peripheral neuropathy, plexopathy, postsurgical pain or procedure related pain or can be unrelated to any of these factors. The World Health Organization (WHO) estimates that 25% of all cancer patients die with unrelieved pain. (World Health Organization 1990)

Pain can be effectively treated in 85% to 95% of patients with an integrated program of systemic, pharmacologic, and anticancer therapy.

Treatment:

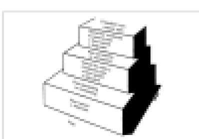


Figure 9-11

The Three-Step Analgesic Ladder.

The WHO has devised a 3-step analgesic ladder to outline the use of nonopioid analgesics, and adjuvant therapy for the treatment of progressively more severe pain. (Figure 9-11)

Nonopioid Analgesics

Nonopioid analgesics are limited by maximum dosages

This group is made up of anti-inflammatory agents (aspirin and NSAIDs) and acetaminophen

Opioid Analgesics

Opioid analgesics have no ceiling, and dosing is guided by pain relief and is limited by side effects

Breakthrough pain is treated with "rescue doses." Dosing should be titrated to a level in which pain is either controlled or side effects limit increasing the dosage of the medication. Oral administration is the first choice; however, there are options for transdermal, rectal, IV, and spinal (epidural and intrathecal) routes. These routes may be indicated in those patients in which oral administration is not possible. An example of opiate analgesic agents and their conversion follows. (Table 9-11)

Table 9-11

	Parenteral (mg)	**Oral (mg)**	**Conversion Factor (IV to po)**	**Duration (parenteral, oral) (hr)**
Narcotic Agonists				
Morphine	10	30	3.0	3–4
Controlled-released morphine				

	Parenteral (mg)	Oral (mg)	Conversion Factor (IV to po)	Duration (parenteral, oral) (hr)
MS Contin®	–	30	–	12
Roxanol SR®	–	30	–	8
Methadone (Dolophine®)	10	20	2.0	4–8
Hydromorphone (Dilaudid®)	1.5	7.5	5.0	2–3
Fentanyl	100µg	–	–	1
Meperidine (Demerol®)	75	300	4.0	2–3
Levorphanol (Levo-Dromoran®)	2	4	2.0	3–6
Codeine	130	200	1.5	3–4
Oxycodone (Roxicodone®, component of Percodan®, Tylox®)	–	30	–	3–5
Hydrocodone				

	Parenteral (mg)	Oral (mg)	Conversion Factor (IV to po)	Duration (parenteral, oral) (hr)
(Lortab®,				
component of Vicodin®)	–	200	–	3–5
Propoxyphene (Darvon®,				
component of Darvocet®)	–	200	–	3–6
Mixed Agonist-Antagonists				
Pentazocine (Talwin®)	60	180	3.0	2–4
Nalbuphine (Nubain®)	10	–	–	4–6
Butorphanol (Stadol®)	2	–	–	4–6

(Garden and Gillis, 1996)

Adjuvant Drugs

Adjuvant drugs include antidepressants, anticonvulsants, Benzodiazepines, neuroleptics, antihistamines, corticosteroids, calcitonin, psychostimulants, and alpha-blockers. These supplement analgesics or treat side effects.

Patients who do not respond to oral medications or have difficulty with limiting side effects may benefit from nerve blocks, TENS, or surgical intervention such as cordotomy, dorsal column stimulation implantation, or centra-spinal opioid injections.

Measuring and Assessing Pain

Appropriate analgesic therapy is based on the pain level of the patient and the dosage of current medications. Pain can be measured on a scale of 0–10. Pain ratings of 1–4 are considered mild pain. Pain levels of 5–6 are consistent with moderate pain, 7–10 is consistent with severe pain. (Wall, 1999)

Using the 3-Step Analgesic Ladder (WHO)

The 3-step analgesic ladder (WHO) should be used to determine the appropriate initiation of analgesic therapy.

Step 1

Patients not on any analgesic therapy with mild/moderate pain are treated with Step 1 nonopiate analgesics. Adjuvant pain medication may be added to facilitate better control or treat side effects or specific pain-related symptomatology. For example, Elavil® has been shown to help with neuropathic pain and insomnia.

Step 2

If a patient has mild to moderate pain despite taking a nonopioid analgesic, dose the nonopioid analgesic should be maximized and a Step-2 opioid analgesic should be added.

Step 3

Patients who have moderate to severe pain despite therapy with Step-2 opioids require an increase in the dose of opioid, or a change to Step-3 opioid when pain is severe. Patients who have mild-moderate pain while taking a Step-3 opioid should have the dose increased to an effective level. (Levy, 1996)

Oral and Parenteral Dose Equivalents of Opioid Analgesic Drugs Step-2 and Step-3 Opioid Analgesics

Table 9-12

Drug	**Dose**	
	Oral	***Parenteral***
Recommended for routine use		
Step 2 opioids		
Codeine	100 mg every 4 hr	50 mg every 4 hr
Dihydrocodeine	50–75 mg every	N/A

Drug	Dose	
	Oral	*Parenteral*
	4 hr	
Hydrocodone	15 mg every 4 hr	N/A
Oxycodone	7.5–10 mg every 4 hr	N/A
Step 3 opioids		
Morphine	15 mg every 4 hr	5 mg every 4 hr
Oxycodone	7.5–10 mg every 4 hr	N/A
Hydromorphone	4 mg every 4 hr	0.75–1.5 mg every 4 hr
Fentanyl	N/A	50 μg/hr every 72 hr
Not recommended for routine use		
Propoxyphene		N/A

Drug	Dose	
	Oral	*Parenteral*
Meperidine		50 mg every 2 hr
Methadone		5 mg every 6 hr
Levorphanol		1 mg every 6–8 hr
Oral opiates begin relief at 30 minutes and last approximately 4 hours		
IV opioids begin relief at 5 minutes an last 1–2 hours		

Treatment of Chronic Pain

- In order to treat chronic cancer pain, the physician should titrate around the clock medications with supplemental rescue doses for breakthrough pain. Rescue doses are based on one-sixth of the 24-hour total daily dose. Sustained-release medication should not be given PRN.

  Example: A patient taking 90 mg of controlled-release morphine every 12 hours would receive 30 mg of immediate-release morphine every 4 hours. The patient who is given Q 12 hour controlled-release morphine or oxycodone appreciates analgesic effect in 1 hour, peaks in 2–3 hours, and lasts for 12 hours when the next schedules dosing is due.

- Patients should be monitored closely, even daily, when beginning or changing an analgesic regimen. The optimal therapeutic regimen should be titrated based on unrelieved pain and side effects. It is important not to abruptly withdraw opioids. If pain has subsided, the dosage may be decreased 25 to 50% each day. If a patient has severe side effects from opioid use, 1 or 2 doses can be withheld and overall doses reduced by 50% to 75%. Avoidance of abrupt discontinuation is essential to prevent physical withdrawal syndrome.

Adequate pain relief, appropriate rehabilitative programs and goals, as well as supportive psychosocial intervention continue to play an important role in improving the quality of life in patients with cancer.

Management of Gastrointestinal Complications

Nutrition

- The nutritional status of the cancer patient can become compromised as a result of radiation and chemotherapy. Radiation therapy causes alteration in the saliva production and in taste. It may also cause nausea, cramps, and diarrhea
- Chemotherapy may lead to folic acid and vitamin K deficiency
- Patients who receive radiation therapy may benefit from a lactose-free, low-residue oral diet
- It is advisable to start parenteral nutrition when > 20% of body weight has been lost.

Emesis

- Effective anti-emetic management of the cancer patient includes the use of serotonin antagonists. One agent commonly used is ondansetron hydrochloride (Zofran®), which blocks 5-HT receptors. Advantages of specific serotonin antagonists over conventional anti-emetics include lack of extrapyramidal side effects, akathisia, and other CNS effects. Mild headache is, however, more common with these agents.

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