

and individual health factors (e.g., history of falls or risk factors for falling, signs of bleeding such as petechiae or bruises, abnormal coagulation levels or receiving anticoagulant medication, nutritional factors such as low albumin levels).

Individuals who have received a platelet transfusion must be monitored carefully during exercise. The elevated platelet levels are sustained for 1 to 4 days, depending on individual factors and platelet consumption during that time; results are variable and unpredictable. High fever and infection can cause increased platelet consumption.<sup>19a</sup> Anyone receiving platelet transfusions whose counts rise very little at 1 hour and who need more than once daily transfusion may be refractory to transfusion and require gentle strength training to avoid muscle or joint bleeds. It is best to wait until counts are safe before instituting resistive exercises for strength training.<sup>22a</sup>

There are centers where bone marrow transplant patients who have white blood cell counts below 1000/mm<sup>3</sup> for several weeks still exercise daily. Special satellite rehabilitation units are set up so the patients can exit their rooms with masks on, go down the hall with a nurse or therapist, and complete an exercise program on a stationary bicycle or treadmill. With airflow-controlled rooms, masks can be removed. The equipment is wiped down carefully between patients; only one patient is allowed in the room at a time.<sup>1\*</sup>

What constitutes aerobic versus subaerobic exercise must be determined on an individual basis based on intensity variations applied by the therapist to the patient. Simple exercises such as ankle pumps, deep breathing, quad sets, or raising arms overhead are usually considered nonaerobic. But for some patients these types of activities (even using a bed pan or sit to stand) might become aerobic given their deconditioned status.

Whenever blood counts are in the questionable range, two comments may be used to guide the rehabilitation staff while training patients who have questionable blood count levels performing bed transfers, mobilizing to and from the bathroom or commode, and so forth<sup>37a</sup>:

- Necessary activities of daily living (ADLs) are permitted
- Document any discussion with the physician and the decision made to proceed/continue with exercise

### Bone Marrow Aspiration

This test is performed to determine the cause of altered blood cell counts or to diagnose disease of the bone marrow. Aspiration is typically performed on the posterior superior iliac spine, or the tibia of children. This test can be quite painful and the affected area can remain so for a number of days. Care must be taken to avoid touching, placing gait belts, doing manual therapy, and so forth at this site.

## ERYTHROCYTE SEDIMENTATION RATE

Although not related to anemia, erythrocyte sedimentation rate (ESR, or sed rate) is clustered with other tests of RBCs and is presented in Table 40-7. Sed rate is a non-specific test for inflammatory disorders, associated with a number of potential disorders, including cancer, autoimmune diseases, and infection. As the name implies, the test is based on how quickly RBCs sink to the bottom of a test solution containing anticoagulated (unclootted) blood. Sed rate is increased in the sense that sedimentation is more rapid (more cells sink to the bottom) when they clump together.

Clumping is caused by a change in blood proteins brought on by inflammation, specifically the presence of globulins or fibrinogen in the blood. The more severe the inflammation, the faster the sedimentation rate or settling of cells and the higher the ESR; a significant increase in the ESR warrants closer investigation.

By itself, this test is nonspecific and therefore not diagnostic for any particular organ disease or injury, but the sed rate may be used as a screening test to rule out certain diseases or to monitor treatment in specific diseases such as juvenile rheumatoid arthritis, Kawasaki's disease, temporal arteritis, gout, and polymyalgia rheumatica. It can be used as an index of musculoskeletal dysfunction (e.g., tissue injury or inflammation or bone infections).

The ESR is a fairly reliable indicator of the course of disease and therefore may be used to monitor the course of a disease or response to treatment of certain diseases. In general, as the disease worsens, the ESR increases and as the disease improves, the ESR decreases. Sed rates also increase with age.<sup>79</sup>

## White Blood Cell Tests

Various disease states are characterized by their effects on specific types of WBCs. The elevation or depression of one type may be useful in diagnosis. A CBC can only demonstrate a normal level, a decreased level (*leukopenia*), or an elevated level (*leukocytosis*). Both the absolute numbers and the numbers of white cells relative to each other can be useful in diagnosis. An analysis of the relative numbers of different types of white cells is known as a white cell differential or *diff*.

### Neutrophils

Neutrophils normally represent the majority of WBCs present in the blood. A decreased number is termed *neutropenia* and an increased number is termed *neutrophilia*. Neutropenia is clinically significant as a risk factor for infection and may result from a large number of causes. In general, neutrophilia indicates the presence of infection.

Because of their appearance, neutrophils are also called polymorphonuclear (PMN) cells, or polys. Mature cells are segmented (called segs), whereas immature cells appear to be banded (bands). Bands make up about 3% to 5% of WBCs and circulate for about 6 hours before

they mature into segmented neutrophils. During counting, PMNs are divided into bands and segs. the presence of relatively high numbers of immature PMNs (bands) indicates rapid production of neutrophils in response to events such as acute infection, necrosis, or autoimmune disease. This may be referred to as a left shift because of the historic method of hand counting the white cell differential.

### Basophils and Eosinophils

Basophils are implicated in immune responses, particularly allergies. Eosinophils are elevated in the presence of certain disease states (*eosinophilia*), worm infestation, or allergies. Monocytes are blood cells that migrate into tissues as needed during injury or infection. After migration they are referred to as macrophages. The role of macrophages in immunity is described in Chapter 7.

### Lymphocytes

Lymphocytes are divided into cells capable of producing antibodies (B cells) and T cells that either produce direct injury to cells carrying foreign markers or assist in modulating B and T cell function (helper and suppressor T cells). Interest in lymphocyte subtypes is primarily a result of the effect of acquired immunodeficiency syndrome (AIDS) on particular subtypes of WBCs. In particular, helper T cells are vulnerable to human immunodeficiency virus (HIV) destruction, resulting in immunosuppression. The relative populations of each is determined by the presence of cell markers denoted CD2, CD4, CD8, and CD19. Cytotoxic (killer) T cells have CD2, helper T cells have CD4, suppressor T cells have CD8, and B cells are detected by CD19. Table 40-10 lists the relative numbers of these cells. The potential indications of varying proportions in the WBC differential are listed in Table 40-11.

## HEMOSTASIS

The process of hemostasis is described in Chapter 14. Both excessive and deficient hemostasis can lead to problems. Tests relevant to hemostasis involve platelets; enzymes required to initiate, promote, or inhibit hemostasis; binding of coagulation factors; and calcium. Platelets are discussed in the previous section on CBC. Lab values related to tests of coagulation listed in Table 40-12 are referred to as the coagulation profile. Coagulation tests are important to determine whether the person clots too easily or does not clot sufficiently to prevent excessive bleeding.

In addition to thrombocytopenia, disorders such as hemophilia, von Willebrand's disease, and bone marrow suppression may lead to excessive bleeding. Therefore knowledge of coagulation status should be known before therapy that might cause bleeding is performed. This might include resistance exercise, activities with risk of falling, or sharp debridement.

Patients/clients may be anticoagulated for a number of reasons. When individuals are treated for venous thrombosis, atrial fibrillation, or coronary artery disease, they may become overly anticoagulated and bleed excessively. Tests for coagulation involve the function of the

**Table 40-10** T- and B-Cell Lymphocyte Surface Markers

Surface Markers	Reference Value
T cells (CD2)	95%
Helper T cells (CD4)	24%-62%
Suppressor T cells (CD8)	19%-65%
B cells (CD19)	4%-25%
T helper/suppressor cell ratio	0.5-2.0

Data from Corbett JV: *Laboratory tests and diagnostics procedures*, ed 7, Upper Saddle River, NJ, 2007, Prentice-Hall Health.

**Table 40-11** Differential White Blood Cell Count Reference Values

Cell	Function	Absolute Count (Cells/mm <sup>3</sup> )	Count (%)	Differential
Neutrophils (PMNs, polys, segs, bands)	Segmented or mature neutrophils are white blood cells that constitute a defense against foreign substances (usually bacterial infection); band cells are immature neutrophils that may be called up from bone marrow to help fight severe (usually bacterial) infections.	1800-7000*	50-60	
Lymphocytes	Produce antibodies, fight tumor cells, and respond to viral infection.	1500-4000	30-40	
Monocytes	Clean up debris after neutrophils have done their job.	0-800	1-9	
Eosinophils	Attack parasites and play a role in asthma and allergy.	0-450	0-3	
Basophils	Release histamines during allergic reactions.	0-200	0-1	

PMNs, Neutrophils.

\*Level less than 500 is referred to as *nadir*; individuals undergoing chemotherapy may exhibit an absolute neutrophil count (ANC) nadir because of bone marrow suppression. Neutrophil levels bear watching because the danger of infection is related more to neutrophils or granulocytes than to the total white blood count.

**Table 40-12** Coagulation Profile (Platelets)

Age	Platelet Count (Cells/mm <sup>3</sup> )	INR	PT	aPTT
Premature infant	100,000-300,000			
Newborn	150,000-300,000			
Infant	200,000-475,000			
Child	150,000-400,000			
Adult, older	150,000-400,000	0.9-1.1 (ratio)*	12-15 sec	30-40 sec

INR, International normalized ratio; PT, prothrombin time; aPTT, activated partial thromboplastin time.

\*Minimal interlaboratory variability.

terminal products of the coagulation cascade. As discussed in Chapter 6, coagulation factors interact and result in the production of thrombin, which activates the reaction to convert fibrinogen to fibrin. The tests in the next section evaluate bleeding time, but because of how the test is performed, the tests indicate different mechanisms within the coagulation cascade.

## Tests of Coagulation

Several tests are related to coagulability. Historically prothrombin time (PT) and activated partial thromboplastin time (aPTT) have been used to determine coagulability either diagnostically or to monitor anticoagulant therapy of heparin and warfarin. These medications are used for many conditions including atrial fibrillation; prevention of acute myocardial infarction in people with peripheral arterial disease; prevention of stroke, recurrent MI, or death in people who have had an MI; valvular heart disease (native and prosthetic); and venous thromboembolism (prevention or treatment).<sup>27</sup>

The international normalized ratio (INR) was developed to provide results that would not vary between laboratories. Individuals receiving anticoagulation therapy because of coronary artery disease, cerebrovascular disease, atrial fibrillation, history of deep venous thrombosis (DVT), and other reasons are anticoagulated to an INR of 2 to 3.<sup>24</sup>

As INR increases, however, the risk of bleeding with minor trauma increases and excessive bleeding may occur during surgery, as well as spontaneous bleeding. Within the past few years, low-molecular-weight heparins (LMWHs) have been developed. In spite of the greater cost, use of LMWHs has increased because of the more rapid onset of anticoagulation, lower risk of platelet-dependent thrombus formation,<sup>41</sup> and less prolongation of bleeding time indices.<sup>23,48</sup>

Although INR has been an effective test for anticoagulation produced by heparin and warfarin, aPTT is used to monitor the effectiveness of LMWH. Therapeutic INR takes days to reach and is related more to extrinsic coagulation pathway, whereas LMWH can reduce coagulability much more rapidly as measured by aPTT, which is a better measure of intrinsic coagulation pathway.

## Components of Coagulation

Specific components of coagulation may be tested on suspicion of their involvement in bleeding disorders.

These include specific coagulation factors that produce hemophilia and von Willebrand's factor.

### Coagulation Factors

Individual factor testing may also be performed as a follow-up to abnormal PT, aPTT, or because of suspected coagulation factor deficiencies. Deficiencies may be genetic (e.g., hemophilia A and B) or acquired in conditions such as disseminated intravascular coagulation (DIC), liver disease, or vitamin K deficiency.<sup>1,8</sup>

Of particular interest are factors VIII and IX. Genetic defects in the production of these factors produce hemophilia A and B, respectively. Hemophilia B is also known as Christmas disease. Genetic defects may also occur in coagulation factors other than VIII and IX but are very rare. Abnormal aPTT (intrinsic pathway) with normal PT indicates involvement of factors VIII, IX, XI, or XII, whereas normal aPTT with prolonged PT (extrinsic pathway) suggests factor I, II, V, VII, or X.<sup>1</sup>

Von Willebrand's disease, a genetic disease like hemophilia, impairs coagulation because of a lack of effective von Willebrand factor, which along with factor VIII, is necessary for binding of platelets to collagen. D-Dimer testing is performed to detect specific types of fibrin degradation products as part of the diagnosis of DVT, DIC, and pulmonary embolism (PE).<sup>39</sup>

Antiphospholipid antibodies may be tested to determine why aPTT is prolonged or to determine the cause of recurrent miscarriages. Antibodies to phospholipids can affect platelet function resulting in thrombus formation in arteries or veins and can lead to thrombocytopenia, as well as causing premature labor, preeclampsia, and second and third trimester miscarriages.

Cardiolipins are the group of these antibodies most commonly involved. Another important member of this group is lupus coagulant. These antibodies are associated with autoimmune diseases, especially systemic lupus erythematosus (SLE).

### Inhibition of Coagulation

Proteins C and S regulate the rate of blood clot formation as part of a feedback loop on thrombin production. As thrombin increases, proteins C and S are produced more rapidly and slow the coagulation cascade, thereby preventing excessive coagulation. Problems with proteins C and S can be inherited or acquired. Lack of protein C or S leads to excessive or inappropriate clotting. The excess-

sive clotting usually occurs in veins, increasing the risk of PE, but can also occur in arteries.

#### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-6

##### **Coagulation Studies (see Table 40-12)**

Certain conditions require the person to be anticoagulated. These conditions include atrial fibrillation, DVT, PE, and placement of artificial heart valves. All the commonly used mechanical valves, as well as bioprosthetic valves, require anticoagulation for the duration of the person's life.<sup>77</sup>

*The physical therapist must be aware when a patient or client is taking an anticoagulant for one of these conditions so that treatment can be modified when there is an increased risk of hemorrhage. The coagulation profile will guide the therapist when determining the plan of care, especially concerning mobilizing individuals after a diagnosis of deep vein thrombosis.<sup>78</sup>*

When the PT is used, it is usually considered therapeutic (i.e., the blood is sufficiently anticoagulated) when the value is 1.5 to 2.5 times the reference range. Values more than 2.5 times the reference range may be a contraindication to physical or occupational therapy intervention because of the risk of spontaneous bleeding. However, this range is the common target range for people who have mechanical heart valves.

When the INR is used (e.g., for most cases of anticoagulation with warfarin therapy), there are two therapeutic ranges. One range is for the treatment of DVT, atrial fibrillation, and PE (INR of 2 to 3), and the other range is for mechanical heart valves (INR of 2.5 to 3.5).

Therapeutic anticoagulation requires an INR of 1.5 to 2.5. As INR increases above this value, the risk of bleeding with activity increases. If INR is high enough, bleeding without trauma or even spontaneous bleeding may occur. Patients may be overly anticoagulated as medication is adjusted, so the therapist should know the most recent value. INR values exceeding 3.0 may place the client at risk of hemarthrosis, requiring special attention during therapy and exercise.

In the absence of documentation of the individual's coagulation status, people with these conditions should be assumed to be more prone to bleeding and precautions should be taken to ensure that the client does not fall. In addition, sharp debridement is done more carefully, and excessive resistance is not used during activity.

#### **CARDIOVASCULAR LAB TESTS**

Cardiac biomarkers have gained increasing significance in clinical cardiology during the last 2 decades. Laboratory parameters play an important role as risk markers for coronary events in primary and secondary prevention, as well as in the diagnosis of acute myocardial infarction

and heart failure. Cardiac biomarkers are increasingly used routinely.

##### **Congestive Heart Failure**

Atrial natriuretic peptide (ANP) was discovered many years ago and found to provide a minor contribution to regulation of body fluid composition. As blood volume increases, stretching the atria, the amount of ANP released increases, causing the loss of sodium and water in the urine to correct excessive volume.

A similar peptide, brain natriuretic peptide (BNP), was discovered in the brain. Subsequent research showed that BNP was also found in the ventricles, but the name was retained. Testing for BNP has gained in popularity recently.

Like ANP, BNP is related to excessive blood volume. It is used for differential diagnosis of shortness of breath as BNP is elevated in congestive heart failure (CHF).<sup>26-37</sup> A value of greater than 100 pg/ml is considered positive for congestive heart failure. Levels of BNP rise with disease severity, so levels from 100 to 300 pg/ml generally indicate mild heart failure; 300 to 700 pg/ml indicates moderate heart failure; and levels above 700 pg/ml indicate severe heart failure.<sup>74</sup>

Research indicates that even smaller elevations of BNP above normal are indicative of impaired cardiac pump function<sup>26</sup> and future mortality.<sup>83</sup> The BNP test can also be used to monitor disease progression in individuals with left-sided heart failure.

##### **Risk Factors for Atherosclerotic Disease**

Although lipids are important molecules involved in the storage of energy, production of steroids and bile acids, and maintenance of cell membranes, inappropriate serum levels of certain lipids are associated with atherosclerotic vascular disease. Those of particular interest include triglycerides, cholesterol, and lipoproteins. Several blood lipids are used for screening in certain populations based on age or presence of risk factors.

##### **Lipids**

The lipids are fat substances that provide energy for metabolism and are necessary for the production of steroids, bile acids, and cellular membranes. The liver metabolizes cholesterol to its free form, which is then transported in the bloodstream by lipoproteins. Lipid measurements are important in detecting genetically determined disorders of lipid metabolism and in assessing the risk of coronary artery disease. In particular, elevation of low-density lipoprotein is a strong predictor of cardiovascular disease. A decreased level of high-density lipoprotein also increases the risk. In addition to genetic defects associated with elevated LDL, other factors, such as smoking, diet, certain drugs (oral contraceptives, sulfonamides, aspirin, and steroids), hypothyroidism, exercise, and alcohol, have been shown to alter one or both.

A full lipid profile includes total cholesterol, low-density lipoprotein (LDL), high-density lipoprotein

**Table 40-13** Full Lipid Profile

Lipids, Lipoprotein	Expected Values (mg/dl)	Comments
LDL	<70	Recommended if at very high risk for heart disease
	<100	Recommended if heart disease or diabetes is present
	<130	Recommended if two or more risk factors are present
	<160	Recommended if one or no risk factors present
	160-189	High
	>189	Very high
	<40	Desirable
HDL	>60	Represents a negative risk factor; the higher the number, the better
	<40	Desirable; recommended
Total cholesterol	<200	Borderline high; moderate risk
	200-239	Higher risk
Triglycerides	>240	Recommended
	<150	Desirable
	<100	Moderate risk
	150-199	High risk
	200-499	Very high risk
	>499	
	>1000	At risk for pancreatitis

LDL, Low-density lipoprotein; HDL, high-density lipoprotein.

Risk factors include cigarette smoking, male older than 45 years old, female older than 55 years old, low HDL (less than 40 mg/dl), hypertension, family history of premature heart disease.<sup>14</sup>

Data from Executive Summary of the Third Report of The National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III), JAMA 285(19):2486-2497, 2001.

(HDL), and triglycerides (Table 40-13). The tests may also be used to assess the need for and the efficacy of treatment.

For screening purposes, total cholesterol may be used. Unlike HDL, LDL, and triglycerides, total cholesterol does not need to be measured after fasting. Approximately 75% of cholesterol is bound to LDL and 25% to HDL. LDL (commonly referred to as "lousy" or "bad" cholesterol) transports excessive amounts of cholesterol because of genetic defects in LDL metabolism, whereas HDL "happy" or "good" cholesterol) is associated with removing excess cholesterol from the blood.

Triglycerides are a component of fat and are converted between glycerol, free fatty acids, and monoglycerides within the liver and adipose tissue as the need to either store or release energy arises. For example, the liver reconverts glycerol, fatty acids, and monoglycerides in adipose tissue to triglycerides when the body requires an additional source of energy.

Elevated serum triglyceride will usually occur in conjunction with elevated cholesterol and is a risk factor for atherosclerotic disease. Because cholesterol and triglycerides can vary independently, measurement of both values is more meaningful than the measurement of either substance alone. Elevated levels of triglyceride usually necessitate treatment with lipid-lowering medications. Poor glycemic control can also elevate triglycerides. A very high level of triglycerides (1000 mg/dl) is also a risk factor for pancreatitis.<sup>1</sup> Reference values for the lipid profile are given in Table 40-13.<sup>14</sup>

### Homocysteine

Other cardiac markers include homocysteine and C-reactive protein (CRP), which are both risk factors and cardiac markers. Homocysteine is a naturally occurring amino acid in the blood produced by the breakdown of various proteins in the body. It is related to free radicals, which

may be involved in the oxidation of LDL and plaque formation in arteries. Homocysteine levels increase with age; high levels have a significant effect in accelerating the aging process of the arteries caused by atherosclerosis.

Homocysteine is also linked to the development of early arterial changes characteristic of development of Alzheimer's disease, hypertension,<sup>87</sup> and the risk of stroke.<sup>86</sup> Lowering serum homocysteine by folic acid and B vitamin supplementation may retard the atherosclerotic process and reduce the number of heart attacks, stroke, and peripheral artery disease,<sup>33</sup> although this has not been conclusively proved.<sup>7,16</sup>

An elevated homocysteine level is also an independent risk factor for osteoporotic fractures in older adults. The magnitude of the effect of homocysteine level on fracture risk is similar to its observed effect on the risk of cardiovascular disease and dementia.<sup>18,82</sup>

The exact mechanism for this phenomenon is not clear, but scientists suspect homocysteine interferes with collagen synthesis since homocysteine and vitamin B6 are both regulatory factors of collagen crosslinking. As with heart disease, taking supplemental folic acid and other B vitamins may lower homocysteine levels and reduce the risk of fractures.

### C-Reactive Protein

CRP is produced by the liver in response to the presence of inflammation anywhere in the body. Several recent studies indicate a role of systemic inflammation in the pathogenesis of atherosclerosis and in particular an association with high-sensitivity CRP (hs-CRP). CRP is an indicator of systemic inflammation<sup>88</sup> and may be directly involved in the atherothrombotic process itself.<sup>65</sup>

Clinically, levels of hs-CRP above 3.0 mg/L indicate elevated risk for MI and stroke, even among apparently healthy individuals with low-to-normal lipid levels.<sup>50</sup> Elevated CRP is an independent predictor of future car-

**Table 40-14** Homocysteine and High-Sensitivity C-Reactive Protein

Homocysteine	5-15 µmol/L: Normal 16-100: Mild hyperhomocysteinemia >100: Severe hyperhomocysteinemia
hs-CRP	<1.0 mg/L: Low risk 1.0-3.0 mg/L: Average risk >3.0 mg/L: High risk

Data from Bortolotto LA, Safar ME, Billaud E, et al. Plasma homocysteine, aortic stiffness, and renal function in hypertensive patients, *Hypertension* 34(4 Pt 2):837-842, 2007; American Association for Clinical Chemistry (AACC): Lab tests online. Available online at <http://www.labtestsonline.org/>. Accessed August 30, 2007.

CRP, C-reactive protein.

diovascular events that also predicts the risk of hypertension, diabetes, and restenosis after angioplasty.<sup>28,66</sup> Values for these tests are listed in Table 40-14.

Half of all heart attacks and strokes in the United States occur in people with normal cholesterol levels, and 20% of all cardiac-related events occur in people with no major risk factors. People with low LDL and high CRP have more cardiovascular events than people with high LDL and low CRP. Using hs-CRP along with traditional methods of measuring risk may help prevent morbidity and mortality associated with vascular disease.<sup>65</sup>

CRP is associated with elevated blood sugar and triglycerides, poor diet, and sedentary lifestyle. Genetic factors may also play a significant role in CRP levels. Although the 2007 American Heart Association Guidelines for Cardiovascular Disease Prevention advise physicians to consider family history of heart attack before age 60 years but not CRP values, some independent researchers are including CRP in the development of risk scores (e.g., Reynolds Risk score).<sup>67</sup>

CRP levels are also measured in secondary prevention (individuals already diagnosed at high risk for coronary events) toward dual-goal therapy of LDL reduction and reduction of CRP levels, since CRP levels correlate with progression of atherosclerosis and clinical outcomes in individuals with coronary artery disease who are treated with statins. This reflects a change from previous policies in which it was assumed CRP levels did not provide additional information for at-risk individuals.<sup>51,64</sup>

Although not a part of this section on cardiac risk factors, elevated levels of CRP have been identified as a predictive factor in HIV disease progression, independent of CD4 T cell count and HIV ribonucleic acid (RNA) level. Levels of CRP above 2.3 mg/L may signal faster progression of HIV to AIDS and may provide additional prognostic information.<sup>40</sup>

#### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-7

##### C-Reactive Protein

High CRP levels have been observed in individuals who are physically inactive, smoke, and demonstrate abdominal obesity, which are all additional risk factors for cardiovascular disease.<sup>61</sup> Exercise is a primary inter-

vention for cardiovascular disease, and the effect of exercise on CRP has been reported by several groups. Results show that aerobic exercise with weight reduction disproportionately lowered CRP levels in apparently healthy but overweight women.<sup>53</sup> In another study of highly fit and moderately fit men, CRP was 76% lower at baseline in the highly fit group.<sup>62</sup>

Animal studies using swimming training 3 times weekly for 12 weeks has also been associated with improved levels of CRP.<sup>81</sup> However, one metaanalysis of randomized controlled trials of aerobic exercise did not show a reduction in CRP levels in adults but did demonstrate improved body composition and physical fitness.<sup>34</sup>

## Cardiac Enzymes and Markers

Enzymes catalyze the chemical reactions that cells need to stay alive, but the enzymes are not destroyed in the reaction and remain in the cell. Normally, these enzymes do not leak into the bloodstream (or leak in small predictable amounts), but when a cell is stressed or damaged it releases its contents (including enzymes) into the bloodstream.

Some enzymes are present in almost all cells; others occur mainly in specific organs. The types and amounts of enzymes circulating in the bloodstream (Table 40-15) can indicate which cells (and therefore which organs) are damaged.

The laboratory tests for differential diagnosis of chest pain have changed in recent years. Carbonic anhydrase, LDH, and AST (formerly SGOT) had been used for determining whether MI had occurred and the severity of the MI. Unfortunately, these tests were not very specific and could be elevated by muscle, liver, renal, or other system injury.

### Creatine Kinase

CK is a major cytoplasmic enzyme of muscle present in three major isoenzymatic forms: skeletal muscle (MM), brain (BB), and cardiac muscle (MB). CK-MM constitutes more than 90% of serum total CK. Trauma to skeletal muscle can cause myofiber contusion and necrosis with release of CK, and elevation of total serum CK levels associated with muscle soreness. Increase in serum CK has been found to occur within 6 to 24 hours of direct muscle injury and may be an even more sensitive indication of skeletal muscle damage than magnetic resonance images.<sup>76</sup>

CK-MM levels have been found to be elevated as a result of orthopedic surgery when muscles are retracted. The effects of the retractor blade pressure on paraspinal muscles during spine surgery has been documented, with the level of CK-MM being a direct result of retraction duration and pressure.<sup>73</sup>

Elevation of this isozyme in plasma is used in conjunction with other enzymes to determine whether cardiac muscle injury has occurred. A ratio of CK-MB to total CK more than 2.5 to 3 is indicative of MI.<sup>1</sup> CK-MB may

**Table 40-15** Serum Isoenzymes and Markers

Isoenzyme	Where Found	Increased In
CK-BB	Brain	CNS surgery, cardiac arrest, Reye's syndrome, cerebral contusion, cerebrovascular accident, malignant hyperthermia, bowel infarction, renal failure
CK-MB	Myocardium	MI, cardiac contusion, cardiac trauma, congestive heart failure without MI, tachyarrhythmias with underlying coronary artery disease, cardiac surgery, myocarditis
CK-MM	Skeletal muscle	Intramuscular injections, skeletal muscle trauma, extreme muscle exertion, tonic clonic seizures, surgery, excess alcohol (toxic effect on muscle), alcohol withdrawal syndrome, seizures, electric countershock, muscular dystrophy, severe hypokalemia, hypothyroidism, extreme hypothermia or hyperthermia
LDH-1	Heart, kidney, red blood cells	MI, cardiac contusion or trauma, myocarditis, cardiac surgery; also, renal disease and infarction, hemolysis, hemolytic anemia, hemolysis with prosthetic heart valves, leukemia, pernicious or megaloblastic anemia
LDH-2	Almost all tissues except skeletal muscle	Injury to any tissue except skeletal muscle
Troponin (I, T, C)	Contractile proteins found in heart and skeletal muscle	MI (specific isoforms or troponin I and T)
Myoglobin	Skeletal and cardiac muscle	Immediate rise when cardiac or skeletal muscle is damaged

CK, Creatine kinase; CK-BB, CK-MB, CK-MM, CK subunits; LDH, lactate dehydrogenase.

require more than 1 to 2 days to indicate MI in the differential diagnosis of chest pain, so other tests that provide results more rapidly are indicated. These include troponin and myoglobin.<sup>54</sup>

Troponin is a molecule specific to muscle tissue; as a biochemical marker, it is quite specific for myocardial injury. Slight elevations are indicative of unstable angina or MI<sup>12</sup> and predict whether a person can benefit from early invasive intervention (i.e., revascularization compared with conservative medical treatment).<sup>49</sup> Those with elevated troponin are also at increased risk for mortality for the next few months.<sup>29,35</sup>

Myoglobin is a small protein involved in the transport and storage of oxygen in muscle cells that leaks out of cells soon after injury. It starts to rise within 2 to 3 hours of a MI and reaches its peak in 8 to 12 hours.<sup>1</sup> However, it falls rapidly back to normal within 1 to 2 days after the MI and therefore could be missed as a serum marker of MI if medical attention is delayed.

LDH remains elevated for 10 to 14 days<sup>1</sup> and can still be useful when medical attention has been delayed several days when other serum markers have returned toward normal. Characteristics for these enzymes are listed in Table 40-15. Reference values for the cardiac isozymes are given in Table 40-16.

ation using pulse oximetry and monitoring vital signs is important. Activity may be increased according to the cardiac rehabilitation protocol in use. Always monitor the client for bradycardia or tachycardia, arrhythmias, and associated signs and symptoms of MI (angina or chest pain, unexplained perspiration, shortness of breath, nausea, vomiting, or feeling of impending doom).

CK-MM may be elevated by injury to muscle, either by trauma or disease. Injury or trauma to muscle may occur with electroconvulsive therapy, intramuscular injections, or vigorous exercise, including boxing and other contact sports. Diseases related to elevated CK-MM include rhabdomyolysis/heat stroke, malignant hyperthermia, myasthenia gravis, muscular dystrophy, poliomyelitis, and steroid myopathy. A small percentage of individuals taking statin drugs to lower cholesterol will have elevated CK-MM.

Serum CK-MM may be used to follow the progress of muscle diseases such as muscular dystrophy. CK-MM may be elevated before clinical signs of weakness and return toward normal as muscle tissue is lost. Approximately 50% to 60% of female carriers of Duchenne's muscular dystrophy/Becker's muscular dystrophy (DMD/BMD) and most males affected by DMD/BMD present with creatine kinase (CK-MM) levels that are approximately two to ten times normal, reflecting severe protein wasting.

Levels are extremely high in the first years of life before the onset of clinical weakness and persist as symptoms develop. Eventually, after replacement of muscle substance has become chronic and extensive, the CK level may be either normal or only mildly elevated (less than five times normal).

#### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-8

##### **Serum Enzymes and Markers**

###### **Creatine Kinase**

If the patient's medical record indicates an increase in CK-MB or when cardiac biomarkers are fluctuating, physical activity is limited and monitoring of oxygen-

**Table 40-16** Cardiac Enzymes and Markers (Serum)

Enzyme	Normal Range (%)	Appears (hr)	Peaks (hr)	Normalizes (days)
CK-MB	<3	3-6	18-24	2-3
LDH-1	17-27	12-24	48-72	6-12
LDH-2	23-28	12-24	48-78	6-12
LDH-1 > LDH-2 (flipped ratio)	*	12-24	48-72	6-12
Myoglobin	50-120 µg/ml	0-2	3+	—
Troponin I	<0.6 ng/ml	3-6	14-48	7-14
Troponin T	<0.1 ng/ml	3-6	14-48	7-14

Data from Corbett JV: Laboratory tests and diagnosis procedures, ed 7 Upper Saddle River, NJ, 2007, Prentice-Hall Health.

CK-MB, Creatine kinase subunit; LDH, lactate dehydrogenase.

\*No actual value is reported, only that LDH-1 becomes higher than LDH-2 for a short period.

## Cardiovascular Pressures

A number of physiologic measurements are made in the ICU or coronary care unit to monitor cardiovascular health and response to treatment. These include central venous pressure (CVP), pulmonary artery wedge pressure (PAWP), and pulmonary artery pressure (PAP).

CVP is measured from a catheter introduced from a peripheral vein such as the subclavian or jugular into the right atrium. CVP indicates the working pressure of the right ventricle, which can either indicate the effectiveness of the right ventricle as a pump or the fluid status of the individual. Increased CVP indicates either poor pumping function of the right ventricle or fluid overload. Dehydration, on the other hand, causes CVP to decrease.

PAWP is an indicator of the effectiveness of the left ventricle as a pump. A balloon-tipped catheter is inserted from a central vein, through the right side of the heart, and fed into the pulmonary arterial vessel. The balloon tip is forced or wedged into a small arterial vessel, and the balloon is inflated. With the balloon inflated, the catheter is exposed only to the pressure present in the fluid between the catheter tip and the left atrium. Poor pumping function of the left ventricle leads to increased pressure as determined by PAWP.

PAP is also determined by a catheter inserted through a central vein, through the right side of the heart, and into the pulmonary arterial circulation. However, no balloon is inflated. The catheter is exposed to the fluctuations in pressure during the cardiac cycle as blood fills and is emptied from the pulmonary arterial vessels. Generally, one is interested in whether pulmonary hypertension exists. PAP can be measured by the same catheter used for PAWP by deflating the balloon and withdrawing the tip so it is no longer wedged. Table 40-17 lists reference values for vascular pressures.

## Oxygenation of the Blood

Assessing the cardiopulmonary system's ability to deliver oxygen may be done simply and noninvasively with pulse oximetry, which provides an estimate of the relative concentrations of saturated and unsaturated Hgb by passing different wavelengths of red light through tissue and determining the absorption at these different wavelengths.

**Table 40-17** Vascular Pressures

Pressure	Reference Range (mm Hg)
Pulmonary artery systolic	20-30
Pulmonary artery diastolic	8-15
Pulmonary artery wedge pressure	4-12
Central venous pressure	0-5

Pulse oximetry also provides the heart rate, but the device has several limitations. Its accuracy declines when arterial blood flow becomes decreased; it does not give information about the ability to rid the body of CO<sub>2</sub> and regulate acid/base balance, and its accuracy is limited to about ± 2%.

## Arterial Blood Gases

A more accurate means of assessing cardiopulmonary function and the effectiveness of ventilation and oxygen transport is by analyzing the oxygen (O<sub>2</sub>) and CO<sub>2</sub> dissolved in the blood and related chemical components. Measurements are performed on a sample of arterial blood, usually withdrawn from a radial artery. These include the partial pressures of O<sub>2</sub> and CO<sub>2</sub>, the blood's pH, the concentration of HCCV, and a calculation of base excess.

The measurements are primarily used to analyze how well acid base is being regulated by the respiratory system. Under normal circumstances, regulation of pH by the respiratory system provides near maximal saturation of hemoglobin by oxygen, as well as maintaining the partial pressure of CO<sub>2</sub> and arterial pH.

Bicarbonate and base excess are related to whether compensations for metabolic or respiratory shortfalls are occurring in regulating pH. Samples from other vessels can be taken to determine the performance of the cardiac and ventilatory pumps in their roles of gas exchange. For example, a person with good arterial blood gases (ABGs), but low venous O<sub>2</sub> and high venous CO<sub>2</sub> would have normal gas exchange in the lungs, but poor cardiac pump performance. ABG analysis includes information about oxygenation, ventilation, and metabolic function. The test measures the amount of dissolved O<sub>2</sub> and CO<sub>2</sub> in

**Table 40-18** Arterial Blood Gas Values

Term	Definition	Reference Value
pH	Measure of blood acidity; ratio of acids to bases.	7.35-7.45
PaCO <sub>2</sub>	Pressure or tension exerted by CO <sub>2</sub> dissolved in arterial blood; measures effectiveness of alveolar ventilation (i.e., how well air is exchanging with blood in the lungs).	35-45 mm Hg
HCO <sub>3</sub> <sup>-</sup>	Amount of bicarbonate or alkaline substance dissolved in blood; influenced mainly by metabolic changes.	22-26 mEq/L
PaO <sub>2</sub>	Pressure exerted by O <sub>2</sub> dissolved in arterial blood in attempting to diffuse through pulmonary membrane.	75-100 mm Hg
O <sub>2</sub> saturation	Oxyhemoglobin saturation: percentage of oxygen carried by hemoglobin.	96%-100%
<b>Critical Values</b>		
pH	≤7.20 or >7.60	
PaCO <sub>2</sub>	≤20 or >70 mm Hg	
HCO <sub>3</sub> <sup>-</sup>	≤10 or >40 mEq/L	
PO <sub>2</sub>	≤40 mm Hg	
O <sub>2</sub> saturation	<95%*	

Modified from Goodman CC, Snyder TE: *Differential diagnosis for physical therapists: screening for referrals*, ed 4, Philadelphia, 2007, WB Saunders.

PaCO<sub>2</sub>, Partial pressure of arterial carbon dioxide; CO<sub>2</sub>, carbon dioxide; HCO<sub>3</sub><sup>-</sup>, bicarbonate ion; PaO<sub>2</sub>, partial pressure of arterial oxygen; O<sub>2</sub>, oxygen.

\*This value varies depending on the clinical situation. For example, a healthy adult with O<sub>2</sub> saturation levels less than 95% would bear further investigation, whereas in someone who smokes, 95% saturation level would not be suspect; resting PO<sub>2</sub> declines with aging after age 70.

arterial blood and indicates acid-base status by measuring the arterial blood pH.

The pH is inversely proportional to the hydrogen ion concentration in the blood. As the hydrogen ion concentration increases (acidosis), the pH decreases; as the hydrogen ion concentration decreases (alkalosis), the pH increases.

The specific measurements associated with ABGs include serum pH, partial pressure of CO<sub>2</sub>, HCCV, partial pressure of O<sub>2</sub>, and O<sub>2</sub> saturation (Table 40-18). A detailed explanation of these measures and how they interrelate is included in Chapter 5.

Arterial blood is a good way to sample a mixture of blood that has come from various parts of the body and gives the added information of how well the lungs are oxygenating the blood. For example, if the arterial O<sub>2</sub> concentration is normal (indicating that the lungs are functioning normally), but the mixed venous O<sub>2</sub> is low, it can be inferred that the heart and circulation are impaired. Arterial samples provide information on the ability of the lungs to regulate acid-base balance through retention or release of CO<sub>2</sub> and the effectiveness of the kidneys in maintaining appropriate HCCV levels.

#### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-9

##### Arterial Blood Gases

When the client demonstrates impaired oxygenation status, supplemental O<sub>2</sub> should be continued throughout the therapy session. Oxygen saturation should be maintained at 90% or higher. Persons with chronic obstructive pulmonary disease (COPD) may retain CO<sub>2</sub>; the use of high concentrations of O<sub>2</sub> is contraindicated in these individuals because it can further depress the respiratory drive, causing death.

If O<sub>2</sub> flow rate is increased during exercise for individuals with chronic lung disease, O<sub>2</sub> flow rate must be returned promptly to its set value at the end of exercise. Failure to return flow rate to the value determined by the physician may result in hypoventilation, retention of CO<sub>2</sub>, and respiratory acidosis. When this is not possible, intervention should be modified and the client should not be overexerted, keeping in mind that increased physical activity means additional oxygen requirements.

Any indication of hyperventilation (e.g., decreased CO<sub>2</sub> level or increased respiratory rate) should be addressed during therapy. Relaxation techniques and breathing exercises, such as pursed-lip or diaphragmatic breathing, can be incorporated into the intervention plan. Hypoventilation as indicated by an increased CO<sub>2</sub> level or shallow breathing may be affected by deep-breathing activities and by positioning (e.g., sitting upright) to improve CO<sub>2</sub> removal and optimize oxygenation.

Changes in metabolic components of ABGs (either primary or compensatory) may affect other organ systems and therefore a person's tolerance for physical activity. The therapist must always treat with the client's tolerance in mind and monitor vital signs, observing for associated clinical signs and symptoms.

The critical values for ABGs (see Table 40-18) have a fairly wide range without specific points at which therapy intervention is contraindicated. Clients with significant ABG changes would be in the hospital and most likely in the ICU or other acute care area. Therapy intervention with these individuals depends on individual tolerance but is usually not carried out when ABGs are outside the critical value ranges.

## SERUM HORMONES

Several hormones may be affected in populations seen in physical therapy and may impact systems relevant to the provision of therapy. Most common is hypothyroidism. Alterations in parathyroid hormone, Cortisol, and adrenocorticotrophic hormone (ACTH) may also occur.

Thyroid hormone is necessary initially for normal growth and development. It is routinely tested in newborns in all states to detect hypothyroidism, a potential cause of cognitive delays or developmental disability when left untreated or when treatment is delayed.

In adults, a slowing of metabolism with hypothyroidism may cause sensitivity to cold; brittle, coarse skin and nails; bradycardia; constipation; and slower cognitive processing. Hypothyroidism has also been linked to musculoskeletal injuries and affective changes, including depression and anxiety.

Severe chronic hypothyroidism may progress to a condition known as myxedemic coma. Hypothyroidism may be caused by either pituitary dysfunction or thyroid dysfunction. Thyroid testing includes both thyroid-stimulating hormone (TSH) and thyroxine ( $T_4$ ). TSH (produced in the pituitary) stimulates the thyroid to produce thyroid hormones ( $T_3$  and  $T_4$ ). Elevated TSH with decreased  $T_4$  indicates thyroid disease, whereas depressed TSH indicates pituitary disease. Hyperthyroidism, most notably from Graves' disease, may produce atrial fibrillation and exophthalmos, which is a protrusion of the eyes.

Parathyroid hormone (PTH) regulates calcium metabolism. In the face of hypocalcemia, release of PTH causes bones to release calcium into the blood.

Cortisol and ACTH are related to adrenal cortex function. ACTH is released by the anterior pituitary to stimulate release of Cortisol by cells of the adrenal cortex. Cortisol, a glucocorticoid, is released in response to stress and provides glucose to circulate in the blood. In particular, protein reservoirs are made available for conversion of amino acids into fuel sources, which can damage musculoskeletal structures. Cortisol also inhibits the immune system.

Fluid volume and composition may be altered by changes in the release of several hormones. ADH may be either elevated or depressed as a result of injury to or disease of the posterior pituitary. ADH is increased in what is termed *syndrome of inappropriate ADH* (SIADH), causing fluid retention and hyponatremia.

The potentially life-threatening disease, diabetes insipidus, produces decreased ADH with extreme loss of water in the urine and hypernatremia. Tests may also be performed for renin, angiotensin, and aldosterone as part of

a workup for low potassium (hypokalemia), muscle weakness, hypertension, or hypotension. Reference values for serum thyroid hormones are given in Table 40-19.

### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-10

#### *Serum Hormones*

Tests to monitor thyroid function have a broad range and cannot always disclose an individual's exact hormone function or requirements. Thyroid hormones do not have their action in the bloodstream but in each cell of the body, which cannot be measured directly. Although the glandular portion of the thyroid system may be functioning, the peripheral portion (cellular uptake and metabolism) may be impaired.

Limited studies on the short-term use of supraphysiologic doses of  $T_3$  (75 to 150 µg; normal replacement doses range from 25 to 75 µg) have been reported.<sup>43,44</sup> Increased thyroid medication carries with it the increased risk for heart arrhythmias and osteoporosis, but the exact parameters for this dosage remain unknown. Some physicians advocate assessing the thyroid system by monitoring symptoms and body temperature. There remains considerable debate and controversy over thyroid function, symptoms in the presence of normal laboratory values, and effective intervention techniques.<sup>2</sup>

Thyroid problems were reported by 7% to 8% of women surveyed in an orthopedic outpatient setting, and all of these women were taking thyroid replacement medication.<sup>6</sup> The percentages for the overall therapy population are likely equal or possibly even higher. With adequate replacement therapy, these people will be euthyroid and present no particular problem to the therapist.

Replacement needs vary over time, however, and these clients may become hyperthyroid or hypothyroid. Signs and symptoms of these conditions include myalgia, arthralgia, and numbness (see further discussion in Chapter 11); all symptoms for which the person may seek out a physical or occupational therapist.

Individuals with hypothyroidism may be referred to therapy because of various musculoskeletal injuries, cramps, and soreness or may complain of profound and persistent fatigue. Some level of suspicion is warranted for anyone who does not respond to therapy or does not have mechanisms of injury that seem to fit the musculoskeletal symptoms, especially when accompanied by other symptoms of hypothyroidism.

**Table 40-19** Thyroid Function Reference Values

Age	Thyroxine ( $T_4$ ) (µg/dl)	Triiodothyronine ( $T_3$ ) (ng/dl)	Free $T_4$ Index (ng/dl)	TSH (µIU/L)
Adolescent, adult, older adult	4.5-11.5	80-200	4.6-11.2	0.35-5.5

Data from Corbett JV: *Laboratory tests and diagnostics procedures*, ed 7, Upper Saddle River, NJ, 2007, PrenticeHall Health. TSH, Thyroid-stimulating hormone.

such as reports of fatigue or feeling cold when others in the same room are comfortable.

Some forms of fibromyalgia are accompanied by a "hypothyroid tendency" (i.e., symptoms of hypothyroidism but the thyroid function test is normal). It is postulated that in these individuals, inadequate T<sub>3</sub> at the cellular level caused by a failed conversion, incomplete conversion, or inadequate conversion of T<sub>4</sub> to T<sub>3</sub>, can lead to neuromuscular molecular abnormality with accompanying stiffness, report of "achiness," decrease in basal body temperature, constipation, and dry skin.<sup>30,42</sup> T<sub>3</sub> is produced in the tissue cells and remains there for the most part, so a blood test does not indicate its level of production or effectiveness. For further discussion see the section on Fibromyalgia in Chapter 7.

The fact that many women develop carpal tunnel syndrome at or near menopause suggests that the soft tissues about the wrist may be affected in some way by hormones.<sup>15,22,58,85</sup> Hormone testing to determine a woman's menopausal status (premenopausal, perimenopausal, and postmenopausal) can be done.

This information is also helpful when the woman is considering hormonal replacement therapy and can be used by the therapist to facilitate client education regarding prevention of osteoporosis.

Genome Project has advanced our knowledge of genetics used to develop molecular signatures for disease diagnosis, prediction of treatment outcomes, and final prognosis.

In the last 30 years, there have been important advances in the understanding of the molecular events that underlie the development of malignancy. New techniques to analyze genetic changes and biomarkers for tumors have advanced the diagnostic and monitoring methods for cancer.

### Polymerase Chain Reaction

The polymerase chain reaction (PCR) is now a common technique used in medical and biologic research labs for a variety of tasks such as the sequencing of genes and the diagnosis of hereditary diseases, the identification of genetic fingerprints (used in forensics and paternity testing), and the detection and diagnosis of infectious diseases. The use of PCR may help prevent misclassification of prosthetic joint problems such as aseptic loosening when infection is present.<sup>4</sup> In the future, other routine uses for PCR may include the early diagnosis of Lyme arthritis using joint fluid or a tissue sample from the synovial membrane.<sup>38</sup>

PCR has greatly simplified the analysis of DNA and facilitated the development of tests that use these changes as markers. Enough DNA can be obtained for analysis from a needle biopsy specimen or in some cases, body fluid (e.g., urine, sputum, or cerebrospinal fluid [CSF]). PCR is a simple, sensitive, and fast test of small quantities of cells.

In cancer screening, PCR is useful in analyzing DNA or RNA of the tumor when it differs from the normal DNA or RNA of the surrounding tissue. Point mutations and chromosomal translocations linked with cancer can also be identified with this technique (e.g., Philadelphia chromosome linked with leukemia or Ewing's sarcoma). PCR may help identify asymptomatic individuals who have a familial predisposition to cancer (e.g., Li-Fraumeni syndrome or familial colon cancer).

The sensitivity of PCR for detecting nucleic acid markers of cancer make it possible to find very small amounts of disease (micrometastases). This is helpful when examining bone marrow for cancer in people being evaluated for bone marrow transplantation. Research around the use of PCR in cancer treatment is focusing now on identifying sets of genes whose expression can be correlated with response to specific drugs and drug combinations making it possible to tailor chemotherapy regimes to the individual, based on tumor or host gene expression profiles.<sup>52,55</sup>

### Tumor-Associated Antigens

Knowledge of the interactions between tumor cells and the immune system have made it possible to identify tumor-associated antigens. Tumor-associated antigens discovered by these methods are being used to develop passive (humoral), as well as active immunotherapy strategies to stimulate the immune system. Development of biomarkers is ongoing in hopes of developing better screening techniques for early detection,<sup>47</sup> along with identifying strategies for antitumor vaccines.

## IMMUNOLOGIC

Diagnostic immunology or serodiagnostic testing uses blood tests to aid in the diagnosis of infectious disease, immune disorders, allergic reactions, neoplastic disease (e.g., genetic changes and tumor-related antigens), and in blood grouping and typing (not discussed further here). Blood tests can be used to determine whether particular antigens are present (bacteria, viruses, parasites, fungi, or enzymes).

Immunoglobulins, the general term for antibodies that are produced in response to antigens, are divided into five subclasses (IgA, IgD, IgE, IgG, and IgM). These classes of immunoglobulins can be differentiated by morphology and by their roles in the immune system. During lab testing, the globulins are separated by electrophoresis into different fractions. Different fractions are indicative of different diseases. For example, alpha ( $\alpha$ )-globulin is elevated in rheumatoid arthritis and beta ( $\beta$ )- and gamma ( $\gamma$ )-globulins are elevated in multiple myeloma.

Ideally, serum is collected at the beginning of the illness during the acute phase and again 3 to 4 weeks later during the convalescent phase. An increase in the quantity (titer) of a specific antibody between these two phases is diagnostically significant. The specific antibody tests for individual antigens are beyond the scope of this chapter. The reader is referred to more comprehensive laboratory and diagnostic manuals.

## Cancer Screening

Cancer has overtaken heart disease as a major cause of mortality in the United States. The Human

Investigations and identification of gene expression profiles and prognostic markers for different types of cancer (e.g., breast, prostate, ovarian, or lung) are ongoing. Efforts to find molecular methods to detect disease recurrence and micrometastases using biomarkers is also underway. Although not completely reliable, tumor antigen markers such as prostate-specific antigen (PSA) and CA-125 for ovarian cancer are already in use.

## Rheumatoid Factor

Rheumatoid factor (RF), an anti- $\gamma$ -globulin antibody, is elevated in rheumatoid arthritis and Sjogren's syndrome. However, a negative test does not rule out either disease. Approximately 20% of those diagnosed with these diseases are negative for RF. A positive RF test may also occur with chronic diseases, such as SLE, endocarditis, syphilis, tuberculosis, sarcoidosis, cancer, and viral infections, and other diseases.<sup>1</sup>

## Antinuclear Antibodies

Antinuclear antibodies (ANA) are generally related to SLE. Exacerbations of SLE are related to elevations in ANA, which may occur with events such as exposure to sunlight. Human leukocyte antigen (HLA) represents the genetic contribution to the immune system. Inheritance of certain HLA proteins increases the risk of specific diseases, especially spondyloarthropathies such as ankylosing spondylitis, reactive arthropathy, Reiter's syndrome, and psoriatic arthropathy. Not all persons with a certain HLA pattern will develop the disease, but those who do have a greater probability for its development than the general population. Other diseases and related HLA proteins are listed in Table 40-20.

**Table 40-20** Diseases Associated with HLA Antigens\*

Disease	HLA Antigen
Ankylosing spondylitis	HLA-B27 (present in 90% of cases)
Multiple sclerosis	HLA-B27, HLA-Dw2, HLA-A3, HLA-B18
Myasthenia gravis	HLA-B8
Psoriasis	HLA-B13, HLA-B17
Reiter's syndrome, reactive arthritis	HLA-B27
Juvenile insulin-dependent diabetes	HLA-Bw15, HLA-B8
Graves' disease	HLA-B27
Juvenile rheumatoid arthritis	HLA-B27, HLA-DR4
Autoimmune chronic active hepatitis	HLA-B8
Polymyalgia rheumatica	HLA-DR4

Data from Pagana KD, Pagana JI: *Mosby's diagnostic and laboratory test reference*, ed 8, St Louis, 2006, Mosby.

HLA, Human leukocyte antigens.

\*HLA testing is used to confirm the diagnosis and is not usually regarded as diagnostic by itself.

## URINALYSIS

Urine is a very complex fluid, composed of 95% water and 5% solids. It is the end-product of metabolic processes carried out in the body. Although urine contains thousands of dissolved substances, the three main components are water, urea, and sodium chloride.

Some constituents of the blood (e.g., glucose) have a renal threshold; that is, a certain elevated level must be reached in the blood before showing up in the urine. Almost all substances found in the urine are also found in the blood, although in different concentrations. Urea, for example, is present in the blood but at a much lower concentration than in the excreted urine.

Testing of urine is centuries old. Simple yet important screening tests are done easily with small patches placed on urine dipsticks. Important components of urinalysis include color, specific gravity, glucose, ketone, WBCs, RBCs (occult blood), electrolytes, and drug screens.

## Color and Appearance

The color of urine is related to a number of factors and the most important is its concentration. A pale yellow color is considered normal. Dilution of solute within increased volume of urine decreases its color, whereas reduced volume caused by dehydration increases its yellow appearance. The presence of blood with intact RBCs produces a more purple-to-red color and hemolyzed blood produces a smoky appearance.

Color may also be altered by medications, including antibiotics, some laxatives, chlorzoxazone (a muscle relaxant), and Pyridium. Pyridium is an anesthetic used for treating the burning pain of urinary tract infection that colors the urine orange. The ingestion of certain foods (e.g., rhubarb, carrots, and beets) or some vitamins and supplements can cause a change in the color of urine.

Dark brown urine may occur with liver disease or with DIC. Highly concentrated urine (e.g., decreased hydration or renal dysfunction) is also colored differently depending on the individual and may appear dark yellow, gold, or orange, often accompanied by a strong odor. Asparagus can also bring about a characteristic odor to the urine, and certain vitamin and herbal supplements can change the color (e.g., vitamin C can cause the urine to turn a bright yellow or orange).

Bleeding from the upper urinary tract (kidney and ureters) may produce dark red urine, whereas bleeding in the lower urinary tract (bladder and urethra) produces bright red urine. Occult blood, meaning hidden blood, represents a more subtle change in urine color than the red, purple, or smoky-appearing urine and is tested as part of urinalysis. Bleeding can indicate a number of disorders such as kidney stones, infection, or cancer. Frank purulence (visible pus in the urine) or a cloudy appearance is indicative of infection of the urinary tract.

## Specific Gravity

Specific gravity is a test to measure the kidney's ability to concentrate urine and depends on the state of hydration;

**Table 40-21** Routine Urinalysis and Related Tests

General Characteristics and Measurements	Chemical Determinations	Microscopic Examination of Sediment
Color: pale yellow to amber	Glucose: negative	Casts: negative, occasional hyaline casts
Turbidity: clear to slightly hazy	Ketones: negative	Red blood cells: negative or rare
Specific gravity (with a normal fluid intake): 1.015-1.025	Blood: negative	Crystals: negative
pH: 4.5-8.0 (average pH: 5-6)	Bilirubin: negative	
	Urobilinogen: 0.1-1.0	White blood cells: negative or rare
	Nitrate for bacteria: negative	Epithelial cells: few
	Leukocyte esterase: negative	

Data from Pagana KD, Pagana TJ: *Mosby's diagnostic and laboratory test reference*, ed 8, St. Louis, 2006, Mosby.

specific gravity is an indicator of the solute present in urine. A high specific gravity indicates concentrated urine, whereas a low specific gravity indicates dilute urine. Renal dysfunction is suspected when the kidney is unable to concentrate or dilute the urine.

Dilute urine has a specific gravity approaching 1.0, whereas the specific gravity caused by dehydration may reach 1.2 or greater. Specific gravity correlates with color. Urine with a specific gravity close to 1.0 will be clear, whereas specific gravity closer to 1.2 produces dark yellow urine.

When urine gives a positive result for occult blood but no RBCs are seen on a microscopic examination, myoglobinuria is suspected. Myoglobinuria is the excretion of myoglobin, a muscle protein, into the urine as a result of traumatic muscle injury (e.g., automobile accident, football injury, or electric shock), muscle disorder (e.g., muscular dystrophy, arterial occlusion to a muscle), or certain kinds of poisoning (e.g., carbon monoxide).

## Glucose and Ketones

Glucose and ketones present in the urine represent alterations in glucose metabolism. Glucose present in the urine indicates saturation of the active transport mechanism for glucose from the filtered urine. Under normal circumstances, virtually all glucose that filters from the blood can be reabsorbed from the urine.

When the blood glucose level exceeds the reabsorption capacity of the renal tubules, glucose will be spilled into the urine. Failure to absorb all of the glucose indicates a very high plasma glucose concentration and most likely diabetes mellitus.

Ketones in the urine represent the failure to obtain sufficient glucose metabolism, leading to a shift of triglyceride metabolism from the Krebs cycle to the production of ketones. In healthy individuals, ketone bodies are formed in the liver and are completely metabolized so that only negligible amounts (if any) appear in the urine.

However, when glucose cannot be transferred into the cell because of an insufficiency or inefficiency of insulin, carbohydrate metabolism is altered, and fat becomes the alternate body fuel (instead of carbohydrates), producing excessive amounts of ketones. Both diabetes mellitus and starvation (including eating disorders) may be the cause of increased ketones in the urine. Table 40-21 lists reference values for urinalysis.

## DRUG SCREENING

Drug screening may be encountered for two primary reasons. Employees of healthcare institutions may be subjected to preemployment screening, random tests, and testing after significant incidents at work. Policies vary between facilities and may include screening of students on clinical affiliations. Patients may also be tested as part of the diagnostic process.

Tests may be performed for a number of substances, including alcohol, amphetamines, methamphetamines, barbiturates, cocaine, LSD, marijuana, opiates, phencyclidine, and other drugs that might impair employee performance or confound patient diagnosis including analgesics, tranquilizers, sedatives, and stimulants.

## MICROBIOLOGIC STUDIES

A large number of microbiologic studies are available to identify potential causes of infection. Identification of the pathogen aids in the prognosis and treatment of infectious disease. In particular, patients may be placed in isolation, requiring special attention to their therapy. Gram stains and cultures are the most commonly encountered microbiologic studies in the therapy practice.

### Gram Stain

Gram stain is used to distinguish organisms that take up the stain (gram positive) from those that do not. A number of common pathogens are gram positive, including *Staphylococcus* and *Streptococcus* species. Gram-negative organisms frequently require different antimicrobial drugs. Potassium hydroxide (KOH) is used for identifying fungal infection. Acid-fast testing is generally for determining tuberculosis infection. Acid-fast bacillus (AFB) is a term generally applied to *Mycobacterium tuberculosis*. Testing is done on sputum samples but may also be done with samples obtained from bronchoscopy or other tissue or fluid samples.

### Cultures

Cultures are obtained to detect the presence of bacteria in the blood (e.g., bacteremia), sputum (e.g., pneumonia or tuberculosis), pleural fluid (e.g., empyema), throat (e.g., streptococci, meningococci, or gonococci), urine

(e.g., urinary tract infection), skin (e.g., staphylococci, streptococci, or *Pseudomonas*), and wounds (e.g., staphylococci, streptococci, or *Pseudomonas*).

Other cultures may include stool and anal, CSF, cervical, and urethral cultures. Cultures are usually performed on the basis of clinical presentation (e.g., chills, fever, or pus). Cultures should be performed before antibiotic therapy is initiated (often the culture is taken and the antibiotic dispensed before results are known); otherwise, the antibiotic may interrupt the organism's growth in the laboratory.

Samples of tissue or body fluids are used to determine the species or quantity of microbes present. A quantitative culture by tissue biopsy or fluid obtained by needle aspiration is best to determine the number of organisms present. Infection, delayed wound healing, and failure of skin grafts are associated with cultures numbering 100,000 or more organisms per gram.  $\beta$ -Hemolytic *Streptococcus* causes infection at a lower number per gram of tissue.<sup>71</sup>

Blood cultures are taken when systemic infection is suspected. These may be done when patients have indwelling catheters, localized infection, and other risk factors in the presence of fever, malaise, or anorexia. Skin, even in healthy individuals, is expected to have a number of organisms on its surface. In particular, species of *Streptococcus*, *Staphylococcus*, and various fungi are commonly present. In some cases, virulent strains may become present and lead to infection. Infection may take the form of a crusty, honey-colored area (impetigo), spread through follicles (folliculitis), cause abscess formation (furuncles), spread through fascial planes (carbuncles), or appear as fungal manifestations such as ringworm or athlete's foot.

Wounds are frequently cultured for a number of reasons. Both quantitative and qualitative cultures may be taken to determine the appropriate medical treatment. Swab cultures with culturettes are still used frequently but only represent surface bacteria, which may not be the source of the infection. Biopsy of the wound or removal of fluid deep in the wound is more likely to identify the problematic microbes than a swab.

The culture should be taken from the suppurative material rather than from the skin edge for a more accurate wound culture. After the wound is cleaned with isotonic saline (and debrided if necrosis is present), then viable tissue is cultured (not a swab culture of exudates or necrotic tissue).

Clinical practice of wound cultures must be careful to avoid culturing wound exudate contaminants, of which there are usually at least three per wound. Identify a 1 cm<sup>2</sup> site that is clean and without pus or eschar if possible. When the swab tip is moist, place it in a sterile container for transport to the lab.

### Skin Lesions

When skin lesions are present, the therapist must follow Standard Precautions carefully both to prevent the spread of infection to the client and to prevent self-inoculation and subsequent infection. For a more detailed discussion of skin lesions and their special implications, see Chapter 10.

## PULMONARY FUNCTION TESTS

Tests may be performed for screening purposes or for diagnosis of specific pulmonary diseases. Pulmonary function studies may reveal abnormalities in the airways, alveoli, and pulmonary vascular bed early in the course of disease when physical examinations and x-ray studies are still normal. In addition, the location of an airway abnormality can be determined (i.e., upper airway, large airway, or small airway).

Tests include static lung volumes, dynamic breathing tests, and physiologic tests. Imaging may also be used to augment these tests. These tests can provide additional information for the physical examination of the person with compromised respiratory function such as distinguishing obstructive from restrictive disease, separating airway disease from issues with elasticity, and determining central from peripheral causes of breathing disorders.

Static lung volumes are shown in Table 40-22. These are obtained with a spirometer that records volumes of air that move in and out of the lungs during breathing. Norms based on height, age, and sex are available for comparison of the individual's results. These values include tidal volume (TV), inspiratory reserve volume (IRV), expiratory reserve volume (ERV), and vital capacity (VC).

TV is the amount that is inspired with a normal breath. The amount that can be inspired in addition to that volume with a maximal inspiratory effort is the IRV. The amount of air that can be expired beyond the normal expiration using maximal expiratory effort is the ERV. Additional volumes are determined by dilution techniques that can be used to compute the volume of air present in the lungs. The residual volume (RV) present in the lungs at the end of maximal expiration is determined by use of helium or nitrogen dilution techniques. When this volume is determined, both functional residual

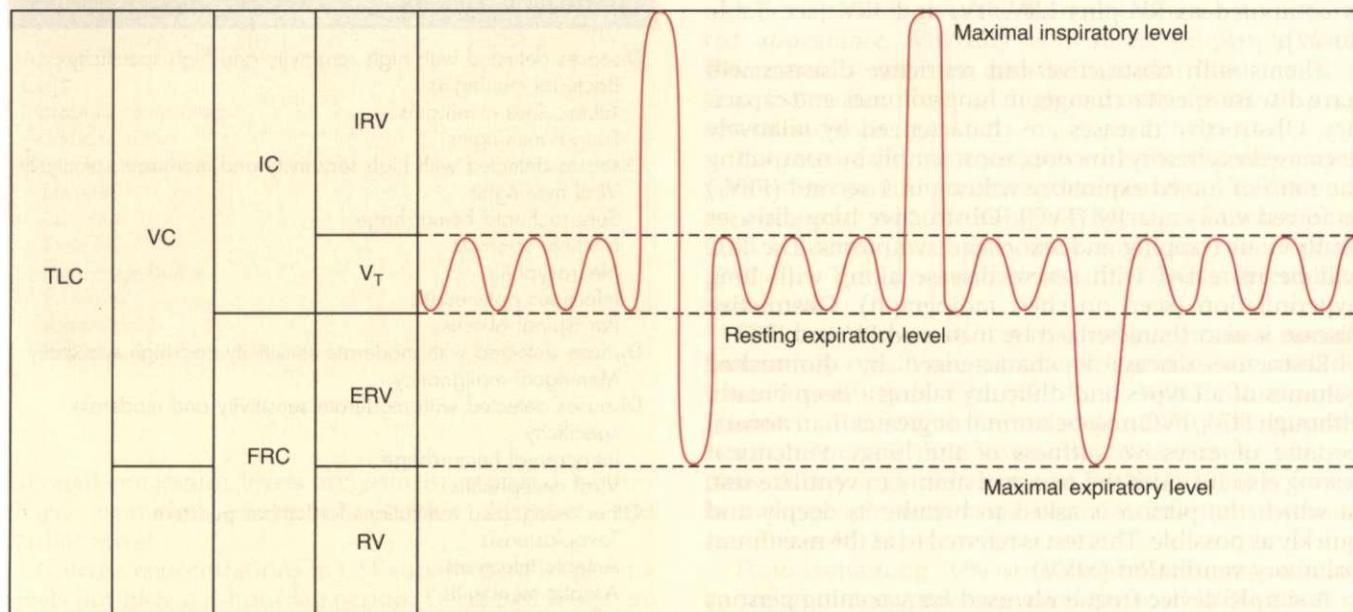
### SPECIAL IMPLICATIONS FOR THE THERAPIST

#### 40-11

### **Microbiologic Studies**

#### **Wound Cultures**

The physician should be notified of the presence of purulent drainage from any wound, including surgical incisions and abscesses, especially if associated with a foul odor or increase in pain, red streaks, swelling, or temperature. In the course of treatment, cultures may be grown to determine the quantity or to identify organisms responsible for infection. Certain pathogens are associated with different qualities of drainage. Purulence from streptococcal infections is thin and serous, whereas pus from staphylococcal infections is more gelatinous and pus from pseudomonal infections is bluish green with a fruity odor.

**Table 40-22** Pulmonary Function Test Components**Lung Volumes and Capacities**

VC	Vital capacity	Volume of air that is measured during a slow, maximal expiration after a maximal inspiration; normal range varies with age, gender, and body size
IC	Inspiratory capacity	Largest volume of air that can be inhaled from resting expiratory volume
IRV	Inspiratory reserve volume	Maximal volume of air that can be expired after a normal inspiration
ERV	Expiratory reserve volume	Largest volume of air exhaled from resting end-expiratory level
FRC	Functional residual capacity	Volume of air remaining in lungs at resting end-expiratory level
RV	Residual volume	Volume of air remaining in lungs at end of maximal expiration
TLC	Total lung capacity	Volume of air contained in lungs after maximal inspiration
V <sub>t</sub>	Tidal volume	Volume of air inhaled or exhaled during each respiratory cycle; normal range: 400-700 ml
f	Respiratory rate	Frequency of breathing is number of breaths per minute; normal range: 10-20

**Lung Mechanics**

FVC	Forced vital capacity	Maximal volume of air that can be forcefully expired after a maximal inspiration to total lung capacity
FEV <sub>t</sub>	Forced expiratory volume (in 1 sec)	Volume of air expired during a given time interval ( $t$ in sec) from the beginning of an FVC maneuver; an indication of how open the respiratory channels are and how much air can get pushed out
FEF <sub>25%-75%</sub>	Forced expiratory flow <sub>25%-75%</sub>	Average of flow during middle of an FVC maneuver
PEFR	Peak expiratory flow rate	Maximal flow rate attained during an FVC maneuver
MVV	Maximal voluntary ventilation	Largest volume that can be breathed during a 10- to 15-sec interval with voluntary effort
MIP	Maximal inspiratory pressure	Greatest negative or subatmospheric pressure that can be generated during inspiration against an occluded airway
MEP	Maximal expiratory pressure	Highest positive pressure that can be generated during a forceful expiratory effort against an occluded airway

**Diffusing Capacity**

D <sub>LCO</sub>	Diffusing capacity for carbon monoxide	Reflects ability of lung to transfer gas across the alveolar/capillary interface (assists in diagnosis of diffuse infiltrative lung disease and emphysema)
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capacity (FRC) and total lung capacity (TLC) can be computed. FRC is computed by adding RV to ERV. TLC is computed as RV plus ERV, TV, and IRV (see Table 40-22).

Clients with obstructive and restrictive diseases will have disease-specific changes in lung volumes and capacities. Obstructive diseases are characterized by relatively decreased expiratory function, most simply by computing the ratio of forced expiratory volume in 1 second (FEV<sub>1</sub>) to forced vital capacity (FVC). Obstructive lung diseases result in air trapping and associated symptoms. The TLC will be increased with severe disease along with lung hyperinflation (seen on chest radiograph). Obstructive disease is also characterized by increased RV and FRC.

Restrictive disease is characterized by diminished volumes of all types and difficulty taking a deep breath, although FEV<sub>1</sub>/FVC may be normal or greater than normal because of excessive stiffness of the lungs. Functional testing also includes the maximal ability to ventilate test, in which the person is asked to breathe as deeply and quickly as possible. This test is referred to as the maximum voluntary ventilation (MV).

A simple device frequently used for screening persons with asthma is the peak flow meter. The person expires as forcefully as possible for one breath. The device is individualized for a given person with areas of the scale marked with colors to indicate whether function is adequate (green), some intervention is needed (yellow), or emergency care should be sought (red).

## FLUID ANALYSIS

Samples of fluid may be drawn from a number of body compartments. Tests are performed for a variety of reasons including determining the cause of fluid accumulation in these spaces, determining whether these compartments are infected, or whether cancer or other cells or substances are present. Compartments may include the area around the brain and spinal cord, joints, the spaces around the lungs or heart, and in the abdomen.

### Cerebrospinal Fluid

This fluid surrounds the brain and spinal cord and exists in cavities within the brain called ventricles and within the central canal of the spinal cord. CSF is typically collected by a *lumbar puncture*. At this site distal to the end of the spinal cord, a needle can be introduced without risk of injuring the spinal cord.

Both the composition and pressure of CSF may be analyzed. Infections (meningitis) may be determined by both presence of bacteria and by alterations in the normal composition of CSF. Pressure within the CSF space may be altered through blockage of the normal flow and reabsorption mechanisms of the brain, which may alter cerebral function or even cause death.

The presence of immunoglobulins (Ig) may be indicative of other disorders, especially the presence of IgG with multiple sclerosis. Other indications for lumbar puncture are included in Box 40-2.

### Box 40-2

#### DIAGNOSTIC LUMBAR PUNCTURE IN ADULTS

Diseases detected with high sensitivity and high specificity

- Bacterial meningitis
- Tuberculous meningitis
- Fungal meningitis

Diseases detected with high sensitivity and moderate specificity

- Viral meningitis
- Subarachnoid hemorrhage
- Multiple sclerosis
- Neurosphylis
- Infectious polyneuritis
- Paraspinal abscess

Disease detected with moderate sensitivity and high specificity

- Meningeal malignancy

Diseases detected with moderate sensitivity and moderate specificity

- Intracranial hemorrhage
- Viral encephalitis

Other recognized indications for lumbar puncture

- Toxoplasmosis
- Amebic infections
- Aseptic meningitis
- Inflammatory neuropathies
- Metastatic brain tumors
- Normal-pressure hydrocephalus
- Hepatic encephalopathy
- Systemic lupus erythematosus

Modified from McConnell H: Current and future clinical utility of cerebrospinal fluid in neurology and psychiatry. In McConnell H, Blanchine J, editors: *Cerebrospinal fluid in neurology and psychiatry*, London, 1994, Chapman & Hall.

### Appearance

Testing of CSF involves measurement of a variety of substances and states. Standard pathologic levels of substances found in the CSF are listed in Box 40-3. Appearance is normally clear; cloudiness indicates a disease state, graded from 0 to 4 (indicating progressive levels of cloudiness); 0 denotes a clear fluid, and 4 indicates inability to see newsprint through the fluid. Bilirubin accumulating in the body (jaundice) can give the CSF a yellow tinge, and blood in the fluid will cause it to turn pink.

Cells found in the CSF usually indicate an abnormality in the central nervous system (CNS), since the CSF is normally virtually free of cells. Cell types found in disease or trauma include WBCs, macrophages, cartilage cells, glial cells, bone marrow, and various tumor cells.

Levels of inorganic compounds in the CSF can reflect disorders of the nervous system. Calcium can alter the activation of various neurotransmitters, and low levels are implicated in seizure disorders. Low levels of calcium are also associated with tetany and tumors of the diencephalon. Increased levels of calcium are seen in meningitis.

Magnesium levels will drop in the person with meningitis and ischemic brain disorders. Increased levels of magnesium are seen after intracranial hemorrhage. CSF sodium levels normally change as the plasma levels change. Sodium levels can be out of proportion in the CSF in encephalomalacia and tuberculous meningitis.

**Box 40-3****FACTORS EVALUATED IN CEREBROSPINAL FLUID**

Appearance
Cells
Inorganic compounds
Acid-base status
Organic compounds
Lactate
Glucose
Proteins
Immunoglobulins
Enzymes
Amino acids
Peptides, neuropeptides

Elevated potassium levels are seen in neonatal hemorrhage, aspiration pneumonia, seizure disorders, and cardiac arrest.

Glucose concentrations in CSF usually parallel plasma levels but have a 4-hour lag period. Decreased levels are seen as a result of subarachnoid hemorrhage, hypoglycemia, neoplastic or inflammatory infiltration of the meninges, and many forms of meningitis. LDH is increased in meningitis. Amino acids acting as neurotransmitters in CSF represent an important regulatory mechanism. Levels are increased in meningitis and in CSF blocks and are decreased in multiple sclerosis. Abnormalities are found in Parkinson's disease and depression.

The CSF plays an important role in the transport of peptides to target areas of the brain. Neuropeptides (e.g., endorphins) are related to higher brain functions, such as learning, memory, posture, and movement, as well as to emotions<sup>57</sup> and pain mechanisms. Persons with phantom and neurogenic pain have been found to have low CSF endorphin levels.

## Synovial Fluid Analysis

Arthrocentesis, the surgical puncture of a joint cavity for aspiration (withdrawal) of fluid, is performed by inserting a sterile needle into the joint space. Although the knee is the most commonly aspirated joint, arthrocentesis can be done on any major joint (e.g., shoulder, hip, elbow, wrist, ankle). This test is performed for many different reasons, such as to establish the presence of infection, crystal-induced arthritis, synovitis, or neoplasms.

Fluid may be aspirated from joints to determine the cause of joint effusion, or simply to relieve pressure caused by effusion due to acute trauma. Joint aspiration also offers the potential benefit of removing WBCs, a source of destructive enzymes, from the joint. Joint effusions may increase intraarticular pressure impairing synovial capillary perfusion. Removing synovial fluid via arthrocentesis could potentially improve the delivery of nutrients to cartilage and surrounding tissues.

Once the fluid sample is obtained, it is examined microscopically and chemically. Classification of synovial fluid is described in Table 40-23. Normal joint fluid is clear, colorless or straw-colored, and viscous because

of hyaluronic acid in the absence of inflammation. A small amount of blood may be caused by needle trauma; true hemarthrosis gives the fluid a homogeneous pink or red appearance. Viscosity is reduced in people with inflammatory arthritis, and the synovial fluid tends to drip like water; fluid of high viscosity forms a string several inches long.

The mucin clot test correlates with the viscosity and is performed by adding acetic acid to joint fluid. Cell counts are also performed, including a WBC count (normal joint fluid contains fewer than  $200/\text{mm}^3$ ) and neutrophils (PMNs). The concentration of WBCs determines cloudiness.

Although a low WBC count usually indicates a noninflammatory condition, a higher count does not exclude traumatic effusion. Synovial fluid WBC counts may approach  $100,000/\mu\text{l}$  immediately after joint surgery. Normal synovial fluid contains 25% or fewer neutrophils. A very high percentage of PMNs ( $>75\%$ ) is found in most people with acute bacterial infectious arthritis (see Table 40-23).

Fluid containing 70% or more of PMNs may indicate an inflammatory process even if the total WBC count is low. The presence of crystals, which is usually associated with an inflammatory process, can be determined by examining the synovial fluid under polarized light. This test is used to differentiate between gout and pseudogout and sometimes other crystal-induced arthropathies. Finding characteristic crystals does not rule out concomitant infection.

## Pleural and Pericardial Fluid Analysis

Accumulations of fluid around the lungs and heart may result from inflammatory diseases, neoplastic disease, infection, or altered lymphatic drainage. Either of these compartments may be affected in isolation or both may be affected, particularly in systemic inflammatory diseases such as amyloidosis, sarcoidosis, rheumatoid arthritis, or SLE. Accumulation of fluid in the pleural space may reduce the inflation of the lungs during inspiration or increase the work of breathing, and in severe cases, cause respiratory failure.

The pericardial space may be filled with inflammatory fluid or blood. Pericarditis may produce audible changes (friction rub) and electrocardiographic changes and other symptoms. Filling of the pericardium with blood, however, is a potentially life-threatening condition called *hemopericardium*.

When the right side of the heart cannot fill sufficiently to maintain cardiac output, the condition is known as *cardiac tamponade* resulting in acute heart failure. Fluid can be drawn from either the pleural (pleurocentesis) or pericardial spaces (pericardiocentesis) with a needle for either analysis or to relieve pressure within these spaces.

Peritoneal fluid may accumulate for a large number of reasons, including hepatic failure. Fluid drawn from the peritoneum will be analyzed for infectious agents, cancer cells, electrolytes, and other fluid components to investigate the reason for ascites, the term used to describe peritoneal fluid accumulation. Withdrawal of fluid from the peritoneum is paracentesis.

**Table 40-23** Classification of Synovial Fluid

	<b>Normal</b>	<b>Noninflammatory</b>	<b>Inflammatory</b>	<b>Infectious/Septic</b>
Color	Clear to yellow	Straw-colored, yellow	Yellow to white	Yellow to white, cloudy to opaque
Clarity	Transparent	Transparent	Translucent to cloudy	Opaque
WBCs/mm <sup>3</sup>	<200	200-2000	2000-100,000	>75,000
PMNs	<25%	<25%	>50%	>75% (tuberculosis: 20% to 80%)
Crystals	0	0	May be +	0
Examples	—	Osteoarthritis, trauma, aseptic necrosis, SLE	RA, gout, pseudogout, SLE, seronegative spondyloarthropathies	Bacterial infection, tuberculosis, fungal disease

WBCs, White blood cells; PMNs, neutrophils; RA, rheumatoid arthritis; SLE, systemic lupus erythematosus.

### SPECIAL IMPLICATIONS FOR THE THERAPIST 40-12

#### Fluid Analysis

##### Cerebrospinal Fluid

To prevent a spinal headache after lumbar puncture, the client may be instructed to stay flat in bed for several hours. However, most adults and children who receive a lumbar puncture in an outpatient setting are allowed to go home without position restrictions. Any report of numbness or tingling in the lower extremities or drainage of blood or CSF at the puncture site must be reported.

##### Synovial Fluid

Joint infection is a rare complication of arthrocentesis and does not normally result from introducing skin bacteria into a joint but rather from rupturing a blood vessel with the aspirating needle in the presence of bacteremia (or when fluid from a contaminated vial is injected into the joint).<sup>72</sup> After arthrocentesis, the therapist should assess the joint for any pain, fever, or swelling (i.e., indicators of infection). Ice can be applied to reduce pain and swelling, and the pressure dressing should be kept on the joint to avoid further joint fluid collection or development of a hematoma. The client should avoid strenuous use of the joint for 48 to 72 hours.

##### Pleural Fluid

After thoracentesis, the client is positioned on the unaffected side to rest the site of insertion and allow the puncture site to seal itself. Therapy is not usually performed until the wound has sealed itself; the therapist should check with nursing staff before proceeding with any therapy, especially manual therapy involving the thorax or chest physical therapy (breathing exercises can be initiated sooner than percussion or vibration). If the client has no complaints of dyspnea,

normal activity can be resumed approximately 1 hour after the procedure.

Possible aftereffects of the procedure include pneumothorax, accumulation of air in the tissues of the skin (subcutaneous emphysema), and bacterial infection. Report any signs of dizziness, changes in skin color, and respiratory and heart rate changes. Other signs of complications after thoracentesis include anxiety, fever, restlessness, excessive coughing, blood-tinged sputum, and tightness of the chest. Assess lung sounds for diminished breath sounds, a possible sign of pneumothorax.

##### Peritoneal Fluid

After paracentesis, the therapist must watch for signs of hypotension if a large volume of fluid was removed. Vital signs must be monitored for any evidence of hemodynamic changes, and any signs of continued drainage, bleeding, or inflammation at the puncture site must be reported. If albumin infusions are ordered after a paracentesis (to compensate for the protein loss—ascitic fluid has a high protein content), the therapist must also monitor for signs of protein and electrolyte (especially sodium) imbalance.

Paracentesis may precipitate hepatic coma in someone with chronic liver disease. The therapist should observe for any indications of shock (e.g., pallor, cyanosis, or dizziness), which would constitute an emergency situation.

#### References

To enhance this text and add value for the reader, all references are included on the companion Evolve site that accompanies this textbook. The reader can view the reference source and access it on-line whenever possible. There are a total of 89 cited references and other general references for this chapter.

## APPENDIX A

# Summary of Standard Precautions<sup>2</sup>

### HISTORICAL PERSPECTIVE

The Centers for Disease Control and Prevention (CDC) and the Hospital Infection Control Practices Advisory Committee (HICPAC) have developed (and continue to revise) the CDC Guideline for Isolation Precautions in Hospitals. These guidelines were developed to assist hospitals in maintaining up-to-date isolation practices governing infection control and strategies for surveillance, prevention, and control of nosocomial infections in U.S. hospitals.

*Nosocomial infection* is a term used to refer only to infections acquired in hospitals. A new term, *health care-associated infection* (HAI), is used now to refer to infections associated with health care delivery in any setting, such as hospitals, long-term care facilities, ambulatory settings, and home care. This updated term reflects the inability to determine with certainty where the pathogen is acquired, since people can be colonized with or exposed to potential pathogens outside of the health care setting, before receiving health care, or while moving among the various settings within the health care system.<sup>2</sup>

The guideline recommendations are based on the latest epidemiologic information on transmission of infection in hospitals. The recommendations are intended primarily for use in the care of patients in acute care hospitals, although some of the recommendations may be applicable for some clients receiving care in subacute care or extended care facilities.

The recommendations are not intended for use in day care, well care, or domiciliary care programs. Because there have been few studies to test the efficacy of isolation precautions and gaps still exist in the knowledge of the epidemiology and modes of transmission of some diseases, disagreement with some of the recommendations is expected.

HICPAC recognizes that the goal of preventing transmission of infections in hospitals can be accomplished by multiple means and that hospitals will modify the recommendations according to their needs and circumstances and as directed by federal, state, or local regulations.

No guideline can address all the needs of the more than 6000 U.S. hospitals, which range in size from 5 beds to more than 1500 and serve very different client popula-

tions. Modification of the recommendations is encouraged if (1) the principles of epidemiology and disease transmission are maintained, and (2) precautions are included to interrupt spread of infection by all routes likely to be encountered in the hospital.

### UNIVERSAL PRECAUTIONS

In 1985, largely because of the human immunodeficiency virus (HIV) epidemic, isolation practices in the United States were altered dramatically by the introduction of a new strategy for isolation precautions, which became known as universal precautions. Following the initial reports of hospital personnel becoming infected with HIV through needlesticks and skin contamination with blood, a widespread outcry created the urgent need for new isolation strategies to protect hospital personnel from blood-borne infections.

The subsequent modification of isolation precautions in some hospitals produced several major strategic changes and sacrificed some measures of protection against client-to-client transmission in the process of adding protection against client-to-personnel transmission.

In acknowledgment of the fact that many clients with bloodborne infections are not recognized, the new universal precautions approach for the first time placed emphasis on applying blood and body fluid precautions universally to all people regardless of their presumed infection status. Until this time, most clients placed on isolation precautions were those with a diagnosis or a suspicion of an infectious disease. This provision led to the new term *universal precautions*.

In addition to emphasizing prevention of needlestick injuries and the use of traditional barriers such as gloves and gowns, universal precautions expanded blood and body fluid precautions to include the use of masks and eye coverings to prevent mucous membrane exposure during certain procedures and the use of individual ventilation devices when the need for resuscitation was predictable. This approach, and particularly the techniques for preventing mucous membrane exposures, was reemphasized in subsequent CDC reports that contained recommendations for prevention of HIV transmission in health care settings.

**Table A-1** Recommendations for Application of Standard Precautions for the Care of All Patients in All Health Care Settings

Component	Recommendations
Hand hygiene	After touching blood, body fluids, secretions, excretions, contaminated items; immediately after removing gloves; between patient contacts
Personal protective equipment (PPE)	See text
Gloves	For touching blood, body fluids, secretions, excretions, contaminated items; for touching mucous membranes and nonintact skin
Mask, eye protection, face shield	During procedures and patient care activities likely to generate splashes or sprays of blood, body fluids, secretions
Gown	During procedures and patient care activities when contact of clothing/exposed skin with blood/body fluids, secretions, and excretions is anticipated
Soiled patient care equipment	Handle in a manner that prevents transfer of microorganisms to others and to the environment; wear gloves if visibly contaminated; perform hand hygiene
Environmental control	Develop procedures for routine care, cleaning, and disinfection of environmental surfaces, especially frequently touched surfaces in patient care areas
Textiles (linen and laundry)	Handle in a manner that prevents transfer of microorganisms to others and to the environment
Needles and other sharps	Do not recap, bend, break, or hand-manipulate used needles; use safety features when available; place used sharps in puncture-resistant container
Patient resuscitation	Use mouthpiece, resuscitation bag, other ventilation devices to prevent mouth contact
Patient placement	Prioritize for single-patient room if patient is at increased risk of transmission, is likely to contaminate the environment or does not maintain appropriate hygiene, or is at increased risk of acquiring infection or developing adverse outcome following infection
Respiratory hygiene/cough etiquette (source containment of infectious respiratory secretions in symptomatic patients, beginning at initial point of encounter)	Instruct symptomatic persons to cover mouth/nose when sneezing/coughing; use tissues and dispose in no-touch receptacle; observe hand hygiene after soiling of hands with respiratory secretions; wear surgical mask if tolerated or maintain spatial separation, >3 ft if possible

From Department of Health and Human Services, Centers for Disease Control and Prevention: *Supplement I: Infection control in healthcare, home, and community settings*, Atlanta, 2005, Centers for Disease Control and Prevention.

## STANDARD PRECAUTIONS

The revised guideline contains two tiers of precautions to update universal precautions with a change in nomenclature (*universal precautions* being replaced by *standard precautions*): standard precautions and transmission-based precautions. Components of all standard precautions are listed in Table A-1.

### Standard Precautions

Most important, standard precautions are designed for the care of all patients in hospitals regardless of their diagnosis or presumed infection status. Implementation of these standard precautions is the primary strategy for successful nosocomial infection control.

Standard precautions synthesize the major features of universal (blood and body fluid) precautions (designed to reduce the risk of transmission of bloodborne pathogens) and body substance isolation (designed to reduce the risk of transmission of pathogens from moist body substances). Standard precautions apply to (1) blood; (2) all body fluids, secretions, and excretions, except sweat, regardless of whether or not they contain visible blood; (3) nonintact skin; and (4) mucous membranes.

Standard precautions are designed to reduce the risk of transmission of microorganisms from both recognized and unrecognized sources of infection in hospitals.

### Transmission-Based Precautions

Transmission-based precautions are designed only for the care of specified patients known or suspected to be infected or colonized by epidemiologically important pathogens that can be transmitted by airborne or droplet transmission or by contact with dry skin or contaminated surfaces.

Transmission-based precautions are designed for patients documented or suspected to be infected or colonized by highly transmissible or epidemiologically important pathogens for which additional precautions beyond standard precautions are needed to interrupt transmission in hospitals.

There are three types of transmission-based precautions: *airborne precautions/airborne infection isolation room*, *droplet precautions*, and *contact precautions*. They may be combined for diseases that have multiple routes of transmission. When used either singly or in combination, they are to be used in addition to standard precautions.

### Airborne Infection Isolation

Airborne infection isolation refers to the isolation of patients infected with organisms spread via airborne droplet nuclei less than 5 µm in diameter. The isolation area receives numerous air changes per hour (ACH) (12 or more ACH for new construction as of 2001; 6 or more

ACH for construction before 2001) and is under negative pressure, such that the direction of the airflow is from the outside adjacent space (e.g., the corridor) into the room.<sup>7</sup>

The air in an airborne infection isolation room is preferably exhausted to the outside but may be recirculated provided that the return air is filtered through a high-efficiency particulate air (HEPA) filter. The use of personal respiratory protection is also indicated for persons entering these rooms when caring for tuberculosis or smallpox patients and for staff who lack immunity to airborne viral diseases (e.g., measles or varicella zoster virus [VZV] infection).<sup>7</sup>

## Preventive Environment

A set of preventive measures termed *protective environment* has been added to the standard precautions used to prevent HAL. These measures consist of engineering and design interventions that decrease the risk of exposure to environmental fungi for severely immunocompromised recipients of allogeneic hematopoietic stem cell transplant (HSCT) during their highest-risk phase, usually the first 100 days after transplantation, or longer in the presence of graft-versus-host-disease.<sup>2</sup>

## Protective Environment

A protective environment is a specialized patient care area, usually in a hospital, with a positive airflow relative to the corridor (i.e., air flows from the room to the outside adjacent space). The combination of HEPA filtration, high numbers of ACH (12 or more ACH), and minimal leakage of air into the room creates an environment that can safely accommodate patients who have undergone HSCT.<sup>7</sup>

## SOURCES OF POTENTIAL EXPOSURE FOR THE THERAPIST

Standard precautions are intended to prevent occupational transmission of infectious diseases such as tuberculosis, HIV infection, hepatitis B, and hepatitis C. All body secretions and moist membranes and tissues (excluding perspiration) are considered to be potentially infectious and require the use of barriers and/or isolation techniques to prevent transmission of organisms.<sup>2,4</sup>

Therapists at greatest risk include those who perform electromyographic studies, therapists in direct contact with clients with tuberculosis (see also Box 15-4), therapists who provide wound management, and those who assess or treat temporomandibular joint (TMJ) disorder or perform manual lymphatic drainage inside the mouth.

Any therapist who assists in toileting or changing diapers (in adults or children) is at increased risk. Other risk factors include human bites and contact with sputum and pleural fluid tinged with blood (bloodborne pathogens). Health care workers are at increased risk of bacterial colonization from damaged skin on the hands after frequent handwashing.

## Mode of Transmission

The potential for hepatitis B virus (HBV) and hepatitis C virus (HCV) transmission in the workplace is 20 times greater than that for HIV, but the modes of transmission for these viruses are similar. All have been transmitted in occupational settings *only* by percutaneous inoculation or contact with an open wound, nonintact skin (e.g., cutaneous scratches; chapped, abraded, weeping, burned, or dermatitic skin), or bloody mucous membranes, blood-contaminated body fluids, or concentrated virus. *Blood is the single most important source of HIV, HBV, and HCV in the workplace.*

In the hospital and other health care settings, standard precautions should be followed when workers are exposed to blood, certain other body fluids (amniotic fluid, pericardial fluid, peritoneal fluid, pleural fluid, synovial fluid, cerebrospinal fluid, semen, and vaginal secretions), or any body fluid visibly contaminated with blood.

HBV can be transmitted through infected saliva, but saliva has not been implicated in HIV transmission except in the dental setting, in which saliva may be contaminated with blood. HBV and HIV transmission has not been documented from exposure to other body fluids, such as nasal secretions, sweat, tears, urine, or vomitus. However, standard precautions still apply whenever handling any body secretions. People who are sexually active should be aware that HIV is intermittently shed in semen.<sup>1</sup>

These fluids are most likely to transmit bloodborne pathogens. The hepatitis B vaccine substantially reduces the risk of infection and is available at no charge to all employees who have occupational exposure to the virus. It is considered so important that an employee must sign a letter of declination if declining the vaccine. Currently there are no vaccines available for HCV or HIV.

## Guidelines for Infected Health Care Workers

Any health care worker with HIV or the most virulent form of hepatitis B or C should not perform exposure-prone procedures in which blood contact might occur. Permission and guidance from special review committees are required before an infected health care worker can perform such procedures.

For the therapist, this would primarily exclude wound care, including debridement and dressing changes. According to guidelines drafted by the CDC, at a minimum, the potential client must be informed of the worker's HIV, hepatitis B, or hepatitis C status if the health care worker will be performing specific exposure-prone procedures.

## Barrier Precautions (Personal Protective Equipment)

Exposure to blood and body fluids can be minimized through the proper use of personal protective equipment (PPE). However, *PPE is not a substitute for good engineering, work practice, and administrative controls, but should be used in conjunction with these controls to provide for a safe*

and healthy workplace. The CDC has provided the following guidelines for putting on, using, and removing PPE<sup>1</sup>:

- All health care workers should routinely use appropriate barrier precautions to prevent skin and mucous membrane exposure when contact with blood or other body fluids of any person is anticipated.
- Gloves should be worn for touching blood and body fluids, mucous membranes, blisters, lesions, and nonintact skin of all persons; gloves should be pulled up over the cuffs of the gown.
- Gloves should be changed and hands washed after contact with each client.
- A thin layer of water-based skin care product (e.g., Aquafor, Eucerin, O'Keeffe's Working Hands Creme) should be applied after glove removal to prevent skin chapping, which is a potential risk factor for employees. Petroleum-based hand creams or lotions, which can damage latex gloves, should not be used.
- Masks and protective eyewear or face shields should be worn during procedures that are likely to generate droplets of blood or other body fluids to prevent exposure of mucous membranes of the mouth, nose, and eyes. Goggles or face shields should come equipped with a foam brow band, which prevents blood and body fluids from dripping from the forehead into the eyes. See also Box 15-4 for additional information regarding specific protective masks (called respirators) to wear when treating clients with active tuberculosis.
- Fluid-proof gowns or aprons should be worn during procedures that are likely to generate splashes of blood or other body fluids. The opening is worn in the back and the gown should be secured. If the gown does not close, a second gown with the opening in the front should be worn.
- Therapists treating clients with whirlpool or pulsatile lavage with suction should wear hair cover; mask; face shield; fluid-proof, long-sleeved gown; knee-high, fluid-resistant boots; and gloves covering the gown cuffs. Shoulder-length gloves should be available for those working with whirlpools. See Box A-1.
- Hands should be washed before and after client contact, after removing PPE and gloves, and immediately if hands are grossly contaminated with blood.
- Hands and other skin surfaces should be washed immediately and thoroughly if contaminated with blood or other body fluids. Hands should be washed immediately after gloves are removed. Antiseptic hand cleaner should be used when handwashing facilities are unavailable.
- Sharp instruments, such as scissors or scalpels, should be handled with great care and disposed of in puncture-resistant containers. Needles should never be manipulated, bent, broken, or recapped.
- Pocket masks or mechanical ventilation devices should be available in areas in which cardiopulmonary resuscitation procedures are likely.

#### Box A-1

#### STANDARD PRECAUTIONS IN THE USE OF PULSATILE LAVAGE WITH SUCTION (PLWS)

##### **PLWS Use and Maintenance**

- Read all device instructions for use and recommended techniques to minimize environmental contamination.
- Use continuous suction (60 to 100 mm Hg).
- Position the splash shield to remain in contact with the wound/periwound area at all times.
- Dispose of the suction waste canister after each use.
- Dispose of all single-use pulsatile lavage components immediately after use.
- Disinfect any reusable item(s). (Only a suction diverter handpiece can be reused—nothing can be sterilized to be reused.)

##### **Environmental Controls**

- Always perform PLWS in an appropriately ventilated private room enclosed with walls and doors that shut.
- Minimize potential contamination of equipment and supplies; do not leave shelves or cabinets open.
- Cover surfaces at risk for aerosol contamination.
- After each treatment clean and disinfect environmental surfaces that can be touched by hand.

##### **Personal Protective Equipment**

- Wear a fluid-proof gown; gloves; mask, goggles, or face shield; and hair and shoe covers.
- Provide patient/client with a droplet barrier (e.g., surgical mask) when appropriate during PLWS treatment.
- Cover all entrance sites of lines and ports, and wounds that are not being treated.

Data from Loehne HB: Pulsatile lavage with concurrent suction. In Sussman C, ed: *Wound care: a collaborative practice manual for health professionals*, ed 3, Philadelphia, 2006, Lippincott Williams & Wilkins; and Fuller J: Cover up and clean up to prevent deadly infections, *Nursing 2005* 35(1):31, 2005.

- A mask or particulate respirator should be worn over the nose, mouth, and chin; the flexible nosepiece should be fit over the bridge of the nose and secured with fasteners or elastic. Particulate respirators must fit properly; to check the fit, inhale then exhale: the respirator should collapse during inhalation and there should be no air leaking out during exhalation.
- Health care workers who have exudative lesions or weeping dermatitis should refrain from all direct client care and from handling equipment belonging to the client until the condition resolves.
- Eating, drinking, applying lip balm or lipstick, and handling contact lenses is prohibited in any area where clients or their body fluids are present.

Once the PPE is in use properly, the therapist should avoid touching or adjusting the PPE; keep your gloved hands away from your face. Remove and replace the gloves if they become torn, heavily soiled, or contaminated. Perform hand hygiene before putting on new gloves.<sup>2</sup>

When the procedure or client visit is completed, remove all PPE except respirators at the doorway before

leaving the room. Respirators can be removed outside the client's door, after closing the door. Continue to practice standard precautions by removing remaining pieces of PPE carefully and correctly avoiding contact with the potentially contaminated exterior surfaces of gloves, face shield, gowns, and so on. Turn gloves and gown inside out as you remove them and discard appropriately. Perform hand hygiene when all pieces of equipment are removed and discarded.<sup>6</sup>

### **Handwashing**

Frequent handwashing has always been recommended as the most effective means of infection control prevention. The subject of handwashing, indications for handwashing, and proper hand hygiene technique are discussed in detail in Chapter 8 (see Boxes 8-4 and 8-5).

When using an alcohol-based hand rub, the antiseptic must remain in contact with all skin surfaces for 15 seconds to kill viruses and other pathogens. Keep the skin moisturized to prevent dry and chapped hands, which provide an opening for pathogens.

The CDC's current recommendations can be found at the CDC Hand Hygiene in Healthcare Setting page at

<http://www.cdc.gov/handhygiene/> (accessed August 9, 2007). Every therapist is strongly encouraged to take the time to read this document regardless of his or her current clinical setting.

### **Pulsatile Lavage with Suction**

Pulsatile lavage with suction (PLWS), a high-pressure irrigation treatment used by physical therapists as a wound debridement system, can aerosolize infectious agents at least 8 feet. Infection control precautions must be used routinely during the procedure (see Box A-1); failure to do so has been linked with an outbreak of multidrug-resistant *Acinetobacter baumannii* from environmental contamination.<sup>7</sup>

### **References**

To enhance this text and add value for the reader, all references are included on the companion Evolve site that accompanies this textbook. The reader can view the reference source and access it on-line whenever possible. There are a total of seven cited references and other general references for this chapter.

## APPENDIX B

# Guidelines for Activity and Exercise

Frequently, older adults with orthopedic dysfunction are inactive, hypertensive, and have multiple risk factors for comorbidities. These factors often are not documented, and the client is treated as an orthopedic case without regard for the past medical history or current cardiopulmonary (or other) condition.

For these reasons, the health care provider must view the effect of other systems on the client's orthopedic condition and rehabilitation outcome. A thorough evaluation may be necessary, and monitoring cardiopulmonary responses to exercise may be required. Postoperative considerations for various conditions are important when planning a rehabilitation program; these guidelines are listed in each section throughout this text whenever possible.

Exercise should be specific to the functional and medical needs of each individual. Whenever possible, physical activity and exercise should be at a level that causes minimal to no symptoms, and progression should be built into the program. For the aging adult, physiologic homeostasis may be altered by stress, medications, illness, and exercise. To assist in balancing and maintaining homeostasis, 1 day of rest between each day of exercise may be recommended for some individuals.

Interval training, consisting of short-term periods of ambulation followed by rest, is now recommended. Such a program activates the oxygen transport to skeletal and circulatory systems for completion of an activity of daily living to develop endurance. Progress slowly by increasing duration to 30 minutes before increasing intensity. Encourage the client to keep an exercise diary that includes any symptoms that may occur during or after exercise. Review the diary and compare this report to the client's verbal report, because the person may forget or deny important information.

### MEDICATIONS AND EXERCISE

Some clients may be taking medications that can have considerable side effects and interactions when combined with other medications, including effects on exercise parameters such as heart rate, blood pressure, or respiratory rate. Medications can also affect balance, posture, motor control, sleep, and mood, which may affect the individual's performance in rehabilitation. Common

drugs with side effects that may affect an exercise program are listed in Table B-1.

People who are taking drugs that can cause volume depletion or orthostatic hypotension should have their blood pressure and pulse checked in both reclining and standing positions. Avoiding sudden postural changes or activities, limiting activities that promote vasodilation, and providing an adequate warm-up and cool-down period are essential. See also Special Implications for the Therapist: Orthostatic Hypotension in Chapter 12. Therapeutic intervention, especially exercise, should be scheduled according to medication peak blood levels to minimize effects on participation and to enhance rehabilitation performance.

### GUIDELINES FOR MONITORING VITAL SIGNS

It is important to know normal responses to movement and activity (including exercise) to be able to identify abnormal responses in the client with a medical diagnosis. Safe and effective exercise can be measured in part by monitoring vital sign responses (temperature, heart rate, respiratory rate, blood pressure, oxygen saturation, pain levels). Such data can be used as specific outcome measures to substantiate decision making. For example, how quickly the heart rate returns to normal is an outcome measurement of fitness and conditioning.

Anyone with a significant past medical history of cardiovascular or pulmonary disease requires monitoring of vital signs and perceived exertion during exercise. The more coronary risk factors present (see Table 12-3), the greater the need for monitoring. For any client with known coronary artery disease and/or previous history of myocardial infarction, exercise testing should be performed before an exercise program is undertaken.

If this testing has not been accomplished and baseline measurements are unavailable for use in planning exercise, the therapist must monitor the client's heart rate and blood pressure and note any accompanying symptoms during exercise. Too rapid a rise in heart rate, respiratory rate, or blood pressure for the workload is a general indication for modifying the activity or exercise program (see later discussion under Abnormal Heart Rate Response and Abnormal Respiratory Rate Response).

**Table B-1** Common Drugs That May Affect an Exercise Program

Drugs	Effects
Anticoagulants	Bleeding into tissues; see Table 40-9
Antidepressants, antipsychotics	Sedation, lethargy, muscle weakness; orthostasis and falls, arrhythmias Antipsychotics only: extrapyramidal motor effects (change in posture, balance, and involuntary movements)
Antihypertensive agents	Hypotension; orthostasis and falls
$\beta$ -Adrenergic blockers	Reduced exercise capacity ( $\beta$ -blockers) Decreased heart rate (resting and exercise), fatigue, masking of hypoglycemic symptoms
Corticosteroids	See Table 5-4
Immunosuppressants	See Table 5-3
Nonsteroidal antiinflammatory drugs (NSAIDs)	See Table 5-2
Diuretics	Hypokalemia—arrhythmias, muscle cramps (see Chapter 5) Dehydration—orthostasis and falls, thermoregulatory disturbance Elevated heart rate with all activity
Insulin, oral hypoglycemics	Hypoglycemia
Pain medication, narcotics, opioids	Blunted respiratory response, sedation, lethargy, muscle weakness, incoordination
Thyroid medication	Altered metabolic state (see Chapter 5) Impaired cardiopulmonary function Myalgias, stiffness, trigger points See further discussion in Chapter 11
Tranquilizers, sedatives	Relaxation, reduced coordination; orthostasis and falls

See also Table 12-5 and Box 5-2.

Type of exercise may make a difference in the changes observed in vital signs in older adults. Measurement of heart rate and blood pressure responses to typical isometric, isokinetic, and eccentric resistance-training protocols in older adults showed that changes in blood pressure, arterial pressure, and rate-pressure product were significantly greater during isometric exercise than during eccentric exercise. Clinically, an isokinetic eccentric exercise program enables older adults to work at the same torque output with less cardiovascular stress than isometric exercise.<sup>17</sup>

## Temperature

Normal body temperature is not a specific number but a range of values that depends on factors such as the time of day, age, medical status, and presence or absence of infection. Oral body temperature ranges from 96.8° to 99.5° F (36° to 37.5° C) with an average of 98.6° F (37° C) (Table B-2).

The clinical implications of fever and approach to fever vary considerably from person to person, institution to institution, and physician to physician. For example, there is a tendency among the aging population to develop an increase in temperature on hospital admission or in response to any change in homeostasis. Alternatively, fever in older adults residing in extended care facilities may suggest an infectious process, whereas postoperative fever can indicate a surgical complication, such as intraabdominal abscess, leaking anastomosis with peritonitis, or an infected surgical site or prosthesis (e.g., valve, joint, graft). Fever response in adults older than 75 years is often blunted and sometimes even absent.

Others who may remain afebrile in the presence of significant infectious pathology include those who are

**Table B-2** Body Temperature Conversions

Celsius (°C)	Fahrenheit (°F)
34.0	93.2
35.0	95.0
35.6	96.1
35.8	96.4
36.0	96.8
36.2	97.2
36.4	97.5
36.6	97.9
36.8	98.2
<b>37.0</b>	<b>98.6</b>
37.2	99.0
37.4	99.3
37.6	99.7
37.8	100.0
38.0	100.4
38.2	100.8
38.4	101.1
38.6	101.5
38.8	101.8
39.0	102.2
39.2	102.6
39.4	102.9
39.6	103.3
39.8	103.6
40.0	104.0
40.2	104.4
40.4	104.7
40.6	105.2
40.8	105.4
41.0	105.9
41.2	106.1
41.4	106.5
42.0	107.6
42.4	108.3
43.0	109.4

**Table B-3** Normal Resting Pulse Rates Across Age Groups

Age	Average Beats/Min	Normal Limits (Beats/Min)
Newborn	125	70-190
1 yr	120	80-160
2 yr	110	80-130
4 yr	100	80-120
6 yr	100	75-115
8-10 yr	90	70-110
12 yr		
Female	90	70-110
Male	85	65-105
14 yr		
Female	85	65-105
Male	80	60-100
16 yr		
Female	80	60-100
Male	75	55-95
18 yr		
Female	75	55-95
Male	70	50-90
Well-conditioned athlete	May be 50-60	50-100
Adult	—	60-80
Aging	—	60-100

From Behrman RE, Kliegman RM, Jenson HB: *Nelson textbook of pediatrics*, ed 17, Philadelphia, 2004, Saunders.

immunocompromised (e.g., transplant recipients, corticosteroid users, individuals with cancer undergoing treatment), alcoholics, individuals with chronic renal insufficiency, and anyone taking excessive antipyretic medications. Establishing a basal body temperature and monitoring for changes in temperature (of more than 2.4°F [1.3°C]) can assist in early detection of infection (see Box 8-1 for other manifestations of infection).<sup>7,28</sup>

Single temperature spikes (sudden elevation that returns to normal without intervention) is usually of no diagnostic significance unless it occurs in an immunocompromised individual.<sup>10</sup> Common causes of sustained fever are listed in Box 8-2 and Table 8-1. Unexplained fever in adolescents may be a manifestation of drug abuse or endocarditis.

The therapist should use discretionary caution with anyone who has a fever. Exercise with a fever stresses the cardiopulmonary and immune systems, which may be further complicated by dehydration.

## Heart Rate (Pulse Rate)

Measuring the heart rate by taking the pulse is really a measurement of the pulse rate. A true measure of the heart rate requires measurement of the electrical impulses of the heart. Resting heart rate is age dependent, with minimal variation for each individual within the normal ranges.

The normal range for the resting pulse rate is 60 to 100 beats/min (or bpm). A rate above 100 beats/min indicates tachycardia; below 60 beats/min indicates bradycardia. Some variations occur with age and training (Table B-3). For example, a well-trained athlete whose heart

### Box B-1

#### FACTORS AFFECTING HEART RATE

- Age
- Anemia
- Anxiety, panic
- Autonomic dysfunction (e.g., diabetes, spinal cord injury)
- Caffeine
- Cardiac muscle dysfunction
- Deconditioned state
- Dehydration (decreased blood volume causes increased heart rate)
- Drugs (e.g., blood pressure medication; asthma inhalants; antihistamines, such as over-the-counter cold medications; narcotics)
- Emotional or psychologic stress
- Exercise
- Fear
- Fever
- Hyperthyroidism
- Infection
- Pain
- Potassium level
- Sleep disturbances/sleep deprivation
- Stress

muscle develops along with the skeletal muscle may have a resting heart rate of less than 60 beats/min.

The force of the pulse represents the strength of the heart's stroke volume. A weak, thready pulse reflects a decreased stroke volume, such as occurs with hemorrhagic shock. A full, bounding pulse indicates an increased stroke volume, possibly associated with anxiety, exercise, or some pathologic condition. The pulse force (pulse amplitude) is recorded using the following three-point scale (some physicians/nurses use a four-point scale):

- 3+ Full, bounding
- 2+ Normal
- 1+ Weak, thready
- 0 Absent

The pulse should be measured before and during the activity using the same position both times. Count for 6 seconds and add a 0 to that number for a beats-per-minute count or count for 10 seconds and multiply by 6. Heart rate response should increase gradually with an increase in the workload of the heart. Once a steady state has been achieved, little change should occur in heart rate during sustained endurance activities (e.g., water aerobics, riding a stationary bicycle). Factors affecting heart rate responses are listed in Box B-1.

Heart rate responses are different in the deconditioned person because the resting heart rate is higher to begin with. The heart rate increases more rapidly for the same workload compared to the change in a healthy individual. A rapid heart rate may occur during activity in response to dehydration, because the decreased plasma volume results in decreased blood volume and subsequent decreased blood to the heart.

A decreased stroke volume (volume ejected per heart-beat) is compensated for by a higher heart rate to match the demands for oxygen caused by the activity. *Cardiac muscle dysfunction* is the term used when a decreased

stroke volume occurs as a result of diseased cardiac muscle that can no longer contract and pump blood out of the heart normally. Decreased stroke volume results in a more rapid rise in heart rate unless the person is taking (3-blocking) medication.

Aging is accompanied by a decreasing maximum heart rate. The age-predicted method for calculating the predicted maximal (target) heart rate (PMHR) is  $220 - \text{age}$ . For example, for a 70-year-old the PMHR =  $220 - 70$ , or 150 beats/min. This principle is based on the fact that the heart's maximal rate is 220 beats/min and that this maximal rate declines by one beat each year (probably as a result of the heart's stiffening and becoming less compliant).<sup>19</sup>

Some concern about the use of this formula has been raised; some consider it inaccurate because it was based on early research that only examined sedentary men under the age of 60. The formula does not take into account female gender, older age, diagnosis, fitness level, or the presence of comorbidities. It has been suggested that the standard formula underestimates maximum heart rate in older adults. This would have the effect of underestimating the true level of physical stress imposed during exercise testing and the appropriate intensity of prescribed exercise programs.<sup>27</sup>

This method should not be applied to individuals with peripheral neuropathies, those with chronotropic incompetence (irregular contraction of the heart), or clients taking  $\beta$ -blockers for hypertension and angina. The  $\beta$ -blockers are medications that block the sympathetic nervous system's input to the receptors in the heart, therefore affecting heart rate and contractility. The net effect is a decrease in the resting and exercise heart rate (drug-induced bradycardia).

The most accurate way to determine maximum heart rate is a stress test in consultation with a cardiologist. Since this is not practical or cost effective, the therapist can teach the client how to use rating of perceived exertion (RPE) as a more user-friendly method. For most clients, it is best to wait until the person has exercised for at least 5 minutes before applying the formula. When using the 6 to 20 scale (very, very light effort to very, very hard effort), multiply the RPE number that matches the client's effort and multiply by 10. This figure gives a close estimate of the actual heart rate; cardiovascular (aerobic) exercise should be in the 11 to 14 RPE range.<sup>5</sup>

There is a revised formula that may be more accurate:  $208 - (\text{age} \times 0.70)$ .<sup>27</sup> For a 70-year-old, using this formula would suggest a maximum heart rate of 159 beats/min. This method does require accurate measurement of the pulse and a calculator and may still be off by up to 8 beats/min. For the active, healthy older adult, another formula has been proposed: PMHR =  $205 - 1/2 \text{ age}$ .<sup>26</sup> For example, evaluating the same 70-year-old under these conditions would be  $205 - 1/2(70)$ , or  $205 - 35$  (PMHR = 170).

Keep in mind that anyone taking cardiac medications may not be able to achieve a target heart rate above 90 beats/min. Therefore symptoms of shortness of breath or the use of RPE is a much better guideline for determining exercise intensity. Many individuals who are compromised need more time to work up to the exercise load

and to cool down. Using RPE still requires close monitoring of heart rate and blood pressure.

Other methods for prescribing exercise intensity by target heart rate include the Heart Rate Reserve (Karvonen) Method, which takes into account the person's resting heart rate; the rate-pressure product method (valid indicator of myocardial oxygen uptake); maximal oxygen consumption ( $\text{Vo}_{2\max}$  or maximal functional capacity); and the systolic blood pressure method. Information on each of these methods and their recommended applications and known limitations is available.<sup>19</sup>

Most methods for determining exercise intensity are based on target heart rates that are 40% to 85% of  $\text{Vo}_{2\max}$ . However, there are some people for whom exercise intensity should not be prescribed by a target heart rate method, such as those who are deconditioned. In such cases exercise should be prescribed at the lower end of the intensity continuum.

A safe rate of exercise will allow the heart rate to return to the resting level within 5 minutes after stopping exercise (blood pressure returns to resting levels after heart rate). Avoid increases of more than 20 beats/min over resting heart rate. (See Exercise and Antihypertensive Medications, Chapter 12.) Do not remove telemetry immediately after exercise (wait 5 to 10 minutes); in the case of cardiac transplantation, cool down may take up to 1 hour (warm-up should last 30 to 45 minutes).

## Abnormal Heart Rate Response

Heart rate should increase commensurately with exercise; as the intensity of exercise increases, the heart rate increases (e.g., like blood pressure, heart rate also increases according to metabolic equivalent [MET]; only a minimal increase in heart rate would be expected with a low-MET activity). The MET system provides one way of measuring the amount of oxygen needed to perform an activity: 1 MET = 3.5 ml of oxygen uptake, which a person requires when resting.

If the pulse is irregular, count the pulse for a full minute and document the number of beats per minute as well as the number of irregular beats (see next section). Abnormal heart rate responses include a rapid rate of rise in heart rate (judging from the activity, age, and training history) or a decreased heart rate with activity (e.g., arrhythmias or pauses in pulse). For example, a doubling of the heart rate with walking on a flat surface (no incline) would be considered outside normal parameters.

A decreased heart rate with activity may occur as a normal response when the person is sympathetically overloaded before treatment. For example, a person who takes inhalants for asthma just before therapy or who drinks more than three cups of coffee within 2 hours of the therapy appointment may have an artificially elevated baseline heart rate. Over the course of therapy, without further stimulation, this person's heart rate may decrease, especially if the therapy session has no exercise component. Factors such as these require individual evaluation of abnormal responses for each person.

Pulse amplitude (weak or bounding quality of the pulse) that fades with inspiration and strengthens with

expiration is paradoxical (paradoxical pulse) and should be reported to the physician. When there is compression or constriction around the heart (e.g., pericardial effusion, tension pneumothorax, pericarditis with fluid, pericardial tamponade) and the person breathes in, the increased mechanical pressure of inspiration added to the physiologic compression from the underlying disease prevents the heart from contracting fully and results in reduced pulse. When the individual expires, the pressure from chest expansion is reduced and the pulse increases. A pulse increase of over 20 beats/min lasting for more than 3 minutes after rest or changing position should also be reported.

If ischemia occurs as evidenced by angina or (on visual readout) depression of ST segment on electrocardiogram, the person should rest and then return to an activity level below ischemic level. For example, if the ST segment drops below baseline with activity or the client experiences angina when the heart rate is at 140 beats/min, the activity level should be reduced so that the heart rate remains below 140 beats/min.

## Heart Rhythm

For the person with an abnormal heart rhythm, the pulse should be palpated throughout the activity if no electrocardiogram or Holter monitor reading is available during exercise. If any abnormal pulse beats are noted (e.g., absent, irregular), the number of pauses per minute should be counted at rest and during activity. There should be no more than six abnormal or absent beats per minute. The normal heart rhythm should not change, and individuals with arrhythmias at rest should not show an increase in number of irregular heartbeats with increased activity.

## Respiratory Rate

Normal resting respiratory rates are presented in Table B-4. The ratio of pulse rate to respiratory rate is fairly constant (4:1). The respirations can be counted at the same time that the pulse is counted. If an abnormality is suspected, these measurements should be taken for a full

minute. A normal pulmonary response to exercise is an increase in breathing rate and depth based on body type and disease present. Factors that can affect respiratory rate include the following:

- Altered lung compliance (chronic obstructive pulmonary disease [COPD], hyaline membrane disease) or any other restrictive condition
- Airway resistance (asthma)
- Alterations in lung volumes/lung capacity (smokers, persons with emphysema or occupational lung disease)
- Body position (diaphragm cannot drop down enough to expand the lungs in the fully supine position in the pregnant, obese, or spinal cord-injured client)

## Abnormal Respiratory Rate Response

An abnormal respiratory rate response is usually characterized by too rapid a rise in respiratory rate for the activity and medical condition of the client. Increases in respiratory rate greater than 10 respirations/min must be monitored carefully. Measuring the respiratory rate may be difficult. The client must be observed for how much work is required to breathe, and whenever possible, a pulse oximeter should be used to measure arterial oxygen saturation noninvasively (Fig. B-1).

### Pulse Oximetry

The saturation of hemoglobin with oxygen can be measured via pulse oximetry ( $\text{SpO}_2$ ) or arterial blood gas (ABG) analysis ( $\text{Sao}_2$ ). A normal  $\text{SpO}_2$  or  $\text{Sao}_2$  value is 95% or higher. An  $\text{Sao}_2$  or  $\text{SpO}_2$  value below 90% means the  $\text{PaO}_2$  is below 60 mm Hg, indicating the person is not adequately oxygenated ( $\text{PaO}_2$  is a measure of the pressure of oxygen dissolved in plasma as measured by ABG analysis).

The  $\text{PaO}_2$  at rest may decline with age because of a loss of surface respiratory space for ventilatory exchange, especially in adults 70 years old or older. The  $\text{PaO}_2$  increases with activity in older adults as blood volume and respiratory volume increase.<sup>8</sup>

Using a pulse oximeter with the pulmonary population can provide an outcome measure with exercise for documentation. Oxygen saturation values must be interpreted within the context of the person's medical status as well as respiratory and metabolic status (as determined by ABG measurements). Respiratory and metabolic status are taken into consideration, because shifts in the oxyhemoglobin curve caused by factors such as temperature fluctuations or acidosis will change the affinity of oxygen to the hemoglobin.

Normal oxygen saturation is 98%, with no change in this measurement during activity or exercise. Clients with chronic respiratory disease may experience a drop in oxygen saturation that is considered normal for them, but this represents a normal response to pathology and is not truly normal.

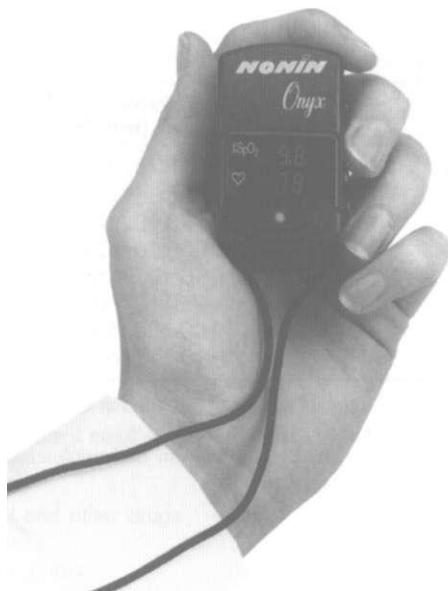
There has been some question as to whether nail polish can affect the accuracy of pulse oximetry readings. Studies to date have not shown a statistically or clinically significant difference in readings with nail polish of any

**Table B-4** Normal Resting Respiratory Rates

Age	Breaths/Min
Premature	40-70
Birth-3 mo	35-55
3-6 mo	30-45
6-12 mos	25-40
1-3 yr	20-30
3-6 yr	20-25
6-10 yr	15-25
10-16 yr	12-30
18 yr	12-20
Adult	10-12*

From Behrman RE, Kliegman RM, Jenson HB: *Nelson textbook of pediatrics*, ed 17, Philadelphia, 2004, Saunders.

\*Typical for average, healthy adult; low for older adult.



**Figure B-1**

Noninvasive monitoring of oxygen saturation ( $\text{SaO}_2$ ), sometimes referred to as the fifth vital sign, can be done with a pulse oximeter. A finger probe is used most frequently during stationary activities. This compact unit (Onyx) is small enough to carry and ideal for spot checks anytime. The person slips this digital pulse oximeter onto a finger for an immediate pulse rate and oxygen saturation percentage. An ear probe (not shown) can be used to measure oxygen saturation continuously during exercise. (Courtesy Nonin, Inc., Plymouth, MN.)

color (including colorless) in healthy or critically ill and mechanically ventilated individuals.<sup>6,9,16,24</sup>

Activity should be terminated if oxygen saturation drops to 90% or less in the acutely ill individual or 86% in the person with chronic lung disease. Individuals with decreased oxygen saturation may require more time to accomplish tasks and often experience fatigue and/or shortness of breath. Panic values may vary according to institution and physician. Increased oxygen during activity may prevent such drops but should be discussed with the physician before it is instituted.

At all times, other vital signs should be monitored (heart rate, respiratory rate, and blood pressure) to assess how well the person is tolerating the activity and oxygen desaturation. In the event of large changes in oxygen saturation as determined by pulse oximetry with no changes in vital signs, the pulse oximetry may not be accurate, thus requiring a mechanical check.

Caution is advised when using a finger probe on an individual with cold, discolored hands (blue or white), which is an indication that blood has already been shunted from the fingers. Pulse oximetry as a measure of oxygen saturation would not be accurate in such a situation.<sup>14</sup> Peripheral arterial vasoconstriction during the early phases of treadmill exercise has been documented in individuals with vascular pathology secondary to atherosclerosis.<sup>25</sup>

### Supplemental Oxygen

Supplemental oxygen is given if an individual has documented or suspected hypoxemia or deficient oxygenation

of the blood, defined as a  $\text{PaO}_2$  below 60 mm Hg, an  $\text{SaO}_2$  or  $\text{SpO}_2$  below 90%, or either value below the desirable range for the clinical situation.<sup>21</sup>

Other times supplemental oxygen may be needed include severe trauma, acute myocardial infarction, during or after labor and delivery, and as part of procedural sedation or general anesthesia. The therapist should be alert for any signs of increasing hypoxia (reduced tissue oxygenation despite adequate perfusion) indicating a possible need for supplemental oxygen. These include increasing tachypnea and dyspnea, skin color changes (pale, cyanotic), increasing tachycardia, hypertension, restlessness, and/or disorientation.<sup>23</sup>

Oxygen supplementation in anyone with COPD must be prescribed and monitored very carefully to avoid oxygen toxicity and absorption atelectasis. The therapist should watch for blunting of the respiratory drive. Too much oxygen can depress the respiratory drive of a person with COPD. For example, in the person with emphysema, low arterial oxygen levels are the respiratory drive triggers. For this reason, too much oxygen delivered as an intervention can depress the respiratory drive, which is now reliant on lower levels of arterial oxygen.

The drive to breathe in a normal person results from an increase in the arterial carbon dioxide level ( $\text{PaCO}_2$ ). Since the individual with COPD chronically retains excessive amounts of carbon dioxide, an increased arterial  $\text{PaCO}_2$  is no longer an effective respiratory drive mechanism.<sup>22</sup>

If oxygen flow rate must be increased during exercise for individuals with chronic lung disease, oxygen flow rate must be returned promptly to its set value at the end of exercise. Failure to return flow rate to the value determined by the physician may result in hypoventilation, retention of carbon dioxide, and respiratory acidosis.

### Blood Pressure

To monitor blood pressure effectively, the therapist must be familiar with normal (see Table 12-8; Table B-5) and abnormal blood pressure responses to exercise and must keep in mind that arterial blood pressure is a general indicator of the function of the heart as a pump and a measure of the peripheral arterial resistance. Systolic pressure measures the force exerted against the arteries during the ejection cycle, and diastolic pressure measures the force exerted against the arteries during rest or against peripheral resistance.

Systolic blood pressure normally rises with increased exertion in proportion to the workload (approximately 7 to 10 mm Hg/MET) with little or no change in diastolic blood pressure,<sup>2</sup> and it rises more quickly in males than in females. For example, during endurance activities, the systolic blood pressure gradually increases, but with sustained activity no further change should occur. Exercise involving a small total muscle mass, such as a single extremity, typically elicits minimal incremental changes in systolic blood pressure and greater increases in diastolic blood pressure.<sup>4</sup>

Diastolic blood pressure may increase or decrease a maximum of 10 mm Hg due to adaptive dilatation of peripheral vasculature. A highly trained athlete may

exhibit more than a 10 mm Hg drop in diastolic blood pressure as a result of increased vasodilation, but this would be considered an abnormal response in an older or untrained adult. A sustained elevation of the diastolic blood pressure during the recovery phase of activity is also considered abnormal. More specific abnormal responses to activity are discussed in detail elsewhere.<sup>15</sup>

If the resting blood pressure is excessively high (systolic blood pressure 200 mm Hg or diastolic blood pressure 105 to 110 mm Hg), physician clearance should be obtained before continuing with evaluation or treatment. Exercise should be terminated if blood pressure becomes excessively high (systolic blood pressure higher than 250 mm Hg or diastolic blood pressure higher than 110 mm Hg). Systolic blood pressure rise during exercise (19.7 mm Hg /min of exercise duration) and a relatively slow recovery in systolic pressure after exercise are associated with the risk of any stroke and of ischemic stroke.<sup>18</sup>

Blood pressure should always be measured in the same position, because it can drop quickly with cessation of activity (e.g., do not measure blood pressure while the client is sitting, then ambulate, and recheck blood pressure in the standing position; measure in the standing position, ambulate, and remeasure while standing). In fact, because blood pressure changes can occur within 10 seconds, a truly accurate postexercise blood pressure may be difficult to obtain. Always observe for associated symptoms, such as shortness of breath, dizziness, palpitations, or increase in heart rate.

### Pediatrics

A child's blood pressure is usually much lower than an adult's. Children are at risk for developing high blood pressure if they exceed the guidelines listed in Table B-5. About 1% of children (including very young babies) have blood pressure that is too high. The cause is often unknown. When a child's high blood pressure is severe, it is often because of another serious condition, such as kidney disease or heart disease.

Children can inherit high blood pressure from their parents. Overweight children are also at higher risk. Children who both have a family history of hypertension and are overweight should be screened for aberrant blood pressure. The American Heart Association recommends that all children 3 years of age and older have their blood pressure checked once a year.

A child's sex, age, and height are used to determine age-, sex-, and height-specific systolic and diastolic blood pressure percentiles (see Table 12-8). This approach provides information that lets researchers consider different levels of growth in evaluating blood pressure. It also demonstrates the blood pressure standards that are based on sex, age, and height and allows a more precise classification of blood pressure according to body size. More importantly, the approach avoids misclassifying children at the extremes of normal growth.<sup>1</sup>

The therapist can provide an important service by including this type of assessment. In children, even a mild elevation of blood pressure can lead to serious medical conditions such as cardiomyopathy and kidney or visual impairments. Medical evaluation and monitor-

**Table B-5** Normal Blood Pressures for Children\*

Age	Blood Pressure Systolic Range/Diastolic Range (mm Hg)
Premature	55-75/35-45
0-3 mo	65-85/45-55
3-6 mo	70-90/50-65
6-12 mo	80-100/55-65
1-3 yr	90-105/55-70
3-6 yr	95-110/60-75
6-12 yr	100-120/60-75
12 yr	110-135/65-85

From Behrman RE, Kliegman RM, Jenson HB: *Nelson textbook of pediatrics*, ed 17, Philadelphia, 2004, Saunders.

\*Normal blood pressure values for children and adolescents of various ethnic groups are under investigation.

ing for signs of early organ damage are needed for any child or adolescent with high blood pressure.

Current guidelines for children may not be very accurate. "Normal" blood pressure values may be different for children and adolescents of various ethnic groups. Heretofore, values have been established without consideration of ethnicity and/or culture and were based mostly on normal values for Anglo children. Investigation to establish more accurate norms and to verify standards for current blood pressure guidelines set by national committees are under way.<sup>21</sup>

### Abnormal Blood Pressure Response

An abnormal blood pressure response may result in hypotension or hypertension as reflected by any of the following responses:

- Too rapid a rise in systolic blood pressure for the workload; in the healthy adult, the systolic blood pressure should go up by 20 mm Hg with minimal to moderate exercise and 40 to 50 mm Hg with intensive exercise. These values are less likely with cardiac clients.
- Very little change in systolic blood pressure with excessive workload in an unfit or deconditioned person.
- Progressive rise of diastolic blood pressure.
- Diastolic blood pressure should remain the same or change slightly (less than 5 mm Hg increase/decrease should be noted); a drop of more than 10 mm Hg in diastolic blood pressure is considered abnormal.
- Drop in systolic pressure (or both systolic and diastolic pressure) of 10 to 20 mm Hg or more associated with an increase in pulse rate of more than 15 beats/min (depleted intravascular volume).
- Narrowing of pulse pressure (systolic blood pressure - diastolic blood pressure).

An increase in diastolic blood pressure of 20 mm Hg or more may be a sign that the person has exceeded cardiac reserve capacity and that blood flow to the liver, kidneys, and digestive tract has been critically reduced. A

**Box B-2****FACTORS AFFECTING BLOOD PRESSURE**

- Age
- Blood vessel size
- Blood viscosity
- Force of heart contraction
- Medications
  - Angiotension-converting enzyme inhibitors
  - Adrenergic inhibitors
  - $\beta$ -Blockers
  - Diuretics
  - Narcotic analgesics
- Diet and exercise
- Obesity
- Time of recent meal (eating increases systolic pressure)
- Caffeine
- Nicotine
- Alcohol and other drugs
- Cocaine
- Anxiety, panic
- Presence or perceived degree of pain
- Living at higher altitudes
- Distended urinary bladder
- Sleep apnea
- Pregnancy
- Pain

**Table B-6****Precautions and Contraindications for Aquatic Physical Therapy**

Precautions	Contraindications
Cardiac conditions	Uncontrolled seizure activity
Unstable vital signs	Unstable medical condition
Incontinence	Client behavior that compromises patient or staff safety
Severe/chronic ear infections	Phobia of water
Chronic obstructive pulmonary disease (COPD)	Fragile medical condition that places client at risk in an aquatic environment may be a contraindication; decided on a case-by-case basis
Pregnancy (complex or involved)	
Any land exercise precaution	
Inability to perceive overworking	
Anxiety regarding water	
Open skin areas	
Low body fat with decreased ability to generate heat with movement	

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process determining whether to include or not include aquatic therapy and, if included, under what conditions the therapist develops the program.<sup>3</sup> Additionally, thermodynamics and its respective interaction with varied client presentations plays a key role in directing the appropriate use of aquatic physical therapy.

In each practice environment, therapists must assess the precautions and contraindications for each respective clientele category. Precautions for aquatic physical therapy participation include but are not limited to the conditions listed in Table B-6.<sup>13</sup>

An overview of examination components, organized by *Guide* categories and systems review, is provided in Table B-7. The therapist can use this tool to guide the examination performed prior to aquatic intervention. Categories of test and measurement tools are also included from which clinicians can choose to complete these additional assessment components.

One example of the clinical decision-making process used in determining if and how the aquatic medium should be used in rehabilitation is the case of Viola, an 80-year-old woman living independently with her husband in a full-spectrum retirement community. She was referred to aquatic physical therapy for severe back pain, after having undergone several spinal fusions. The back pain was interfering with her activity level.

Viola participated in an initial land-based physical therapy examination and a course of therapeutic exercise and manual therapy. After a 3- to 4-week land-based physical therapy intervention, an aquatic physical therapy referral was recommended with the goals of reducing lumbar spasm and pain that interfered with her functional activities. Viola reported several comorbidities, including a 15-year history of Parkinson's disease.

For Viola's program, the clinician must consider the client's body type and structure, and whether she demonstrates any changes in muscle tone as a result of Par-

decrease in diastolic blood pressure may occur as a result of rapid vasodilation, an effect of training in the athletic individual.

A drop in diastolic blood pressure may also indicate normalization in a hypertensive individual as a result of vasodilation and decreased peripheral resistance. For example, this may occur if the hypertensive person experiences a calming effect as a result of participating in a regular routine of exercise after driving in heavy traffic to get to the clinic on time. Other factors that affect blood pressure are listed in Box B-2.

## GUIDELINES FOR AQUATIC PHYSICAL THERAPY

*Paula Richley Geigle and Charlotte O. Norton*

The decision to include aquatic physical therapy in a treatment regime is made for each client based on the *Guide to Physical Therapist Practice*.<sup>12</sup> For each individual a risk-benefit analysis is completed at each intervention point, wellness through tertiary care.<sup>10</sup> Sound clinical decision making is required to determine if the positive impact of hydrostatic principles offsets any potential risks created by the aquatic environment.<sup>13</sup>

The clinician must consider the static properties of water, including density and specific gravity, hydrostatic pressure, and the effects of buoyancy on each client. The effects of time-dependent properties such as viscosity, laminar flow, turbulent flow, and their effects on the amount of resistance encountered with water activity are additional critical elements considered in the thought

**Table B-7** Aquatic Practice for the Physical Therapist

Systems Review	Evaluation/Examination	Tests and Measures	Date/Results/Initials
Cardiovascular/pulmonary	Dyspnea on exertion Decreased endurance  Increased pulmonary response to low-level activity loads  Increased cardiovascular response to low-level activity loads  Impaired ventilatory forces and flow  Impaired ventilatory volumes  Integrity of tracheotomy	Vital signs, EEG, exertion scales Physiologic response to position changes: <ul style="list-style-type: none"><li>• Vital signs (HR, BP)</li><li>• Observations</li><li>• Laboratory values</li></ul> Increased cardiopulmonary responses to low load: <ul style="list-style-type: none"><li>• Breath/voice sounds</li><li>• Cyanosis</li><li>• Respiratory pattern/rate/rhythm</li><li>• Ventilatory flow/force/volume (spirometry, oximetry)</li></ul> Increased cardiovascular responses to low load: <ul style="list-style-type: none"><li>• BP</li><li>• HR/rhythm/sounds</li><li>• Angina/claudication/dyspnea</li><li>• ECG</li></ul> Impaired ventilation: <ul style="list-style-type: none"><li>• Gas analyses from chart</li><li>• Observations</li><li>• Oximetry</li><li>• Airway clearance tests</li><li>• Pulmonary function tests</li></ul> Impaired ventilation: <ul style="list-style-type: none"><li>• Gas analyses from chart</li><li>• Observations</li><li>• Oximetry</li><li>• Airway clearance tests</li><li>• Pulmonary function tests</li></ul> Observation, blood gas analysis, oximetry Observation: <ul style="list-style-type: none"><li>• Light touch, hot/cold</li><li>• Sensory integration</li><li>• Inspection of integument</li><li>• Augmented photography</li><li>• Thermography</li></ul>	
Integumentary	Impaired sensation: abrasion injury from bottom/sides/underwater lights Discontinuity of skin integrity: vascular disease—arterial/diabetic/venous Long-term medication use Lymphedema: skin integrity/drainage/hydrostatic pressure effect Skin lesions: trauma—burns/frostbite, cellulitis, postradiation, postsurgical status surgery		
Musculoskeletal	Strength/power/endurance: ability to control center of balance, equipment use Recent surgical episodes: passive/active/active assist Fatigue issues: changing presession/postsession; access in/out of pool; during/after aquatic session	<ul style="list-style-type: none"><li>• Manual muscle test</li><li>• Dynamometry</li><li>• Performance tests</li><li>• Technology-assisted analysis (PEAK Bidex platform, etc)</li><li>• Activities of daily living scales</li><li>• Postural analysis grids</li><li>• Videography</li></ul>	

Continued.

**Table B-7** Aquatic Practice for the Physical Therapist—cont'd

<b>Systems Review</b>	<b>Evaluation/Examination</b>	<b>Tests and Measures</b>	<b>Date/Results/Initials</b>
Neuromuscular	Seizure activity (within last 3–6 mo) Alteration in auditory/sensory/ somatosensory/position sense  Vestibular dysfunction: moderate to severe Decreased strength  Dysfunction: recruitment/timing/sequencing  General deconditioning  Postural control issues in varied positions  Oral motor control	Client/caregiver/medical record/review of current medications Stereognosis Tactile discrimination Kinesthesiaometry Observations Vibration Hot/cold Vestibuloocular reflex, nystagmus  Dynamometry Manual muscle testing Timed activities Physical capacity scales Electromyography Coordination Motor proficiency Motor planning Postural challenge tests Vital signs Perceived exertion scales Spirometer Aerobic capacity measurement Observations Technology-assisted analyses Grid measurement Functional assessment in pool: can client reposition head out of water independently? Coordinated breath control Mouth closure Controlled exhalation/inhalation on request (blowing bubbles) Motor and sensory integrity tests Quality-of-life scales Orientation assessment Communication assessment Ability to follow directions: safety of client/staff/other clients and caregivers	
Psychologic	Peripheral nerve integrity Fear of water Impulsivity Aggression Confusion Short-term memory issues Attention to task difficulties Immune system compromise: waterborne/airborne infections Systemic issues: diabetes mellitus, kidney function Dialysis/chemotherapy ports		
Endocrine/metabolic	Bowel incontinence Bladder incontinence Unpredictable vomiting PEG tube/stoma Catheter care		
Gastrointestinal/genitourinary	Pregnancy (before/after): water temperature, infection risk, discharge into pool Incontinence Pelvic floor surgery: risk of infection, discharge into pool		
Obstetric			

Courtesy Paula Richley Geigle, PT, PhD, and Charlotte O. Norton, DPT, MS, ATC, CSCS. Used with permission.  
ECG, Electrocardiogram; HR, heart rate; BP, blood pressure; PEG, percutaneous endoluminal gastrostomy.

kinson's disease. Changes in tone must be considered in relation to density and specific gravity, as both affect the amount of buoyancy support the person may need while participating in aquatic physical therapy.

The use of hydrostatic pressure and the effects of buoyancy in deeper water to minimize the effects of gravity may help decrease the amount of muscle spasm and pain (*Guide* Musculoskeletal category). Viola experiences from both her spinal involvement and tone changes from a longstanding neuromuscular pathology. The increased movement that buoyancy offers allows Viola to increase her cardiovascular reserve (*Guide* Cardiovascular/Pulmonary category) without increasing her back pain.

Scaling of speed and amplitude<sup>11</sup> is enabled by the buoyancy principle, both from ease of movement and decreased fear of balance loss (*Guide* Neuromuscular and Musculoskeletal categories). In other words, the aquatic environment facilitates larger, full range-of-motion movement as a result of a decreased falling anxiety and the increased proprioceptive input from hydrostatic pressure.

Examination of her postural control in a variety of positions with particular attention to safety issues (*Guide* Neuromuscular category) associated with Parkinson's disease-related muscle tone fluctuations during positioning transitions will allow the clinician to determine the most appropriate application of viscosity and resistance

for her exercise program. For example, Viola demonstrates the "typical" Parkinson's rigidity when in a full supine position. Any horizontal aquatic techniques should place Viola in about 25 to 30 degrees of trunk flexion via flotation supports.

Finally, the clinician must consider the water temperature (*Guide* Neuromuscular category). Warmer temperatures, approximating 90° F (32.2° C), will facilitate relaxation of the muscles and help to reduce the rigidity associated with Parkinson's disease and may increase the ease of spinal muscle activation.

Using the *Guide to Physical Therapist Practice* and hydrodynamic principles as a conceptual framework for clinical decision making, optimal aquatic care can be initiated. The Aquatic Physical Therapy Section of the American Physical Therapy Association provides current clinical information on its website and produces both a how-to manual on aquatic programming and a bibliography updated every 2 years ([www.aquaticpt.org](http://www.aquaticpt.org)).

## References

To enhance this text and add value for the reader, all references are included on the companion Evolve site that accompanies this textbook. The reader can view the reference source and access it on-line whenever possible. There are a total of 28 cited references and other general references for this chapter.

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