

ropathy. In a myopathy, the weakness tends to be proximal; in a neuropathy, motor symptoms tend to first occur distally.

Finally, because the nerve fibers from the ANS are also located in peripheral nerves, they, too, are subject to the effects of trauma or disease. Preganglionic fibers are myelinated and can be affected by segmental demyelination. In the presence of axonal degeneration, changes

will occur in vascular control and sweating. For example, when a person has sustained a laceration of the median nerve in the region of the hand that lacks innervation, autonomic involvement creates smooth skin that does not sweat or wrinkle, or when a neuropathy has a systemic metabolic cause, the person may develop hypotension with cardiac irregularities.²⁶



Figure 39-5

A stocking and glove pattern of sensory loss occurs in polyneuropathy. A gradient of greater distal loss tapering to less proximal involvement is seen.

PATHOGENESIS AND DIAGNOSIS OF PERIPHERAL DYSFUNCTION

Trauma, inherited disorders, environmental toxins, and nutritional disorders may affect the myelin (myelinopathy), axon (axonopathy), or cell body of a peripheral nerve. The anatomic region or regions affected determine the severity of the involvement and the amount of function lost (see Table 39-2). Although the phenotype of peripheral dysfunction (i.e., physical characteristics/traits) remains unchanged, much of the recent research in pathophysiology of these disorders has delved into genetic and molecular causes and consequences for what occurs. Findings in these areas may allow development of treatments aimed at altering cellular problems.

Because the nervous system is the means of signaling from the CNS to the muscle, conduction of the action potential is affected in neuropathies and myopathies. In most disorders, electrophysiologic studies are used to determine where and how the nerve or muscle may be affected.

HEREDITARY NEUROPATHIES

Hereditary neuropathies were once considered rare, genetically determined disorders; however, recent studies reflect, in some cases, that these represent 43% of undiagnosed neuropathies.¹⁵⁴ Hereditary neuropathies can be divided into two broad categories: those in which neuropathy is the primary disorder and those in which neu-

Table 39-4 Normal Nerve Conduction Velocities And Distal Latencies*

Nerve	Motor Conduction Velocity (m/sec)	Motor Distal Latency (ms)	Motor Amplitude (mV)	Sensory Conduction Velocity (m/sec)	Sensory Distal Latency (ms)	Sensory Amplitude (mV)
Median	63.5 ± 6.2	3.49 ± 0.34	7.0 ± 2.7	56.2 ± 5.8	2.84 ± 0.34	38.5 ± 15.6
Ulnar	61.0 ± 5.5	2.59 ± 0.39	5.5 ± 1.9	54.8 ± 5.3	2.54 ± 0.29	35.0 ± 14.7
Tibial	48.5 ± 3.6	3.96 ± 1.00	5.1 ± 2.2			
Peroneal	52 ± 6.2	3.77 ± 0.86	5.1 ± 2.3			

Normal F Wave Values

Nerve	Stimulation Site	F Wave Latency to Recording Site (ms)
Median	Elbow	22.8 ± 1.9
Ulnar	Above elbow	23.1 ± 1.7
Peroneal	Above knee	39.9 ± 3.2
Tibial	Knee	39.6 ± 4.4

*In general, in the upper extremities, nerve conduction velocity for motor fibers averages about 60 m/sec. Investigators have reported values ranging from 45 to 75 m/sec. In the lower extremity, the normal range for motor nerve conduction is in the 40- to 50-m/sec range. Distal latency is a time value, reported in milliseconds (m/sec), that it takes for an evoked potential to be propagated along the nerve and recorded from either the muscle (motor) or the skin (sensory).

Adapted from Dyck PJ, Thomas PK (eds): *Peripheral neuropathy*, ed 3, Philadelphia, 1993, WB Saunders.

Table 39-5 Relationship of Electromyographic Findings to Innervation

Condition	Normal Innervation	Segmental Demyelination	Axonal/wallerian Degeneration	Myopathy
Insertion	Normal insertional noise	Normal insertional noise	Increased insertional noise	Increased insertional noise
At rest	Quiet	Quiet	Spontaneous (abnormal) potentials: fibrillation potential, positive sharp wave potential	Quiet, except endstage: fibrillation potentials
Minimal contraction	Normal motor unit potential	Affected fibers: no motor unit potential	Affected fibers: no motor unit potential	Low amplitude, polyphasic potential
Maximal contraction	Complete interference pattern	Nerve partially affected: decreased interference pattern	Nerve partially affected: decreased interference pattern; nerve completely affected: no interference pattern	Low amplitude full interference pattern, accomplished with increased frequency of firing and with moderate effort

ropathy is part of a greater multisystem disorder.⁹ This section concentrates on the first group, which includes Charcot-Marie-Tooth disease and its related hereditary polyneuropathies.

Charcot-Marie-Tooth Disease

Charcot-Marie-Tooth (CMT) disease, also known as hereditary motor and sensory neuropathy (HMSN) or peroneal muscular atrophy, is the most common inherited disorder affecting motor and sensory nerves. It was originally described by three neurologists, Jean Martin Charcot, Pierre Marie, and Howard Henry Tooth, in the 1880s. Initially the disorder involves the fibular (peroneal) nerve and affects muscles in the foot and lower leg. It later progresses to the muscles of the forearms and hands, making activities like buttoning or writing difficult. CMT is a genetically heterogeneous group of disorders with the same clinical phenotype, characterized by distal limb muscle wasting and weakness, usually with skeletal deformities, distal sensory loss, and abnormalities of DTRs.¹¹⁸

Incidence

Of the neuropathies, CMT is relatively common; it is estimated that 1 in 2500 persons in the United States has some form of CMT. Onset may occur in childhood or adulthood.¹⁰⁸

Etiology

CMT is a genetically heterogeneous neuropathy that is inherited as autosomal dominant, autosomal recessive, or X-linked pattern.¹⁷⁰ Over fifty loci defects on chromosomes have been identified through deoxyribonucleic acid (DNA) testing.^{9,112,146} These chromosomal defects create either duplication, deletion, or point mutations in the genetic code for proteins that are involved in the process of myelination. CMT1 is the most common autosomal dominant pattern and is subdivided into three forms: CMT1A, 1B, and 1C. CMT1A accounts for 70% of all CMT1 cases and is caused by a DNA duplication on chromosome 17 for peripheral myelin protein 22 (PMP22),

creating segmental demyelination of the fibular (peroneal) nerve.¹²⁸ A less common form, CMT2, has had chromosomal abnormalities mapped to chromosomes 1, 8, and X. On chromosome 1, CMT2 is associated with a mutation in human myelin protein zero (P0), which has been associated recently with axonal dysfunction. This second form of CMT is associated with axonal degeneration. CMT2 has an onset that varies between the second and seventh decades and has less involvement in the small muscles of the hands than CMT1.²⁴

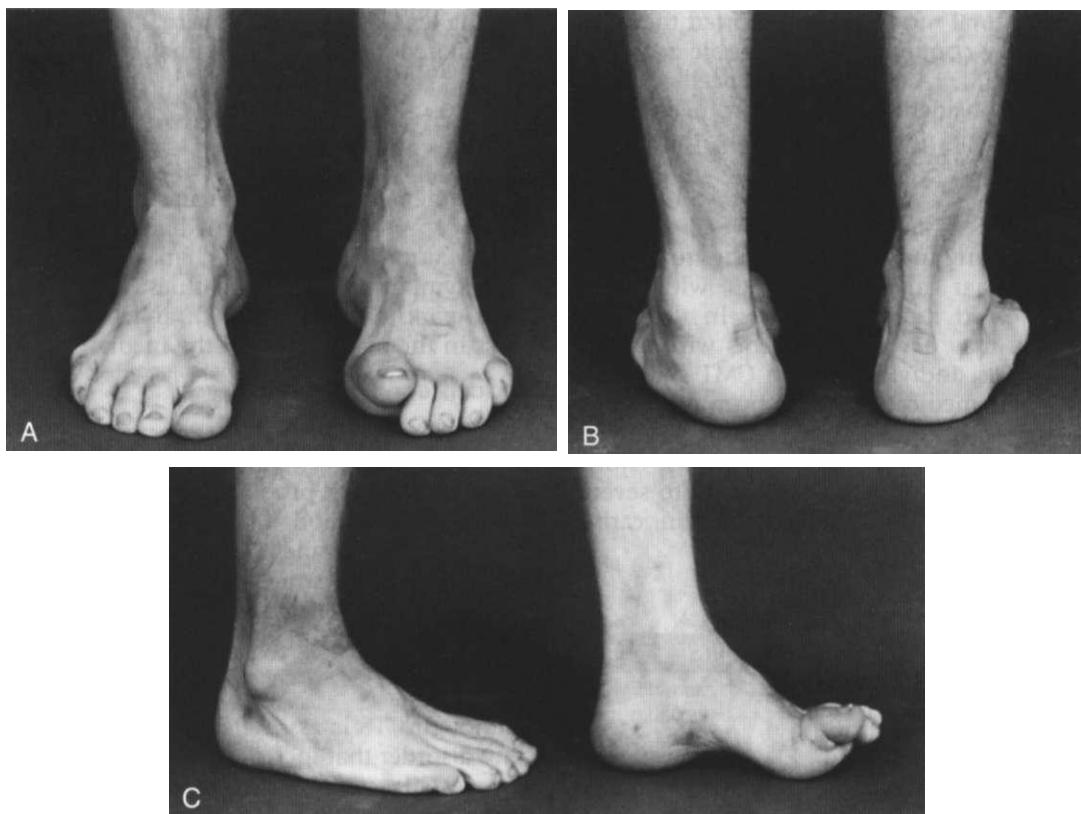
Pathology

Mutations in proteins (PMP, P0, and connexin) associated with Schwann cell myelination create extensive demyelination along with a hypertrophic onion bulb formation in which demyelinated axons are surrounded by Schwann cells and their processes as remyelination is attempted. The onion bulb formation creates palpable, enlarged peripheral nerves. CMT2 is associated with genetic mutations that disrupt neurofilament assembly and thus affect axonal transport, creating axonal involvement.⁹

Clinical Manifestations

Although the two major types of CMT have differing chromosomal etiologies, it is nearly impossible to tell CMT1 from CMT2 clinically. In all autosomal dominant disorders, there are degrees of genetic dominance. The presence of symptoms are not all-or-none but are graded, with differing degrees of signs and symptoms among family members who have inherited the defective gene. This is termed *variable expressivity*. In CMT1 some members of a family with the genetic mutation may have greater signs of the disorder than others who have only minor involvement.⁹⁵ In the X-linked form of CMT, men are affected and have signs of both demyelination and axonal degeneration are evident.

CMT is a slowly progressive disorder and although CMT1 begins in childhood, the actual onset may be difficult to determine. Clinical signs of CMT include distally symmetric muscle weakness, atrophy, and diminished DTRs. Feet have pes cavus (high arch) deformities and

**Figure 39-6**

Pes cavus foot deformity in Charcot-Marie-Tooth disease. **A**, Clawing of left great toe. **B**, Left foot varus deformity. **C**, Cavus deformity with hammer toes. (From Canale ST: *Campbell's operative orthopaedics*, ed 10, St Louis, 2003, Mosby.)

hammer toes (Fig. 39-6). Because of the muscles affected, the client will have weakness of the dorsiflexors and evertors (peroneal musculature) and will ambulate with a footdrop (steppage) gait pattern. As CMT progresses, involvement will be seen distally in the upper extremities. Weakness and wasting of the intrinsic muscles of the hand occurs, followed by progressive wasting in the forearms. Because CMT1 demyelinates peripheral nerves, proprioception is lost in the feet and ankles, and cutaneous sensation is diminished in the foot and lower legs. Sensory loss is minimal in CMT2. Sensory symptoms can include tingling and burning in the feet and legs, as well as impaired proprioception.¹⁷⁷

As muscle atrophy progresses below the knee, the appearance of the client's legs takes on the shape of an inverted champagne bottle because normal muscle bulk is maintained above the knees.

MEDICAL MANAGEMENT

DIAGNOSIS. CMT is diagnosed by history and clinical examination, hereditary picture, electrophysiologic studies, and nerve biopsy. Most recently, because of the sensitivity and specificity of genetic studies, the diagnosis of CMT can be confirmed using gel electrophoresis to detect duplication, deletions, or sequence variations in genes.⁹ Although CMT1 produces demyelination, electrophysiologic testing reveals underlying axonal degeneration. Slowed motor nerve conduction does not have a

linear correlation with the clinical severity of the disease.⁸³

Both motor and sensory NCVs will be slowed in CMT1⁹⁴ but are normal or only slightly slowed in CMT2. Abnormalities of electrophysiologic studies in CMT2 will be a decreased amplitude of the potential, indicating axonal loss. The nerve biopsy is abnormal and will demonstrate either a demyelinating or axonal degenerative process.

TREATMENT. Because CMT is an inherited disorder, there is no specific treatment to alter its course. Treatment is symptomatic to ensure that function is maintained in a safe manner. Footdrop and hand deformities can be helped by orthotic devices. Because the possibility of skin ulceration exists when tactile sensation and proprioception are affected, skin care precautions should be followed when total contact orthoses are used (see Chapter 10). To prevent contractures clients should be instructed in range of motion (ROM) exercises. Whether strengthening exercises can be used to counteract the effects of CMT has not been addressed; however, the long-term effects would be of little benefit in the presence of ongoing axonal degeneration. In a study examining the effects of weakness in CMT, results have found that individuals with CMT tend to be obese and have poor exercise tolerance. It is unknown whether exercise interventions can improve body composition and function.¹⁷

Studies using animal models have reported that anti-progesterone therapy combined with ascorbic acid have a positive effect on CMT1A. Although stem cell and gene therapy have been considered, the most promising treatment is pharmacologic therapies targeting the genetic mutation.¹¹²

PROGNOSIS. CMT is a slowly progressive disorder; if unmanaged, contracture formation resulting from weakness will create further gait abnormalities, with clients reporting an increased number of falls. In the upper extremities, clients may develop problems with writing and handling objects. Individuals with CMT should be cautioned that some medications have been reported to cause an exacerbation of CMT. A database of the drugs that should be avoided is maintained by CMT North America. Among the identified medications are several anticancer drugs, including: vincristine, cisplatin, carboplatin, and taxoids.¹¹²

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-1

Charcot-Marie-Tooth Disease

PREFERRED PRACTICE PATTERNS

5G: Impaired motor function and sensory integrity associated with acute or chronic polyneuropathies.

The goal in this progressive disorder is to minimize deformity and maximize function. As with other peripheral neuropathies in which muscle imbalances arise, for CMT, the physical therapist should anticipate that deformities will arise from the imbalance between the tibialis anterior and peroneus longus and the tibialis posterior and peroneus brevis, which leads to a pes cavus and varus deformity, respectively. This weakness may be combined with diminished or lost proprioception and some degree of cutaneous involvement that can lead to an unsteady gait. These problems should be addressed with stretching, ROM exercises, and bracing to improve ambulation. Along with an orthotic check-out and gait training, appropriate skin care should be taught to the client when total contact orthoses are used. When the individual has developed rigid deformities, a triple arthrodesis is the option to salvage remaining function.¹¹⁴

MECHANICAL INJURIES: COMPRESSION AND ENTRAPMENT SYNDROMES

The proximity of peripheral nerves to bony, muscular, and vascular structures can cause entrapment neuropathies characterized by changes in sensation and motor function, resulting from chronic neural compression. Another mechanical injury occurs as a result of traction on a nerve. As tension exceeds 10% to 20% of the axon's

resting length, the axon's internal slack within fascicles is eliminated and structural damage occurs.¹⁴⁴

Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS) is the most common entrapment neuropathy in the United States. It results from compression of the median nerve within the carpal tunnel at the wrist. CTS is characterized by general signs and symptoms of neuropathies: pain, tingling, numbness, paresthesia (Fig. 39-7), and later, muscular weakness in the distribution of the median nerve.

Incidence

Incidence in the United States is nearly 3.5 cases per 1000 individuals per year, and prevalence is estimated at 2.1%. As a condition, it produces one of the largest number of lost workdays among occupations. Nearly 70% of all CTS cases occur in women. Approximately 500,000 surgeries annually are performed for CTS. The incidence of surgery peaks in the 45- to 55-year-old group in women and in the over-65-year-old group in men.

Etiology

Although CTS is associated with occupational activities, any disorder that increases the volume of the contents of the carpal tunnel or that decreases the volume of the carpal tunnel will create a sustained rise in pressure within the tunnel that impinges on the median nerve. This includes synovial proliferation in rheumatoid arthritis, edema from local and systemic infections, congestive heart failure, pregnancy, and tumors. Callus formation after fracture, as well as malalignment of fractures, may reduce the volume of the canal. CTS is also more 2.5 times more likely in obese individuals (body mass index >29).¹⁴⁵ Although some investigators¹⁴¹ have hypothesized that a compressive lesion located more proximally (thoracic outlet syndrome or cervical radiculopathy) on a nerve may predispose it to further injury (CTS), more recent examinations of clients with CTS have refuted this "double crush" hypothesis.^{84,161}

Risk Factors

Also at risk for developing CTS are people with rheumatoid tenosynovitis, edema, pregnancy, hypothyroidism, and post-Colles' fractures (Box 39-1).^{78,151} Although CTS has been reported in several occupations, because of the quality of the research, the convincing link between work and CTS is now questioned.¹⁴⁶ In examining occupational studies, the literature identifies studies that report greatest incidence of CTS in frozen food workers and butchers. These support a positive association between a combination of factors: force and repetition and/or force and posture. Although the job of a computer operator has been linked to CTS, when symptoms of paresthesia are rigorously assessed, CTS and other musculoskeletal pain disorders associated with long-term keyboarding can be alleviated with 5 minute breaks every hour.¹⁵¹ Patients over the age of 63 years have a different pattern of risk factors for CTS than younger patients. This suggests that CTS in the elderly population may have different underlying pathogenetic mechanisms.¹⁰

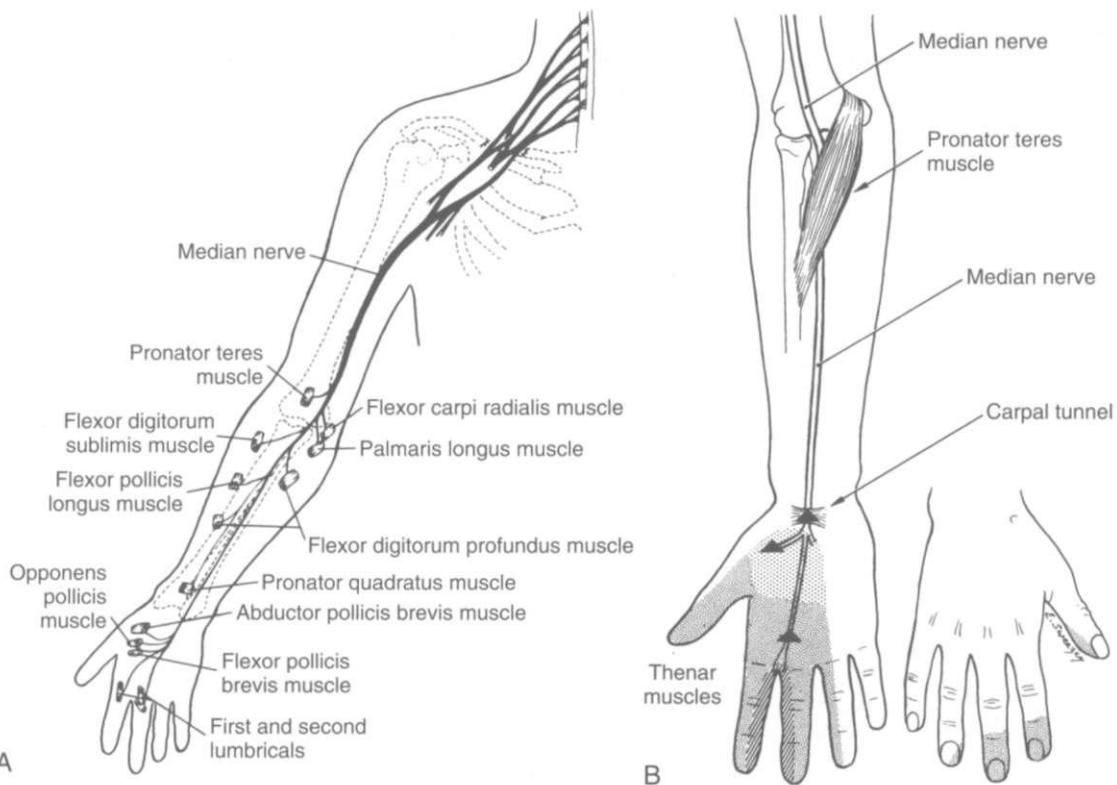


Figure 39-7

A, Median nerve course and motor innervation. **B**, The point of compression of the median nerve as it passes through the carpal tunnel. The lightly stippled area shows the sensory supply of the palmar cutaneous branch, which arises proximal to the carpal tunnel and thus is spared in the carpal tunnel syndrome. The densely stippled zone represents the cutaneous sensory area of the median nerve distal to the carpal tunnel. (A from Canale ST: *Campbell's operative orthopaedics*, ed 10, St Louis, 2003, Mosby.; B from Noble J: *Textbook of primary care medicine*, ed 3, St Louis, 2001, Mosby.)

Pathogenesis

In the carpal tunnel where there are 10 structures in a constrained compartment, normal tissue pressures are 7 to 8 mm Hg (Fig. 39-8). In CTS, these pressures rise above 30 mm Hg, when wrist flexion or extension occurs. Pressures go as high as 90 mm Hg when the wrist is fully flexed and up to 79.5 mm Hg when the wrist is extended.³⁹ Pressure this great produces ischemia in the nerve. Ischemia accounts for the nocturnal symptoms or those that occur with wrist flexion. Unrelieved compression creates an initial neurapraxia with segmental demyelination of axons. Because the axons have lost their myelin padding they are more vulnerable, so that unrelieved compression can create an axonotmesis in which axon continuity is lost and Wallerian degeneration occurs.

Clinical Manifestations

Persons with CTS experience sensory symptoms in the median nerve distribution (see Fig. 39-7). Pain may be located distally in the forearm or wrist and radiate into the thumb, index, and middle fingers. It may also radiate into the arm, shoulder, and neck. Comparing self-reported symptoms recorded on the Katz hand diagram allows symptoms to be assessed as classic, probable, possible, or unlikely to be CTS.²⁵ Nocturnal pain is the hallmark of CTS. Even in the early stages of CTS most people will

report being awakened by painful numbness in the middle of the night. Sensory symptoms usually precede motor symptoms. Diminished 2-point discrimination, diminished ability to perceive vibration, and elevation of threshold in Semmes-Weinstein monofilament testing routinely occur. Thenar weakness is seen in advanced cases. In nearly half of all cases, symptoms occur bilaterally. If CTS goes untreated, symptoms escalate into persistent pain with atrophy of the thenar musculature and the person will have a loss of grip strength. The combined loss of grip strength, inability to pinch, and sensory loss causes clumsiness in the hands.²⁷ Because conditions that impinge nerve fibers in the neck (radiculopathy) or in the thoracic outlet also cause sensory symptoms that are referred to the hand, it is important to ascertain that the symptoms are related to CTS (see Box 39-1).

MEDICAL MANAGEMENT

DIAGNOSIS. The diagnosis of CTS is considered in any person with hand or wrist pain, numbness, and weakness and must be distinguished from a cervical radiculopathy or ulnar neuropathy.²⁷ Diagnosis is determined by history, physical examination, and specialized tests. Provocation tests are used to replicate CTS symptoms. Phalen's test, in which the wrist is flexed to 90 degrees for 1 minute (Fig. 39-9, A); Tinel's test, or wrist percussion over the

Box 39-1**CAUSES OF CARPAL TUNNEL SYNDROME*****Neuromusculoskeletal***

- Amyloidosis
- Anatomic sequelae of medical or surgical procedures
- Basal joint (thumb) arthritis
- Cervical disk lesions
- Cervical spondylosis
- Congenital anatomic differences
- Cumulative trauma disorders
- Peripheral neuropathy
- Poor posture (may also be associated with TOS)
- Repetitive strain injuries
- Tendinitis
- Trigger points
- Tenosynovitis
- TOS
- Wrist trauma (e.g., Colles' fracture)

Systemic

- Alcohol
- Arthritis (rheumatoid, gout, polymyalgia rheumatica)
- Leukemia (tissue infiltration)
- Liver disease
- Medications
- NSAIDs
- Oral contraceptives
- Statins
- Alendronate (Fosamax)
- Multiple myeloma (amyloidosis deposits)
- Obesity
- Pregnancy
- Scleroderma
- Use of oral contraceptives
- Hemochromatosis
- Vitamin deficiency (especially vitamin B6)

Endocrine

- Acromegaly
- Diabetes mellitus
- Hormonal imbalance (menopause; posthysterectomy)
- Hyperparathyroidism
- Hyperthyroidism (Graves' disease)
- Hypocalcemia
- Hypothyroidism (myxedema)
- Gout (deposits of tophi and calcium)

Infectious disease

- Atypical mycobacterium
- Histoplasmosis
- Rubella
- Sporotrichosis

From Goodman CC, Snyder TEK: *Differential diagnosis for physical therapists: screening for referral*, Philadelphia, 2007, WB Saunders.

TOS, Thoracic outlet syndrome; NSAIDs, nonsteroidal antiinflammatory drugs.

carpal tunnel (Fig. 39-9, B); and the carpal compression test (pressure is applied by the examiner by pressing his or her thumbs at the wrist over the flexor retinaculum) are all deemed positive when pain, numbness, and paresthesia are produced. The flick sign is a positive indicator of CTS when the client demonstrates what he/she does to relieve symptoms. Ask "What do you do with your hand(s) when your symptoms are the worst?" and the client demonstrates a flicking movement of the hand that looks similar to the motion seen in shaking a thermometer.²⁵ When tests available to diagnose CTS have been compared to the gold standard of NCV, varying degrees of reliability have been reported. Most recently, Tinel's test has sensitivity of 0.90 and specificity of 0.81, and Phalen's test to reproduce symptoms only has a sensitivity of 0.85 and specificity of 0.79.²⁵

The gold standard to confirm CTS is NCV testing. Distal motor and sensory latencies and sensory NCV across the carpal tunnel are most frequently administered. Changes in the sensory conduction across the wrist are reportedly the most sensitive indicator of CTS.¹⁷⁴ A modified NCV technique, termed *inchng*, has been shown to provide greater sensitivity and specificity for precise

localization of anatomic entrapment for carpal tunnel.¹⁴² Although NCV testing generally provides the benchmark for CTS, a negative NCV study alone does not exclude the possibility of CTS. There are other imaging methods that are helpful in diagnosing CTS. Although magnetic resonance imaging (MRI) has also been found effective in identifying anomalies in the carpal tunnel, including altered tendon position, altered nerve position, swelling of the median nerve, and thickening of the tendon sheath to aid in establishing the diagnosis of CTS,⁵ but controversy exists over its use in diagnosis¹⁷⁵ because of its variable sensitivity and specificity.¹⁸⁰ Some believe that ultrasonography is more helpful in estimating the severity of symptoms and nerve conduction deficit.^{37,76,87}

TREATMENT. There is no universally accepted treatment for CTS. Although many studies have been conducted over the years, there are few well-controlled investigations that demonstrate the most effective treatment intervention. Thus many approaches are used for symptom management.⁴⁴ For clients with mild symptoms, demonstrated by only subjective and objective sensory symptoms, conservative management is generally instituted.

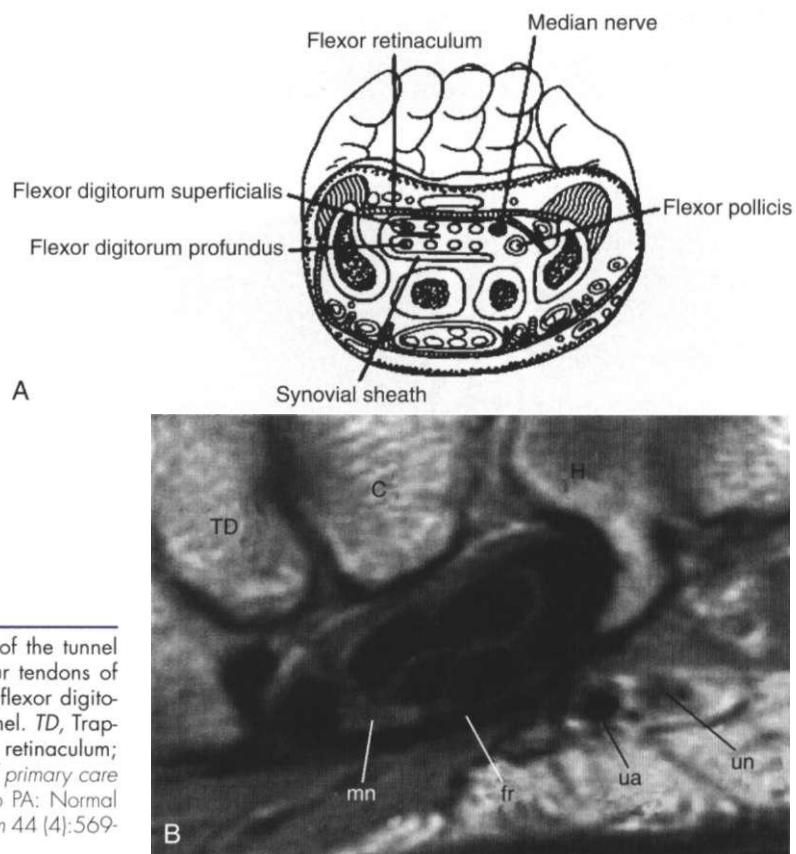


Figure 39-8

A, Cross-section of the carpal tunnel at the wrist. Contents of the tunnel include the tendon of the flexor pollicis longus (*FPL*), the four tendons of the flexor digitorum profundus (*FDP*), the four tendons of the flexor digitorum superficialis (*FDS*), and the median nerve. **B**, Carpal tunnel. *TD*, Trapezoid; *C*, capitate; *H*, hamate; *mn*, median nerve; *fr*, flexor retinaculum; *ua*, ulnar artery; *un*, ulnar nerve. (A from Noble J: Textbook of primary care medicine, ed 3, St Louis, 2001, Mosby; B from Yu JS, Habib PA: Normal MR imaging anatomy of the wrist and hand, *Radiol Clin North Am* 44 (4):569-581, 2006.)

Medical management of mild symptoms includes steroid injection into the carpal canal to provide initial relief of symptoms. Early management also addresses ergonomic measures and modification of the client's occupation. Alternative computer keyboards have been evaluated and three configurations are reported to promote a more neutral wrist position than use of a regular keyboard.¹⁰¹ Wearing of wrist splints to immobilize the wrist near neutral to minimize carpal tunnel pressures and client education are also instituted. These conservative approaches provide symptom relief up to 6 months.⁵⁵ However, the long-term use of antiinflammatory medications and immobilization demonstrated a cure rate of only 18%. Relapse was noted within 1 year. Most recently, injection of methylprednisolone proximal to the tunnel has resulted in symptom relief for 77% of those treated when reassessed after 1 month. Fifty percent of those treated reported prolonged relief (at least 1 year) after injection.²⁴

Surgical intervention is advocated for persons without resolution of symptoms following a traditional conservative approach for 2 to 3 months. Surgery is also indicated in untreated persons whose symptoms have lasted longer than 1 year and who demonstrate both motor and sensory NCV involvement or in persons with denervation as evidenced by fibrillation potentials on EMC. Release of the transverse carpal ligament is commonly performed and is usually successful. Complications fall into two categories: errors in diagnosis or surgical technique. Newer surgical techniques (flexor tenosynovectomy with transverse carpal ligament division, endoscopic release of the liga-

ment, and neurolysis of the median nerve) are performed through limited incisions and require less exposure and less manipulation of the nerve than the classic open techniques. Seventy-six percent of the surgical cases experience return of normal 2-point discrimination and up to 70% have normal muscle strength return.⁷³ However, a systematic review of surgical procedures has identified that newer procedures are no more effective than traditional approaches. In offering symptom relief, conflicting evidence exists about whether endoscopic release allows earlier return to work than open tunnel release.¹³⁹ After surgery, nerve and tendon gliding techniques are advocated to reduce scarring, adhesions, and subsequent formation of fibrotic tissue.¹⁰¹

PROGNOSIS. Prognosis relates directly to the severity of the nerve entrapment at diagnosis, clinical cause, and mode of treatment.

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-2

Carpal Tunnel Syndrome

PREFERRED PRACTICE PATTERNS

4E: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range of Motion Associated with Localized Inflammation

5F: Impaired Peripheral Nerve Integrity and Muscle Performance Associated with Peripheral Nerve Injury

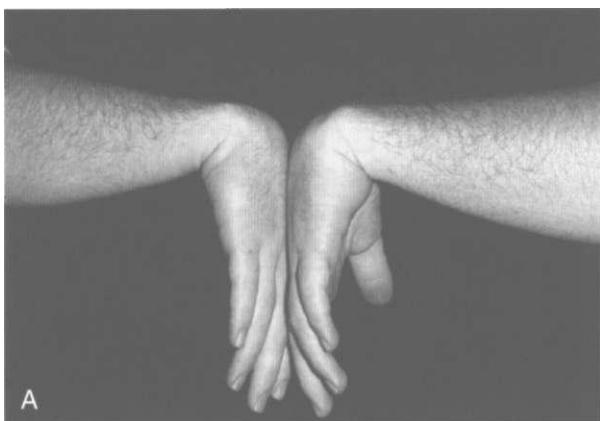


Figure 39-9

A, Phalen's test. Patients maximally flex both wrists and hold the position for 1-2 minutes. If symptoms of numbness or paresthesia within the median nerve distribution are reproduced, the test is positive. **B**, Tinel's sign in carpal tunnel syndrome. (A from Frontera WR, Silver JK: *Essentials of physical medicine and rehabilitation*, Philadelphia, 2002, Hanley and Belfus; B from Noble J: *Textbook of primary care medicine*, ed 3, St Louis, 2001, Mosby.)

Sciatica

Incidence and Etiology

Sciatica is a radiculopathy occurring most often in individuals between the ages of 40 and 60 years in which the nerve root is affected, most typically by compression. Of those developing lumbosacral radiculopathy, 10% to 25% develop symptoms that last more

than 6 weeks. Less commonly, sciatica may occur in the presence of abscess, blood clots, or tumors. Sciatica may be mistaken for intermittent claudication or low back pain without discogenic involvement and is one of the most common conditions managed in primary care settings.

Pathogenesis

The epidural space is innervated by a meningeal branch of the spinal nerve, the recurrent sinuvertebral nerve. Arising from the dorsal root ganglion, this nerve enters through the intervertebral foramen, divides into ascending and descending branches to blood vessels, and supplies the posterior longitudinal ligament, the superficial anulus fibrosis, anterior dura mater, and dural sleeve.¹⁰² In animal studies, the sinuvertebral nerve responded to high threshold mechanical stimuli. Conduction velocity for fibers in the nerve corresponded to types III and IV, which lead researchers to correlate nerve function with nociception.¹⁴¹ Herniation of the intervertebral disk can impinge on the nerve root or structures innervated by the recurrent sinuvertebral nerve to cause pain.

Clinical Manifestations

In addition to low back pain, when sensory fibers are affected, pain will radiate into one or both legs. One of the reasons the motor and sensory nerves are affected so easily in a radiculopathy is the pressure occurs in an area where CNS connective tissue coverings meet the protective tissue coverings of the peripheral nerve, leaving that region of the nerve "at risk."⁷² Coughing, sitting, and sneezing worsens the pain. For further information, see Chapter 27. Both clinical and experimental studies have shown that adjacent nerve roots may be affected when the lumbar disc herniates. Inflammatory chemical mediators released into the epidural space affect nearby nerve roots, without any direct compression of those roots.¹¹³

MEDICAL MANAGEMENT

DIAGNOSIS. Both radiologic tests and electrophysiologic studies are ordered. Various specific tests have been reported to provide reliable results. MRI is preferred to computed tomography (CT) scanning for lumbar spine imaging; however, because 60% of people without back symptoms have disk bulging on MRI, protrusion and bulges may not correlate with symptoms.⁷ A screening EMG examination of only four muscles in the leg identified over 89% of surgically confirmed.³² Others have noted that the H-reflex has provided better predictive value than standard motor and sensory nerve conduction radiculopathies.² Just as radiologic studies are not sufficient alone to distinguish sciatica neither is electrophysiologic testing.

TREATMENT. The effectiveness of medications has been reported as disappointing. Selective epidural injection of steroids at target nerve roots through the intervertebral foramina has offered short-term benefit for pain relief, as has the use of nonsteroidal antiinflammatory drugs (NSAIDs).²¹ Also unclear are the long-term effects of chemonucleolysis, which has been reported to be less effective than discectomy.⁵⁰

PROGNOSIS. Subjects who were evaluated 1 year after discectomy had recovery in unmyelinated and small myelinated fibers; the function of larger myelinated fibers did not improve. This provides a physiologic rationale for residual motor and sensory involvement.¹¹³

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-3

Sciatica

PREFERRED PRACTICE PATTERNS

4F: Impaired Joint Mobility, Motor Function, Muscle Performance, Range of Motion, and Reflex Integrity Associated with Spinal Disorders

4I: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range of Motion Associated with Bony or Soft Tissue Surgery

For those physical therapists using the visual analogue scale (VAS) to assess pain in sciatica, a range of minimal clinically relevant change has been reported. Using a 100-mm VAS, Todd et al¹⁰⁰ reported that a 13-mm change is needed to discriminate a crude change in pain, whereas Farrar et al⁴¹ estimated a 20-mm change was needed to discriminate a crude change in pain. Most recently, Giraudeau et al¹¹³ also reported that 30 mm reflected a crude change in pain.

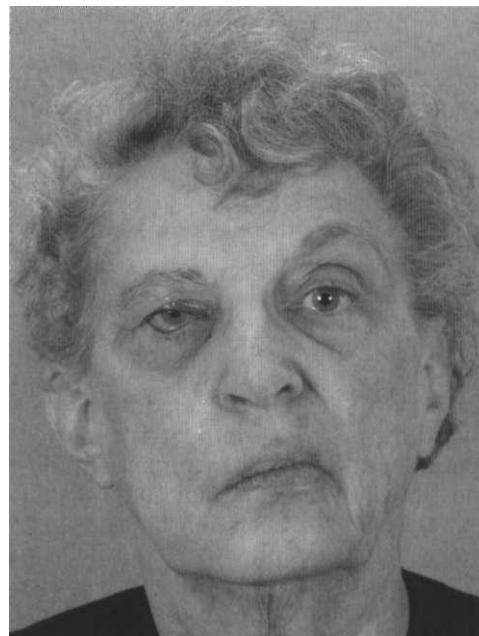


Figure 39-10

Patient with right facial paralysis. [From Cummings C, Haughey B, Regan T, et al: *Cummings otolaryngology: head & neck surgery*, ed 4, St Louis, 2005, Mosby.]

Idiopathic Facial Paralysis/Bell's Palsy

Incidence

Bell's palsy is a common clinical condition in which the facial nerve is unilaterally affected. Bell's palsy affects 20 of 100,000 people each year. Although any age group can be affected, it is most common in persons between the ages of 15 and 45 years.⁵⁵

Etiology and Pathogenesis

The cause of Bell's palsy is uncertain; however, evidence is increasing that indicates that the primary cause of Bell's palsy is a latent herpes virus (herpes simplex type 1/herpes zoster) that has been reactivated.^{19,122} Days before Bell's palsy onset, the client may recall experiencing severe pain in the area of the mastoid or a sensation of fullness in the ear. Pain suggests that this disorder is a product of an inflammatory response. Because the facial nerve lies in the auditory canal, any agent that causes inflammation and swelling creates a compression that initially causes demyelination. However, if the inflammatory response is more fulminating, ischemia will cause an axonal degeneration.

In addition, centrally located structures, such as acoustic neuromas (tumor), can produce unilateral paralysis in the face by impinging on the facial nerve as it emerges from the brainstem; however, these tend to produce a slowly progressive paralysis.

Risk Factors

People with diabetes mellitus and pregnant women¹⁹ have an increased incidence of Bell's palsy.

Clinical Manifestations

A unilateral facial paralysis develops rapidly, often overnight. Paralysis of the muscles of facial expression on one side creates an asymmetrical facial appearance (Fig. 39-10). The corner of the mouth droops, the nasolabial fold is flattened, and the palpebral fissure is widened because the eyelid does not close. In addition to the motor fibers providing innervation for facial musculature, the facial nerve also innervates the stapedius muscle of the middle ear and the sensory and autonomic fibers, which innervate for taste and lacrimation and salivation, respectively. Therefore involvement of these fibers may produce additional signs and symptoms to those of facial paralysis. If the lesion is proximal to where the fibers of the chorda tympani enter the facial nerve, the client will experience loss of taste on the affected side. In a similar fashion, if the autonomic fibers are involved, the client will experience dry eye (lack of tearing) and will produce less but thicker saliva. Some clients report that sounds are louder than normal because the stapes bone of the middle ear is less able to accommodate sound when the stapedius muscle's innervation is lost.

MEDICAL MANAGEMENT

DIAGNOSIS. Ask the client to wrinkle the forehead, close the eyes tightly, smile, and whistle while you observe for facial asymmetry. In addition to the clinical presentation and history, electrodiagnostic tests can be used to demonstrate whether the lesion is one of demyelination or axonal degeneration. However, EMG as a diagnostic tool is only helpful after the nerve has degenerated; therefore testing is most accurate after 1 week. Tests of facial nerve

excitability will also indicate whether the paralysis is complete.

The LMN involvement of the facial nerve can be differentiated from an upper motor neuron (UMN) involvement of this nerve because with UMN involvement the client can close the eye and wrinkle the forehead but cannot smile voluntarily. With LMN involvement, the client is unable to close the eye, wrinkle the forehead, or smile voluntarily.

TREATMENT. Since the outcome (demyelination or degeneration) is unknown initially, prophylactic administration of high-dose corticosteroids for 5 days, followed by a tapered dose for 5 days, has been advocated. For more severe involvement, this treatment is reported to help prevent permanent damage. Treatment should begin as soon as possible and no later than 10 days after onset of signs of paralysis. The association that has been discovered between herpes simplex virus and Bell's palsy suggests that treatment with antiviral medications, such as acyclovir or acyclovir paired with corticosteroids, may aid in recovery.⁶³ Patients who received a combined treatment of acyclovir (antiviral) with prednisolone (corticosteroid) had a recovery rate of 95.7% (better than corticosteroids alone, 89%). Treated within 3 days on onset of paralysis, a 100% recovery has been reported; the rate of recovery drops to 86% when treatment was delayed until day 4). Benefits of antiviral medications or nerve root decompression have not been established definitely.^{57,64} Yet controversies exist related to the medical management of Bell's palsy. One systematic review reports that available evidence does not show significant effects of corticosteroids,¹³³ whereas a metaanalysis found that corticosteroids provided both clinically and statistically significant recovery of motor function in facial nerve-innervated musculature.¹²⁶ Studies of Bell's palsy in children have indicated that there is no supporting evidence for the use of steroids or antiviral medications in children.¹³⁴

To protect the cornea, the client should cover the eye with a patch or glasses and use artificial tears. Other palliative treatments, such as gentle massage and gentle heat, may also be used.¹

PROGNOSIS. Ninety-four percent of individuals with incomplete involvement make a full recovery, generally within 3 weeks. For complete involvement, 75% recover normal motor function, although the time course of recovery is longer.⁶⁵ Factors associated with a poorer outcome include age greater than 60 years, presence of systemic comorbidities such as diabetes mellitus and hypertension, and symptoms indicating a lesion with autonomic involvement.¹⁶ Plastic surgery, using fascial slings to replace active muscle contraction, can help restore facial function when recovery does not occur. Another complication that can occur during recovery is a phenomenon called *motor synkinesis* (crocodile tears), which occurs when motor fibers of the facial nerve cross-innervate the autonomic branch of the greater superficial petrosal nerve. When muscles of the face contract, tears appear. This has been noted up to 1 year after the start of treatment.¹⁴⁸

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-4

Bell's Palsy

PREFERRED PRACTICE PATTERNS

4E: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range of Motion Associated with Localized Inflammation

5F: Impaired Peripheral Nerve Integrity and Muscle Performance Associated with Peripheral Nerve Injury

Because experiments using animals have indicated that electrical stimulation suppresses neuronal sprouting, some scientists have proposed that electrical stimulation should not be used. To promote enhanced motor control of fascial musculature and recovery of function, a twice daily exercise program emphasizing facial movement has been proposed. Progress can be assessed using the facial grading scale, paresis index, and question score.¹⁶

Tardy Ulnar Palsy/ Retroepicondylar Palsy

Anatomy

The ulnar nerve arises from the lower trunk of the brachial plexus and carries fibers from C8 and T1 nerve roots. At the elbow, it passes behind the medial epicondyle and then passes between the two heads of the flexor carpi ulnaris through the forearm to the wrist (Fig. 39-11). The distal portion of the nerve enters the palm by crossing the flexor retinaculum and divides into a superficial and deep branch in the hand.

Etiology

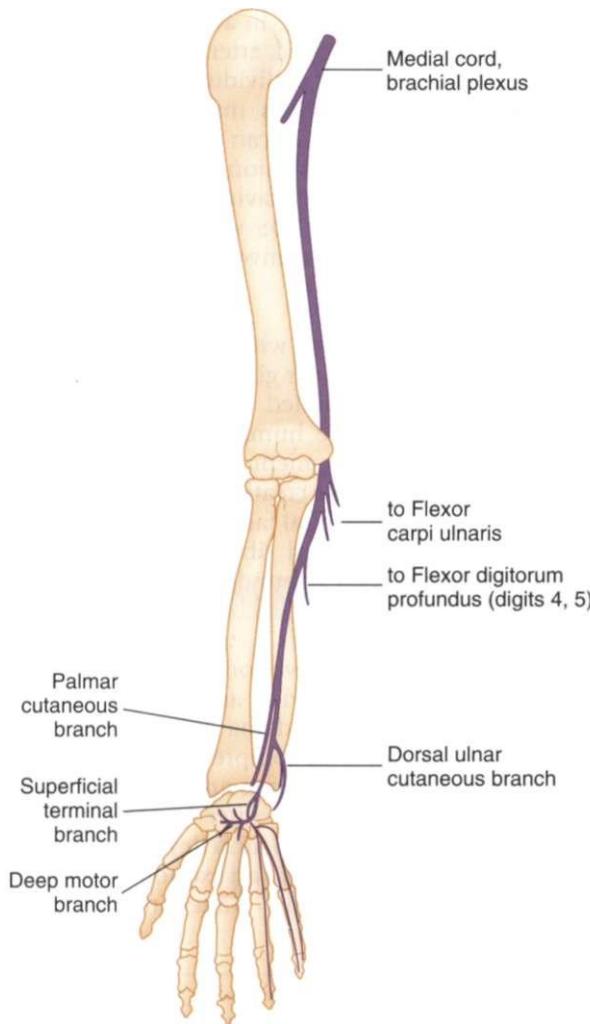
Because of its anatomic location, ulnar nerve palsy is a common complication of fractures in the region of the elbow. A late or tardy ulnar palsy may occur years after a fracture and is associated with callus formation or a valgus deformity of the elbow. These produce a gradual stretching of the nerve in the ulnar groove of the medial epicondyle.

Risk Factors

A similar type of tardy ulnar palsy occurs with repeated trauma for relatively long periods of time in clients with a shallow ulnar groove at the elbow. Ulnar neuropathy from entrapment at the elbow is the second most frequent upper extremity neuropathy (after carpal tunnel).

Pathogenesis

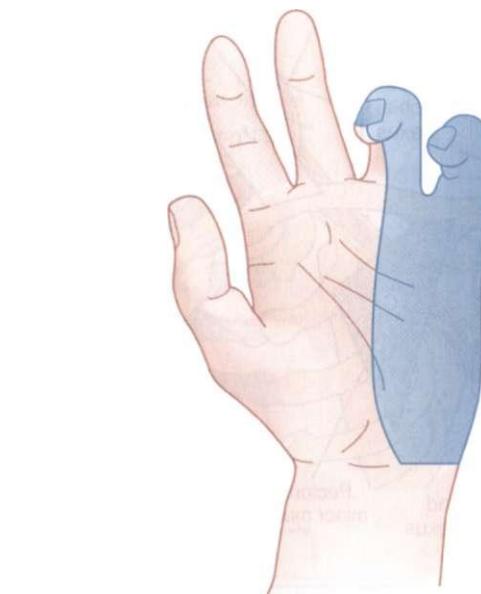
The mechanism of injury compressing the ulnar nerve has been attributed to recurrent microtrauma associated with fracture and fibrous bands or recurrent cubital subluxations, as well as entrapment at the entrance or exit of the cubital tunnel.⁹² Elbow flexion aggravates symptoms. Compression will initially cause a neurapraxia with demyelination of the nerve; if the pressure goes unrelieved, this will progress to an axonotmesis with denervation occurring below the level of the elbow.

**Figure 39-11**

Distribution of the ulnar nerve. A tardy ulnar palsy impinges the ulnar nerve as it passes behind the medial epicondyle of the humerus. (From Steward JD: *Focal peripheral neuropathies*, ed 3, Philadelphia, 2000, Lippincott Williams & Wilkins.)

Clinical Manifestations

Expect a clawhand deformity with metacarpophalangeal (MCP) extension and interphalangeal (IP) flexion of the ring and little fingers because of the unopposed action of the extensor muscle group and paralysis of the third and fourth lumbricals that normally flex the MCPs and extend the IPs (Fig. 39-12). Flattening of the hypotenar eminence along with abduction of the little finger coincides with weakness of the palmaris brevis and abductor digiti minimi. Marked atrophy of the interossei on the dorsal surface of the hand with guttering between the extensor tendons indicates the presence of denervation. Abduction and adduction movements of the fingers are impaired. Paralysis of the flexor carpi ulnaris (FCU) produces a radial deviation of the hand when wrist flexion is attempted. Sensory loss is variable, but impaired sensation may be expected involving the little finger and the ulnar aspect of the ring finger and along the ulnar aspect of the palm of the hand to the wrist. Occasionally, sensory

**Figure 39-12**

Clawing of the ring and little fingers (hyperextension of the metacarpophalangeal joint and flexion of the interphalangeal joints) from unopposed action of extensor musculature combined with paralysis of the intrinsic muscles of the hand occurs when there is involvement of the ulnar nerve. Shaded area represents ulnar nerve sensory distribution in the hand. (From Marx RS, Hockberger RS, Walls RM: *Rosen's emergency medicine: concepts and clinical practice*, ed 6, St Louis, 2006, Mosby.)

symptoms extend proximally to the wrist (see Fig. 39-12).

MEDICAL MANAGEMENT

DIAGNOSIS. Percussion of or bending the elbow can replicate symptoms.⁹² NCV studies are helpful only when sufficient nerve damage has occurred to produce definite strength or sensory changes in the hand. NCVs are slowed through the involved region but are relatively normal above and below the epicondyle. Electromyography reports slowing of sensory or motor NCV across the elbow, prolonged conduction (termed a *latency*) to the FCU, along with changes in amplitude, duration, or shape of the sensory potential across the elbow. Sensory fibers were affected first. Detection of an abnormal latency requires accurate measurement of ulnar nerve segment length.¹⁰⁶

TREATMENT. Mild entrapments are managed conservatively; moderate and severe compression require surgery. To relieve the compression, either decompression, the preferred method (medial epicondylectomy), or transposition of the ulnar nerve to the anterior aspect of the elbow is performed.^{13,150} Symptomatically, the clawhand deformity should be treated with a splint that blocks MCP hyperextension (lumbrical bar) and allows the extensor digitorum to extend the IP joints.

PROGNOSIS. Results of surgery are normally good when the individual has not had a chronic tardy ulnar involvement. Decompression surgery should have complete res-

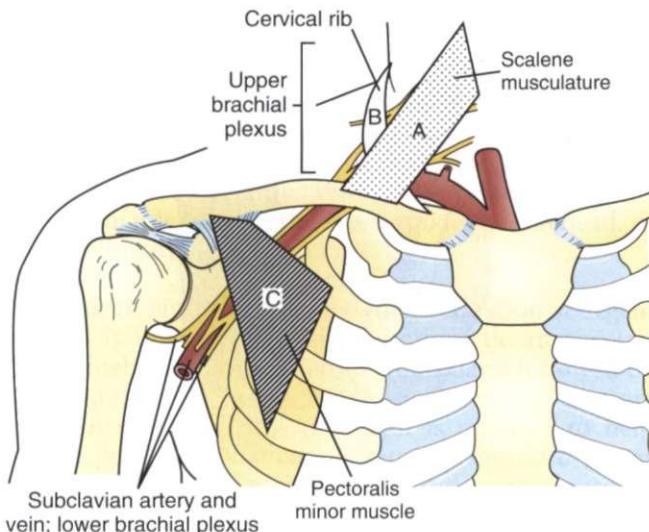


Figure 39-13

Schematic relationship of structures in development of thoracic outlet syndrome (TOS). Compression of the neurovascular bundle can occur with: (A) hypertrophy of scalene musculature impinging on structures lying between middle and anterior scalene; (B) the presence of cervical rib or fibrous bands between the cervical and first rib; or (C) compression by pectoralis minor during hyperabduction. [From Rakel RE: *Textbook of medicine*, ed 7, Philadelphia, 2007, Saunders.]

toration of function quickly, but recovery after transposition surgery may take up to 6 months. Surgery to treat chronic involvement (over 3 months) may have a less certain restoration of function.¹¹⁰ After nerve transposition, most NCVs at follow-up are improved. However, the magnitude of change in the motor conduction velocity does not correlate well with clinical improvement. One factor that has been identified to effect outcome is body mass index; increased body weight is related slightly to patient's perception of poorer improvement.¹¹⁰

Thoracic Outlet Syndrome

Because clients diagnosed with thoracic outlet syndrome (TOS) have vague symptoms or symptoms that are difficult to interpret, TOS remains a controversial diagnosis. Because this disorder is complex and poorly defined, many clients have been labeled neurotic.

Definition

TOS is an entrapment syndrome caused by pressure from structures in the thoracic outlet on fibers of the brachial plexus at some point between the interscalene triangle and the inferior border of the axilla. In addition, vascular symptoms can occur because of pressure on the subclavian artery (Fig. 39-13).

Etiology

The anatomy of the region of the thoracic outlet is extremely complex. Spinal nerve roots of the brachial plexus interact with surrounding bony ribs, muscles, and tendons (subclavius, anterior and middle scalene, and pectoralis minor) and the vascular supply (subclavian

artery and vein) to the region. In addition to neurologic structures becoming entrapped, arterial and venous structures also may be affected individually or in combination. Thus multiple specialists may be involved in a person's care. Practically, TOS can be divided into three groups: neurogenic (compression of brachial plexus), vascular (compression of subclavian artery and/or vein), and disputed (nonspecific TOS with chronic pain and symptoms of brachial plexus involvement).^{11,68}

Risk Factors

Postural changes associated with growth and development, trauma to the shoulder girdle, and body composition have all been identified as contributing to the development of TOS. The human upright posture has contributed to the development of TOS because gravity pulls on the shoulder girdle creating traction on the structures. Additionally, congenital factors that affect the bony structures, such as a cervical rib or fascial bands, also compress the neurovascular bundle.

Pathogenesis

Chronic compression of nerve roots or proximal plexus and arteries between the clavicle and first rib or impinging musculature results in edema and ischemia in the nerves (see Fig. 39-13). This compression initially creates a neurapraxia in which the axons are preserved, but segmental demyelination occurs. After loss of myelin the axons are more vulnerable to unrelieved compression. The neurapraxia can progress to an axonotmesis in which axon continuity is lost and Wallerian degeneration occurs.

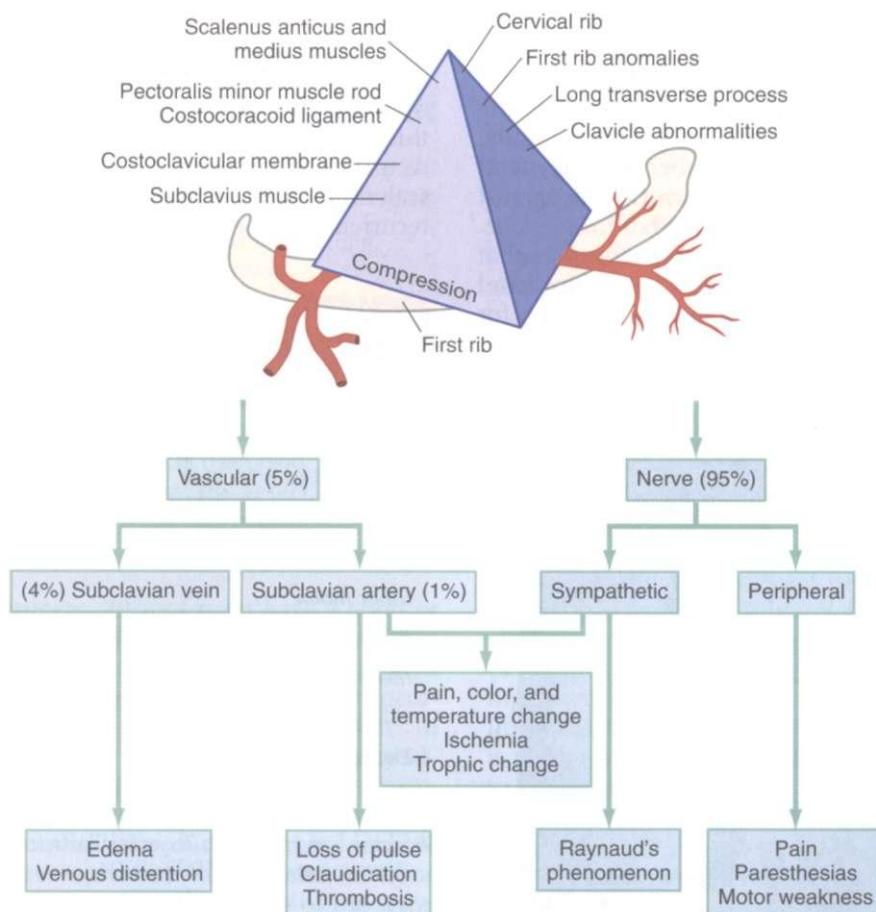
Clinical Manifestations

Signs and symptoms reflect the structures that have been compressed. When the nerves are compressed, most people report paresthesias and pain in the arm; most often these are nocturnal. Other symptoms may include pain, tingling, and paresis. If the upper nerve plexus is involved (C5 to C7), pain is reported in the neck; this may radiate into the face (sometimes with ear pain) and anterior chest, as well as over the scapulae. Symptoms may also extend over the lateral aspect of the forearm into the hand. If the lower plexus is compromised (C7 to T1), pain and numbness occur in the posterior neck and shoulder, medial arm and forearm, and radiate into the ulnarly innervated digits of the hand. Weakness is usual in the muscles corresponding to nerve root innervation, and atrophy occurs in severe cases. Vascular symptoms may include coldness, edema in the hand or arm, Raynaud's phenomenon (cyanosis), fatigue in hand and arm, and superficial vein distention in the hand. (Fig. 39-14).

The clinical presentation usually relates to posture and activities that aggravate symptoms. Overhead and lifting activities, along with movements of the head, produce symptoms in the upper plexus.

MEDICAL MANAGEMENT

DIAGNOSIS. Provocative tests are used to elicit symptoms of TOS, but these tests have a high false-positive response. Maneuvers are performed bilaterally, and the pulse is monitored to note a change in its quality. Based on the

**Figure 39-14**

Relationship of thoracic outlet abnormalities and impairments. (From Marx RS, Hockberger RS, Walls RM: *Rosen's emergency medicine: concepts and clinical practice*, ed 6, St Louis, 2006, Mosby.)

belief that the anterior scalene compresses the neurovascular bundle, the individual is positioned to elicit the symptoms. However, mere obliteration of the peripheral pulse does not necessarily mean that TOS exists as an entrapment problem; sensory symptoms must be reproduced. For persons with a vascular component, blood pressure may differ from side to side. Although there is no universally accepted reliable diagnostic test for TOS, *Adson's maneuver* (Fig. 39-15) appears among the most effective. Several other maneuvers with a positional component of the head, shoulder, or arm have been found to compress vascular or neural structures and thus evoke symptoms. These tests include the Allen's, Wright's, Halsted's, costoclavicular, Roos/elevated arm stress test (EAST), and provocative elevation tests (Table 39-6).⁵⁶ The sensitivity and specificity of Adson's test improve when used in combination with the hyperabduction test (symptom replication), the Wright's test (symptom replication), or the Roos test (Table 39-7).⁵¹

Radiographic Tests. Radiographic procedures are used to identify bony abnormalities. Presence of a cervical rib may indicate that the nerve has been compressed; however, presence of the rib alone does not necessarily replicate symptoms. Plain films are used to distinguish between a C7 to T1 discogenic lesion and TOS.

Electrophysiologic Studies. Because symptoms of TOS are related to neural compression, electrophysiologic studies are valuable in documenting the presence of neuropathy. NCV allows the examiner to pinpoint the lesion, either because of a change in amplitude or a slowing in conduction velocity (Box 39-2). Other, more refined electrophysiologic techniques, including somatosensory evoked potentials and F waves, are used to confirm a diagnosis of nerve root entrapment.

DIFFERENTIAL DIAGNOSIS. TOS must be distinguished from other disorders with similar symptoms. These include cervical radiculopathy, reflex sympathetic dystrophy, tumors of the apex of the lung (Pancoast's tumor, see Chapter 15), and ulnar nerve compression at either elbow or wrist. The sensory pattern of TOS distinguishes it from an ulnar neuropathy such as tardy ulnar palsy. Because the nerve roots are affected, the sensory changes extend above the hand and wrist into the forearm in TOS and follow a dermatomal pattern. Myofascial pain patterns may also mimic TOS symptoms.

TREATMENT. Management is divided into conservative and surgical approaches. The initial treatment of the person with TOS is conservative when symptoms are

mild to moderate in severity. Postural and breathing exercises and gentle stretching are the cornerstones of the initial conservative program. This is followed by strengthening exercises for shoulder girdle musculature, especially the trapezius, levator scapulae, and rhomboids. Initially, overhead exercises should be avoided because they tend to evoke symptoms. Therapists are cautioned against forceful stretching to mobilize the first rib.²⁹

Surgical management of TOS is reserved for cases that are refractory to postural and exercise correction and those with vascular compromise.²⁰ Once the decision for surgical intervention has been made, the physician must

select a procedure and the anatomic approach. There are at least six different surgical procedures and six different anatomic approaches (Box 39-3). In scalenotomy the muscle is detached from the first rib; unfortunately, with this approach a high percentage of people experience recurring symptoms. Scalenectomy, removal of the scalene muscle, is advocated for people who have had recurrence of their symptoms. Clavicle resection is indi-

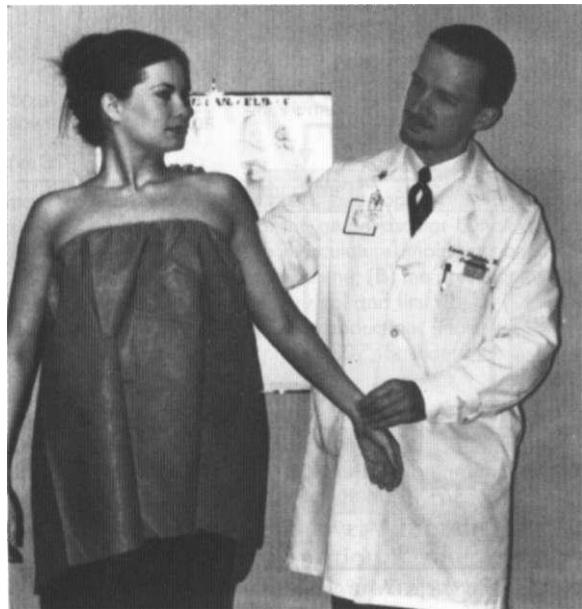


Figure 39-15

Adson's test is one of many diagnostic tests used to examine the upper extremity to determine presence of thoracic outlet syndrome: arterial or neurologic. Hold patient's arm in slight abduction while palpating the radial pulse. Ask the patient to inhale and hold the breath while extending the neck and rotating toward the affected side. Adson's test is positive if the patient reports paresthesias or if the pulse fades away. (From DeLee JC, Drez D, Miller MD: *DeLee and Drez's orthopaedic sports medicine*, ed 2, Philadelphia, 2003, WB Saunders.)

Box 39-2

TYPICAL ELECTROPHYSIOLOGIC FINDINGS IN THORACIC OUTLET SYNDROME

Upper Sensory

- Decreased amplitude

Median Sensory

- Normal

Ulnar Motor

- Normal or decreased amplitude

Median Motor

- Decreased amplitude

Electromyography

- + Fibrillation potentials: first dorsal interosseous

Adapted from Huang JH, Zager EL: Thoracic outlet syndrome, *Neurosurgery* 55:897-903, 2004.

Table 39-7 Diagnostic Utility of Tests for Thoracic Outlet Syndrome

Provocation Test	Sensitivity	Specificity
Adson's	0.79	0.76
Hyperabduction (HA)–pulse abolition (HAp)	0.84	0.4
Adson's + HAs (symptom replication)	0.72	0.88
Adson's + Wright's	0.54	0.94
Adson's + Roos	0.72	0.82

Table 39-6 Special Tests and Patterns of Positive Findings That Characterize Thoracic Outlet Syndrome*

NEURAL		
Vascular Component	Upper Plexus	Lower Plexus
3-minute elevated test	Point tenderness over C5-C6	Pressure above clavicle elicits pain
Adson's sign	Pressure over lateral neck elicits pain or numbness	Ulnar nerve tenderness when palpated under axilla or along inner arm
Swelling (hand, arm)	Pain with head turn or tilted to opposite side	Tinel's test for ulnar nerve in axilla
Discoloration of hand	Weak biceps	Hypoesthesia in ulnar nerve distribution
Costoclavicular test	Weak triceps	Serratus anterior weakness
Hyperabduction test	Weak wrist	Weak handgrip
Upper extremity claudication	Hypoesthesia in radial nerve distribution	
Differences in blood pressure from side to side	3-minute abduction stress test	
Skin temperature changes		
Cold intolerance		

From Goodman CC, Synder TEK: *Differential diagnosis for physical therapists: screening for referral*, Philadelphia, 2007, WB Saunders.

*With the use of special tests, patterns of position objective findings may help characterize thoracic outlet syndrome.

Box 39-3**SURGICAL PROCEDURES AND APPROACHES FOR THORACIC OUTLET SYNDROME**

Procedures	Approaches
• Scalenotomy	• Axillary
• Scaleneectomy	• Supraclavicular
• Clavicle resection	• Combined axillary and supraclavicular
• Pectoralis minor release	• Posterior
• First rib resection	• Subclavicular
• Cervical rib resection	• Transclavicular

cated primarily when the clavicle is damaged. When scalenectomy, with or without first rib resection, is the surgical approach used, its 5-year success rate is about 70%.¹³⁵

PROGNOSIS. After surgery, 70% of cases have a good or excellent response using a supraclavicular or transaxillary resection of the first rib. Improvement in pain symptoms ranges from 70% to 80%, some patients require occasional analgesics, and 10% note no improvement. In individuals with signs and symptoms and electrophysiologic changes consistent with classic TOS, no improvement in strength is noted when atrophy was present before surgery.²⁰ Complications during surgery include pneumothorax, nerve compression, and transient winging of the scapula because the upper digitations of the serratus are detached.

A 4-year follow-up reported no significant difference in return to work or symptom severity when the first rib was resected compared to a conservative, nonoperative approach.²⁶ Factors that are associated with long-term disability include preoperative depression, single status, and less than high school education.⁶

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-5**Thoracic Outlet Syndrome****PREFERRED PRACTICE PATTERNS**

4E: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range of Motion Associated with Localized Inflammation

4F: Impaired Joint Mobility, Motor Function, Muscle Performance, Range of Motion, and Reflex Integrity Associated with Spinal Disorders

5F: Impaired Peripheral Nerve Integrity and Muscle Performance Associated with Peripheral Nerve Injury

Therapists need to consider using an upper-quarter screen to rule out cervical radiculopathy or shoulder dysfunction during their evaluation. If this screen is negative, ROM and posture should be evaluated to identify soft tissue restrictions. The client's response to provocative maneuvers should be assessed along with a sensory evaluation, preferably using Semmes-Weinstein monofilaments. Finally, a manual muscle test or other method of evaluating strength should be per-

formed. Treatment is aimed at pain relief along with postural correction.¹⁶⁹

One of the reasons TOS has been difficult to diagnose relates to the client's subjective report. Frequently, signs and symptoms do not correspond to a single lesion, but to multifocal lesions, either of vascular and/or neurogenic origin. For clients who do not respond to treatment, some believe that compression at a proximal or distal source might increase the vulnerability of nerves, making them more susceptible to compression at another site.

Saturday Night Palsy/Sleep Palsy**Definition and Etiology**

Saturday night palsy is associated with radial nerve compression in the arm. It results from direct pressure against a firm object and typically follows deep sleep on the arm with compression of the radial nerve at the spiral groove of the humerus in a person who is sleeping after becoming intoxicated. Sleep palsy has also been associated with lipoma compressing the radial nerve.⁴³ If the radial nerve is compressed in the axilla, the damage is often referred to as a crutch palsy.

Pathogenesis

Compression of the nerve causes segmental demyelination.

Clinical Manifestations

Symptoms of radial nerve paralysis depends on the level of the lesion. The more proximal the involvement, the more extensive the paralysis. When involvement occurs in the axilla, weakness occurs in elbow extension (triceps), elbow flexion (brachioradialis), and supination (supinator). If the nerve is damaged in the upper arm the triceps is spared. In addition, in both instances there will be paralysis of wrist extensors and the extensors of the fingers and thumb, diminishing grip strength. Sensory loss with radial nerve involvement is variable. If present, it is typically confined to the dorsum of the hand but may extend to the dorsum of the forearm.

MEDICAL MANAGEMENT

DIAGNOSIS. Diagnosis is by history, clinical examination, and electrophysiologic examination. This type of paralysis is usually classified as a neurapraxia or conduction block, signifying demyelination. There is slowing of nerve conduction in both motor and sensory fibers across the lesion site.

TREATMENT. Medical management is aimed at asymptomatic management. A cock-up splint is used to maintain the wrist in an extended position until return of function.

PROGNOSIS. If a neurapraxia is reported, normal conduction can be anticipated within a few months because the paralysis is related to a focal demyelination.⁵⁹

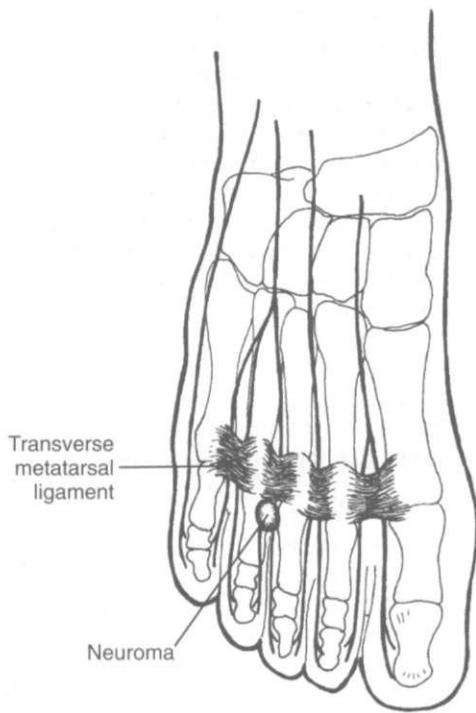


Figure 39-16

Morton's neuroma involves the common digital nerve. The most frequent location is between third and fourth metatarsals. (From Frontera WR, Silver JK: *Essentials of physical medicine and rehabilitation*, Philadelphia, 2002, Hanley and Belfus.)

Morton's Neuroma

Morton's neuroma is a common entrapment neuropathy in the forefoot, also called *interdigital perineural fibroma* (IPF), and most often involving the third toe interspace.

Definition and Etiology

No incidence or prevalence for Morton's neuroma has been published in any study. However, the average age of individuals diagnosed with Morton's neuroma is reported between 45 and 60 years, with women affected 5:1 more than men. Bilateral involvement is uncommon.¹⁸

Pathogenesis

Three common digital nerves, two arising from the medial plantar nerve, and third from the lateral plantar nerve, pass between divisions of the plantar aponeurosis where each bifurcates into two interdigital nerves. The first common digital nerve supplies adjacent sides of the great and second toe, those of the second common digital nerve supply adjacent sides of the second and third toes, and the sides of the third and fourth toes are supplied by the third common digital nerve (Fig. 39-16). Mechanical irritation resulting from intrinsic factors, such as diminished intermetatarsal head distance⁹⁰ and poor foot mechanics (excessive pronation during gait) that pulls the nerve more medially than normal and taut as the toes extend during terminal stance, and extrinsic factors, such as high heels in which the weight is transferred onto the

forefoot, maintaining the nerve in a taut condition; narrow toe box on shoe that creates a greater compression in the area; and thin-soled shoes where ground forces interact with the deep transverse metatarsal ligament, causing compression in this confined space, have been implicated as contributing to this condition. Additional inflammatory conditions, such as arthritis, and activities that involve application of repetitive forces to the plantar nerves, such as jogging on a hard surface, produce shear forces that can irritate the nerve.

Entrapment produces some or all of the following histopathology: thickening of the endoneurium, hyalinization of endoneurial vessels, thickened perineurium, and demyelination of nerve fibers.^{18,137}

Clinical Manifestations

Symptoms include burning, tingling, or sharp lancinating pain in one of the interspaces of the forefoot that occurs while walking. Pain may radiate into adjacent toes or proximally into the foot. Individuals may state that they must stop, remove their shoe, and massage their foot to relieve the symptoms. At its worst, the person may be apprehensive about stepping with the involved foot. Symptoms occur paroxysmally over many years.

MEDICAL MANAGEMENT

DIAGNOSIS. Typically, history and clinical examination have been used to diagnose this disorder. Two tests that provoke symptoms include plantar palpation of the involved space at the metatarsal heads as mediolateral compression is applied to the metatarsal heads (Mulder's sign) and dorsiflexion of the involved toe producing symptoms and plantarflexion of the toe relieving them (Lasegue's sign).⁴⁵ The reported positive predictive values of these clinical tests vary widely. Recently, sonography and MRI have been used to assess the presence of Morton's neuroma. Whereas the sensitivity for predicting the presence of Morton's neuroma is reported at 0.79 and 0.86, respectively, the specificity of both sonography and MRI is 1.0¹⁴⁵ and has been used to diagnose Morton's neuromas.^{125,157}

Differential diagnoses considered would include metatarsal stress fractures, metatarsalgia, and metatarsal phalangeal derangement.

TREATMENT. Conservative, nonoperative management is directed at pressure relief and involves use of a soft orthosis (insoles) or metatarsal pad. These may provide symptom relief as long as the shoes the person is wearing have a wider toe box and a lower heel. If symptoms continue, injection of a local anesthetic or corticosteroid from the dorsal direction may be helpful. Finally, surgical treatment involves either neural decompression by releasing the intermetatarsal ligament or neurectomy, proximal to the location of the neuroma to allow retraction of the plantar nerve away from the weight-bearing surface.

PROGNOSIS. A systematic review of these interventions reports that for studies in which orthoses have been used, 45% to 50% of the participants reported pain relief of more than 50% up to 1 year postintervention. For various surgical approaches, pain relief of more than 50%

occurred in 65% to 100% of patients up to 3 years postsurgery.¹⁵⁹

Neurotmesis

Definition

A neurotmesis occurs after total loss of axon and connective tissue continuity; the nerve is severed.

Etiology

Neurotmesis occurs after a gunshot wound, stab wound, or avulsion injury.

Pathogenesis

When the axon is lacerated, *wallerian degeneration* occurs distally and proximally the cell body also responds to the trauma. It swells and undergoes chromatolysis. The ribosomes that normally make protein for the cell disperse throughout the cytoplasm. *Chromatolysis* reflects a change in the metabolic priority of the cell as it switches from daily needs to a repair mode. Distally the axon begins to degenerate and myelin fragments within 12 hours of the lesion (see Fig. 39-3, C). This material is removed by macrophages responding to the inflammatory process.

As long as the cell body remains viable, a regenerative process begins with sprouting of a growth cone as soon as new cytoplasm is synthesized and transported down the axon from the cell body (see Fig. 39-3, D). As the growth cone grows, it releases proteases that dissolve material and permit the axon to enter the tissue more easily. Filopodia, which are fingerlike projections extending from the growth cone, sample the environment searching for chemical and tactile cues to guide the regenerating axon; however, because the tactile cues provided by the endoneurium are absent, many times these fibers become misguided and form a neuroma. The standard used to anticipate return of function is based on a growth rate of 1 mm a day or an inch a month. In reality, this is an average reflecting the delays that occur while the growth cone crosses the repair site and makes connection with sensory end organs or motor endplate. Growth occurs faster nearer the lesion site (3 mm/day) and slower as the length of the axon increases (1 mm/day).¹¹⁵

Clinical Manifestations

The degree of involvement relates to the nerve involved and its level of involvement. In any case, an immediate flaccid paralysis occurs in muscles distal to the lesion. Rapid atrophy ensues because of loss of the trophic influences of the nerve that innervated the muscle fibers. Sensory function is also lost below the level of the lesion.

MEDICAL MANAGEMENT

DIAGNOSIS. History and clinical examination are used to diagnose neurotmesis. In addition, electrophysiologic studies may be performed after a week. EMG will demonstrate the presence of fibrillation potentials and positive sharp waves, indicating denervation of muscle fiber. EMG can be used to determine whether the lesion is complete or partial.

TREATMENT. Surgical management is needed to suture the connective tissue bundles together to guide the regenerating growth cone. Various microsurgical techniques (cable and interfascicular grafts) are used to try and direct the axon into the appropriate fascicle by restoring connective tissue continuity. After complete axonal transection, the neuron undergoes a number of degenerative processes, followed by attempts at regeneration. A distal growth cone seeks out connections with the degenerated distal fiber. The current surgical standard is epineurial repair with nylon suture. To span gaps that primary repair cannot bridge without excessive tension, nerve-cable interfascicular autografts are employed. Unfortunately, results of nerve repair to date have been no better than fair, with only 50% of patients regaining useful function. There is much ongoing research regarding pharmacologic agents, immune system modulators, enhancing factors, and entubulation chambers. Clinically applicable developments from these investigations will continue to improve the results of treatment of nerve injuries.⁸⁸ Ideally, a primary repair will be carried out; operative delays lead to shrinkage and fibrosis of the distal connective tissue support structures.⁶⁶

Other treatments are symptomatic. For the therapist this means splinting to support structures. Use of electrical stimulation to maintain muscle bulk is controversial; recent studies have shown that the chemical signal guiding the nerve (neural cell adhesion molecule [NCAM]) disappears when denervated muscle receives electrical stimulation.¹³⁶ However, muscle bulk is maintained for up to 4 weeks. Because denervated skin does not wrinkle after it has been soaked in water, this has been used to evaluate denervation patterns.¹²³

PROGNOSIS. Recovery after neurotmesis is dependent on whether the nerve was repaired and the length of nerve that must be regenerated. Following transection, muscles atrophy rapidly, and after 2 years, they have undergone irreversible changes and have become fibrotic. If reinnervation occurs after 1 year, function is poor; with a delay of 18 to 24 months there is no hope for return of function.

METABOLIC NEUROPATHIES

Diabetic Neuropathy

Definition

A consensus conference has agreed that a detailed definition of diabetic neuropathy (DN) is "a descriptive term meaning a demonstrable disorder, either clinically evident or subclinical, that occurs in the setting of diabetes mellitus without other causes for peripheral neuropathy."^{3,90} DN is a common complication associated with diabetes mellitus (see Chapter 11) comprised of a heterogeneous group of progressive syndromes with diverse clinical manifestations. Neuropathies may be focal or diffuse and involve the autonomic or somatic PNS.^{11,12,167} Typically, the involvement occurs in a distally, symmetric pattern, termed *diabetic polyneuropathy*, although single, focal nerve involvement may be seen.

Incidence

In the United States, diabetes mellitus affects over 20 million people, and this number is expected to increase by 5% every year. The prevalence of DN is greater (54%) in type I diabetes (insulin-dependent diabetes mellitus [IDDM]) than the prevalence of DN in type 2 diabetes (noninsulin-dependent diabetes mellitus [NIDDM]), which is 30%. The most reliable estimates from clinical studies report that DN, although present in individuals with diabetes lasting longer than 25 years, is present in 7% of people within 1 year of diagnosis with diabetes.¹⁴⁷

Etiology

DN is probably caused by the chronic metabolic disturbances that affect nerve cells and Schwann cells in diabetes. For years, hyperglycemia was considered the sole cause of these secondary complications of diabetes. Although consequences of hyperglycemia include elevated levels of sorbitol and fructose, which coincides with deficiencies of sodium-potassium and adenosine triphosphate (ATP) that alter the function of peripheral nerves, chronic hyperglycemia leads to abnormalities in microcirculation, creating endothelial capillary changes and local ischemia that affect the nerve. Excess sorbitol also damages Schwann cells. Most recently, researchers have suggested that alterations in insulin levels alter its regulatory roles in gene-regulation of neurotrophic factors, cell-cell adhesion molecules, and modification of proteins.¹⁴⁷

Risk Factors

Although hyperglycemia is not directly attributed to damaging nerve fibers causing DN, it is a contributing factor. Conversely, some people develop neuropathies when glycemic control is good. A clear relationship does exist between duration of diabetes and development of DN. After the onset of the neuropathy, control of hyperglycemia is known to enhance the possibility of regeneration of fibers. Although studies have confirmed a genetic predisposition to diabetes, they have not confirmed such a predisposition to development of DN nor has a familial tendency been reported. Up to 50% of all people with diabetes never develop symptoms of neuropathy.

Pathogenesis

Many hypotheses exist for the pathogenesis of this disorder. The metabolic effect of hyperglycemia exposes nerves and their associated Schwann cells to glucose. The most prominent change in DN is loss of both myelinated and unmyelinated axons. Nerves are affected distally more than proximally. Subtle changes have been reported at the nodes of Ranvier in nerves of people with DN. This is associated with slowing of the NCV.¹⁶⁶

A number of studies suggest that vascular changes affect peripheral nerves in diabetes. Evidence demonstrates endoneurial microvascular thickening. In the sural nerve, this has resulted in increased numbers of closed capillaries, which are believed to cause multifocal regions of ischemia and hypoxia in the nerve, resulting in an axonal degeneration.

Box 39-4

CLASSIFICATION OF DIABETIC NEUROPATHY

Rapidly Reversible

- Hyperglycemic neuropathy

Generalized Symmetric Polyneuropathies

- Acute sensory
- Chronic sensorimotor
- Autonomic

Focal Neuropathies

- Cranial
- Focal limb

Adapted from Boulton AJ, Vinik AI, Arezzo JC, et al: Diabetic neuropathies. A statement by the American Diabetes Association, *Diabetes Care* 28:956-962, 2005.

Another explanation for the development of diabetic neuropathy proposes that the concentration of nerve growth factor (NGF), which has a structure that is molecularly and physiologically similar to insulin, is reduced. Since NGF acts as a trophic factor, its reduction also reduces nutrition to the nerve.

Clinical Manifestations

DN has been classified in a number of ways: presumed etiology, pathologic features, anatomic location, and a mixture of these. The most recent classification reflects the disturbances that occur in DN (Box 39-4)

Rapidly Reversible Neuropathy

Hyperglycemic Neuropathy. Hyperglycemic neuropathy occurs in individuals with poorly controlled diabetes, and in those who have been newly diagnosed, rapidly reversible nerve conduction abnormalities have been reported. These abnormalities are accompanied by distally symmetric sensory changes such as burning, paresthesias and tenderness in the feet and legs. Symptoms disappear when the individual's blood sugar is controlled, although abnormalities in nerve conduction may persist.¹¹

Generalized Symmetric Polyneuropathies

Acute Sensory Neuropathy. Hallmarks of acute sensory neuropathy, are the rapid onset of severe burning pain, deep aching pain, a sudden sharp "electric shock-like" sensation, and hypersensitivity of the feet that is often worse at night. Signs of this painful DPN are relatively normal: normal motor examinations in which the tendon reflexes are normal or reduced at the ankle. The patient may have no or only mild symmetric sensory loss, with allodynia. Testing procedures to confirm allodynia should apply the following concepts: apply a phasic stimulus (rub) to various parts of the body and ask the person whether burning occurs in a nearby region; Application of a cotton ball or Semmes-Weinstein monofilament is not applied long enough for the slow summation required for allodynia. Place a towel on the patient's body and wait for a period of time before asking whether the cover creates pain; Do NOT use a sharp-dull to test for allodynia because it is pain from nonpainful stimuli. Noci-

Box 39-5**MANIFESTATIONS OF AUTONOMIC DIABETIC NEUROPATHY**

Cardiovascular	Gastrointestinal	Genitourinary	Other
<ul style="list-style-type: none"> • Tachycardia • Exercise intolerance • Orthostatic hypotension • Dizziness 	<ul style="list-style-type: none"> • Esophageal motility dysfunction • Diarrhea • Constipation 	<ul style="list-style-type: none"> • Neurogenic bladder • Bladder urgency, incontinence • Erectile dysfunction 	<ul style="list-style-type: none"> • Sweating, heat intolerance • Dry skin • Pupillary dysfunction, blurred vision

Adapted from Boulton AJ, Malik RA, Arezzo JC, et al: Diabetic somatic neuropathies, *Diabetes Care* 27:1458-1486, 2004.

ceptive stimuli are perceived normally in acute sensory neuropathy. Electrophysiologic studies (NCV) may be normal or show minor changes. If the person can achieve and maintain stable blood glucose, recovery can occur within 1 year, even with severe symptoms.¹¹

Chronic Sensorimotor Neuropathy. Chronic sensorimotor neuropathy, or diabetic polyneuropathy (DPN), is the most common type of DN and up to 50% of patients may develop this condition. Typically, its onset is insidious, but occasionally signs and symptoms appear acutely. DPN's clinical features include sensory loss, occasionally with selective fiber type involvement. Small fiber involvement leads to burning pain, and paresthesias, such as those described for acute sensory neuropathy, are more profound at night in the feet and lower legs (stocking pattern). Large fiber involvement results in painless paresthesia with impaired vibration, proprioception, touch, and pressure along with loss of ankle DTRs. Clients may report that they feel as if they were walking on cotton or clouds. In DPN, motor weakness is mild (presence of hammer toes and/or pes cavus) with wasting of small muscles in the feet and hands in more advanced cases. The presence of pronounced motor involvement implies that this is not DPN. DPN may be accompanied by clinical or subclinical autonomic involvement that can include cardiovascular and sympathetic disturbances resulting in sweating, orthostatic hypotension, and resting tachycardia (>100 bpm at rest).¹¹

Autonomic Neuropathy. Sympathetic and parasympathetic involvement may occur in both type I and type II diabetes; however, in type 2 diabetes, parasympathetic functions are more affected. After 10 to 15 years, 30% of patients have subclinical manifestations of autonomic involvement. Major manifestations associated with autonomic involvement are shown in Box 39-5.¹²⁷

Focal Neuropathies

Mononeuropathies. Mononeuropathies in the limbs or cranial nerves may occur in diabetes less often than the generalized, symmetric patterns. The median, ulnar, and peroneal nerves are most commonly affected in limb focal neuropathies. The somatic division of the oculomotor nerve is most commonly involved.

MEDICAL MANAGEMENT

DIAGNOSIS. The diagnosis is based on the history, clinical examination, electrodiagnostic studies, quantitative sensory evaluation, and autonomic function testing. Diagnosis of DN should not be based on a single symptom, sign, or test; a minimum of two abnormalities

(signs and symptoms from NCV, sensory, or autonomic tests) has been recommended.¹ Tools required for the sensory examination include a 128 Hz tuning fork to assess vibration and a 1 gm monofilament for touch. Autonomic functions can initially be assessed by blood pressure and heart rate response at rest, in standing and with exercise. Because diabetes is a common disorder and because neuropathies may be related to other causes, mere association of neuropathic signs and symptoms in a person with diabetes is not sufficient to diagnose DN. Other causes must be excluded.⁶¹

Sensory, motor, and F responses are important to assess nerve function at baseline and intermittently at follow-up visits. The most common electrical changes is a reduced amplitude in the sensory action potential (SNAP), which suggests axonal degeneration. A recent report found that a high percentage of newly diagnosed patients with type II diabetes have reduced SNAP in upper extremity nerves.¹³⁰ Slowing of sensory and/or motor NCV suggests a demyelinating neuropathy, and pronounced slowing suggests that an alternative diagnosis should be explored.⁸ Sensory fibers are generally affected first before motor fibers.

TREATMENT. Management is divided into general and specific measures. General measures include control of hyperglycemia¹⁶⁵ and specific measures address the symptomatic management of the disorders (see section on Diabetes Mellitus in Chapter 11). Because there is evidence that further complications can be reduced by maintaining control of the diabetes, this is one specific area addressed by health care professionals. In addition, specific drug therapies are being evaluated. Currently, studies on medications and biochemical factors, such as ganglionosides and NGFs, are being conducted and although some show promise. Tricyclic antidepressants are used alone or in combination with fluphenazine to treat painful neuropathies and gabapentin or carbamazepine is an efficacious approach to the management of pain in focal neuropathies.¹⁶⁵ Although topical capsaicin has been recommended for allodynia, a systematic review concluded that it had moderate to poor efficacy in the management of chronic pain.¹⁰³ Angiotensin-converting enzyme (ACE) inhibitors act on the vascular dysfunction and prevent the development and progression of diabetic neuropathy.¹⁰⁰ In a systematic analysis of seven qualifying studies, researchers found vitamin B12 (either as B12 complex or methylcobalamin, one of two coenzyme forms of B12) had beneficial effects on pain and paresthesia more than

electrophysiologic changes. Methylcobalamin improved autonomic symptoms in three studies.¹⁵²

If the person has a painful DN, an algorithm has been developed that begins with physical modalities to manage pain. This is combined with simple analgesics. Further management may include a trial of topical or benign drugs.¹⁶⁶ A common complication of DN is the development of neuropathic foot ulcers. When great toe and ankle joint mobility is limited greater forefoot pressures occur during gait, which may place patients with diabetes (type I or II) at risk for development of metatarsal ulceration.¹⁷⁹ In type II diabetes, early detection of diabetic neuropathy along with prophylactic foot care regimens has led to fewer foot ulcerations and amputations.¹⁴³ Institution of foot care procedures is essential (see Special Implications for the Therapist discussion of foot care in diabetes in Chapter 11). With the development of a foot-drop gait, orthotic devices should be considered for the person's safety. The type of orthosis and shoe construction prescribed should be carefully considered based on the sensory picture and the person's ability to demonstrate appropriate foot care.

PROGNOSIS. DN is a slowly progressive disorder. Because it is a metabolic disorder, other systems are often affected. Estimates are that over 50% of nontraumatic amputations in the United States are performed in diabetic clients. The presence of autonomic involvement is associated with an increased mortality risk.

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-6

Diabetic Polyneuropathy

PREFERRED PRACTICE PATTERNS

- 5G:** Impaired motor function and sensory Integrity Associated with Acute or Chronic Polyneuropathies.
- 7A:** Primary Prevention/Risk Reduction for Integumentary Disorders

Alcoholic Neuropathy

Peripheral neuropathies, typically with distally symmetrical involvement, appear in alcoholics after years of chronic alcohol abuse.

Etiology and Risk Factors

Although the exact pathogenesis of alcoholic neuropathy remains unclear,¹⁶⁸ lesions affecting the peripheral nerves have been attributed to both the direct toxic effects of alcohol on nerve and nutritional deficiencies in thiamine and other B vitamins from poor dietary habits. However, there is more recent evidence that neither age nor nutritional status play a part in development of alcoholic neuropathies. Rather, alcohol-related neuropathies appear to be due to the total lifetime accumulation of ethanol.¹⁸ Patients exhibiting alcoholic neuropathy were divided into those with and without a coexisting thia-

mine deficiency. Researchers reported that patients without thiamine deficiency tended to have a more slowly progressive disorder in which sensory symptoms were dominant, primarily pain or a burning sensation. Along with these symptoms, the nerve biopsy demonstrated greater small fiber axonal loss. Those with alcoholic neuropathy with thiamine deficiency had large fiber involvement with segmental demyelination, and an acutely progressive motor dominant pattern along with loss of superficial and deep sensation was noted. These findings further support the view that alcohol directly effects nerve fibers.⁸²

Pathogenesis

The exact pathogenesis of alcoholic neuropathy remains unclear. Segmental demyelination and axonal degeneration have been described in persons with alcoholic polyneuropathy; these differences may relate to the presence of vitamin deficiencies, as noted above. Changes occur distally at first and become more marked and proximal.⁵⁴

Clinical Manifestations

Mild forms of alcoholic neuropathy exhibit minor loss of muscle bulk, diminished ankle reflexes, impaired sensation in the feet, and aching in the calves. Distal sensory changes include pain, paresthesia and numbness in a symmetric stocking-glove pattern. In addition, vibratory perception is impaired. It begins insidiously and progresses slowly; occasionally the onset may occur acutely. In the most advanced cases, symptoms involve all four extremities. Weakness and atrophy of distal musculature should be anticipated, with lower extremity involvement greater than upper extremity. Bilateral footdrop is observed during gait, and a wristdrop contributes to a diminished grip strength because of the client's inability to extend the wrist. Both of these features are often combined with varying amounts of peripheral weakness in other muscles.

MEDICAL MANAGEMENT

DIAGNOSIS AND TREATMENT. The diagnosis is made by history, clinical examination, and electrodiagnostic testing showing loss of action potential amplitude (sensory and motor). Although diet is no longer implicated as a contributing factor in the development of alcoholic neuropathies, diet to improve nutritional status, along with vitamin supplements and abstinence from alcohol, is the treatment of choice. All other treatment is symptomatic. Orthotic devices, such as ankle-foot orthoses (AFOs) and cock-up splints, are used to manage weakness and improve function. Medications for sensory changes include carbamazepine, salicylates, and amitriptyline.

PROGNOSIS. If the client totally abstains from alcohol, mild improvement can be expected, but recovery is slow (months to years) and incomplete when axonal degeneration has occurred.¹¹⁷ Therefore, to anticipate the outcome, review the client's electrophysiologic studies to determine whether demyelination or degeneration is present.

Compression neuropathies, such as Saturday night palsy or peroneal nerve compression, may result from a bout of chronic alcohol intoxication where prolonged pressure compromises nerve function. Excessive alcohol intake may also produce rhabdomyolysis which produces proximal muscle weakness, swelling, and pigmented urine. Rhabdomyolysis occurs as product of renal failure after drinking.

Chronic Renal Failure

Clinical Manifestations

Neurologic. Alteration of CNS and PNS function often occurs with chronic renal failure associated with uremia. CNS involvement (uremic encephalopathy) is manifested by recent memory loss, inability to concentrate, perceptual errors, and decreased alertness. Uremic toxins contribute to atrophy and demyelination of both sensory and motor nerves of the PNS. The lower extremities are much more commonly affected than the upper extremities; neurologic changes are typically symmetric and can also be manifested as peripheral neuropathy or restless leg syndrome, which is more pronounced at rest.

Anemia

CNS symptoms can develop in cases of severe pernicious anemia, whereas neuropathy is observed in early cases of B12 deficiency, allowing for early identification. The findings typically consist of a symmetric sensory neuropathy that begins in the feet and lower legs, although it rarely may involve the upper extremities, especially fine motor coordination of the hands. This upper extremity neuropathy may clinically manifest as problems with deteriorating handwriting. Affected individuals may also describe moderate pain or paresthesias of the extremities, especially the feet. The person may interpret the neuropathy as difficulty with locomotion when in fact they are experiencing the loss of proprioception. The affected individual may need to hold on to the wall, countertops, or furniture at home as a result of difficulties maintaining balance. There may be an associated positive Romberg sign. Loss of motor function is a late manifestation of B12 deficiency. Although a symmetric neuropathy is the usual pattern, B12 deficiency occasionally presents as a unilateral neuropathy and/or bilateral but asymmetric neuropathy. Rarely, subacute degeneration of the spinal cord caused by vitamin B12 deficiency can occur in pernicious anemia, characterized by pyramidal and posterior column deficits. CNS manifestations may include headache, drowsiness, dizziness, fainting, slow thought processes, decreased attention span, apathy, depression, and irritability.

INFECTIONS/INFLAMMATIONS

Guillain-Barre Syndrome

Overview and Definition

Guillain-Barre syndrome (GBS) was originally described by and named for the French neurologists who published case reports describing a syndrome of flaccid paralysis,

areflexia, and albuminocytologic dissociation. More recently, the syndrome has been viewed as having distinct subtypes with varying distributions worldwide. Since the virtual elimination of poliomyelitis, GBS is the most common cause of rapidly evolving motor paresis and paralysis and sensory deficits. Individuals affected with GBS typically reach maximal weakness within 2 to 3 weeks but spend weeks to months recovering. The most common form of GBS is also known as acute inflammatory demyelinating polyradiculoneuropathy (AIDP).

Incidence

Annual incidence varies from 1 to 2 cases per 100,000 people. Although GBS occurs at all ages, peaks in frequency can be seen in young adults and in the fifth through the eighth decades. Occurrence is slightly greater for men than women and for whites more than blacks. Some researchers have noted a seasonal relationship associated with infections.

Etiology and Risk Factors

Evidence supports the view that GBS is an immune-mediated disorder. Bacterial (*Campylobacter jejuni*) and viral (*Haemophilus influenzae*, Epstein-Barr virus, and cytomegalovirus [CMV]) infections, surgery, and vaccinations have been associated with the development of GBS. Of the two-thirds of persons reporting an acute infection within 2 months preceding onset of GBS, 90% had illnesses (e.g., respiratory or gastrointestinal) during the preceding 30 days.¹¹⁹

Pathogenesis

Lesions occur throughout the PNS from the spinal nerve roots to the distal termination of both motor and sensory fibers. Originally, GBS was classified as a single entity characterized by PNS demyelination. Now, however, it is defined as several heterogenous forms (Table 39-8). *C. jejuni* is associated more commonly with the axonal form, whereas greater sensory involvement is seen following CMV.⁶⁹ The axonal pattern of involvement can involve motor fibers only or in the more severely involved form, motor and sensory fiber degeneration. Finally, Miller Fisher syndrome is characterized by an acute onset of extraocular muscle paralysis with sluggish pupillary light reflexes, a peripheral sensory ataxia, and loss of deep tendon reflexes with relative sparing of strength in the extremities and trunk. Facial weakness and sensory loss in the limbs may also occur.

Molecular mimicry, an autoimmune theory, is the primary theory for the cause of GBS because evidence exists for antibody-mediated demyelination. Myelin of the Schwann cell is the primary target of attack. Researchers theorize that circulating antibodies to gangliosides penetrate and bind to an antigen on the surface of the myelin and activate either complement or an antibody-dependent macrophage.⁷⁰ The earliest pathologic changes in the PNS take the form of a generalized inflammatory response. Lymphocytes (T cells) and macrophages are the inflammatory cells present. Demyelination, initiated at the node of Ranvier, occurs because macrophages, responding to inflammatory signals, strip myelin from the nerves. After the initial demyelination, the body initi-

Table 39-8 Guillain-Barré Syndrome and Its Variants

Abbreviation	Name	Clinical Characteristics
AIDP	Acute inflammatory demyelinating polyneuropathy	Primary demyelination: progressive paralysis, areflexia
AMAN	Acute motor axonal neuropathy	Axonal variant, more severe: frequent respiratory involvement/ventilator dependence and significant residual impairments
ASAN	Acute sensory ascending neuropathy	Sensory changes more prominent than weakness
AMSAN	Acute motor and sensory axonal neuropathy	Manifested by postural hypotension, impaired sweating, lacrimation, bowel and bladder function
	Acute autonomic neuropathy	Ophthalmoplegia, ataxia, areflexia with significant weakness
	Fisher/Miller-Fisher syndrome	
CIDP	Chronic inflammatory demyelinating polyneuropathy	Slower onset, relapses and remissions, or progressive course over a year

ates a repair process. Schwann cells divide and remyelinate nerves, resulting in shorter internodal distances than were present initially.

In addition to the demyelination, there is another process that has longer-lasting effects. Although there is an axonal subtype, axonal degeneration to some degree occurs in most cases of demyelinating GBS. In the latter, many believe that the axons are damaged during the inflammatory process, according to what has been called a "bystander effect." Products that are liberated by the macrophages as they strip myelin (e.g., free oxygen radicals and proteases) also damage axons.

Axonal patterns of involvement display a diminished or absent inflammatory response seen in demyelination. Researchers have reported the presence of macrophages that invade periaxonal spaces, causing the axon to degenerate within the ventral roots. Recovery for this Wallerian-like degeneration would require an extremely long period. For those individuals with acute motor axonal neuropathy (AMAN), another mechanism may promote rapid recovery for what appears to be axonal involvement. Binding of antibodies to the nodes of Ranvier may cause blocking of nerve conduction by altering sodium channel conductance has been established in rabbits.

Although the autoimmune theory is the main one advanced for this disorder, it may not be the only reason for the development of GBS. Cases of GBS have been reported in immunosuppressed individuals after renal transplant.

Clinical Manifestations

Various subtypes of GBS exist; however, the "classic" picture is an acute form in which the time from onset to peak impairment is 4 weeks or less. A recurrent form of GBS is reported in up to 10% of cases. Acute relapses may occur in GBS and this characteristic may make it difficult to differentiate the acute from the chronic form, called *chronic demyelinating polyradiculoneuropathy* (CIDP). Most cases of CIDP progress over a period of months instead of weeks.

In GBS, symptoms are characterized by a rapidly ascending symmetric motor weakness and distal sensory impairments. The first neurologic symptom is often paresthesia in the toes. This is followed within hours or days

by weakness distally in the legs. Weakness spreads to involve arms, trunk, and facial muscles. Flaccid paralysis is accompanied by absence of DTRs. Occasionally, sensory and motor symptoms begin in the hands and arms instead of the feet and legs. Palatal and facial muscles become involved in about half of all cases; even the muscles of mastication may be affected, but nerves to extraocular muscles typically are not involved. Up to 30% of all cases require mechanical ventilation.

Because the preganglionic fibers of the ANS are myelinated, they, too, may be subject to demyelination. If this occurs, tachycardia, abnormalities in cardiac rhythm, blood pressure changes, and vasomotor symptoms occur.

In 50% of the cases, progression of symptoms generally ceases within 2 weeks and in 90% of the cases, progression ends by 4 weeks. After the progression stops, a static phase begins, lasting 2 to 4 weeks before recovery occurs in a proximal to distal progression. This recovery may take months or even years.

MEDICAL MANAGEMENT

DIAGNOSIS. Careful clinical and neurophysiologic examinations and laboratory tests are needed to diagnosis GBS. Criteria have been developed by the National Institute of Neurologic and Communicative Disorders and Stroke (NINCDS) (Box 39-6); however, these criteria omit the variants that have been identified.¹³

After symptoms have existed for 1 week, a lumbar puncture can be performed to withdraw cerebrospinal fluid (CSF). Albumin (a protein) is elevated in the CSF with 10 or fewer mononuclear leukocytes present. Electrophysiologic tests will reveal slowed NCVs the entire length of the nerve when demyelination is present, as well as fibrillation potentials when axonal degeneration occurs. When both axonal involvement and demyelination occur, the amplitude of the evoked (NCV) potential will be reduced and the velocity is slowed, respectively.

These abnormalities may not be apparent during the first few weeks of the illness. In addition, to determine the extent of demyelination of the more proximal nerve roots, an F wave electrophysiologic test may be performed; it is often prolonged or absent. As recovery occurs, slowed NCVs persist, even though the person has

Box 39-6**CRITERIA FOR DIAGNOSIS OF GUILAIN-BARRÉ SYNDROME****Symptoms Required for Diagnosis**

- Progressive weakness in more than one extremity
- Loss of deep tendon reflexes

Symptoms Supportive of Diagnosis (in Order of Importance)

- Weakness developing rapidly that ceases to progress by 4 wk
- Symmetric weakness
- Mild sensory symptoms and signs
- Facial weakness common and symmetric; oral-bulbar musculature may also be involved
- Recovery usually begins 2-4 wk after GBS ceases to progress
- Tachycardia, cardiac arrhythmias, and labile blood pressure may occur
- Absence of fever

CSF Features

- CSF protein levels increased after 1 wk; continue to increase on serial examinations
- CSF contains 10 or fewer mononuclear leukocytes/mm³

Electrodiagnostic Features

- Nerve conduction velocity slowed

Adapted from Hund EF, Borel CO, Cornblath DR, et al: Intensive management and treatment of severe Guillain-Barré syndrome, *Crit Care Med* 21:435, 1993.

GBS, Guillain-Barré syndrome; CSF, cerebrospinal fluid.

made a full clinical recovery. Although electrophysiologic studies are used for diagnosis, the distal compound motor action potential (CMAP) is a predictor of prognosis. If the CMAP amplitude is less than 20% of normal limits at 3 to 5 weeks, it predicts a prolonged or poor outcome.¹²⁴

DIFFERENTIAL DIAGNOSIS. Hysteria is the most common misdiagnosis. Because of the speed of onset, a stroke involving the brainstem will also be considered. Less common causes of acute neuropathies must also be considered, including tick paralysis, and metabolic disorders such as porphyria.

TREATMENT. Because GBS is believed to be an autoimmune disease, treatment has been aimed at controlling the response. In two major trials, plasmapheresis, a technique (also called plasma exchange [PE]) that removes plasma from circulation and filters it to remove or dilute circulating antibodies, has been shown to significantly improve the impairments in GBS. Typically, the client will have 4 to 6 exchanges of 500 ml per treatment over the period of a week. Time on a respirator and time to independent ambulation (53 days) were both shorter than in the control group (85 days). Plasmapheresis is instituted when respiratory function drops precipitously (to 1.0 to 1.5 L), and the person is placed on a respirator.

High-dose intravenous (IV) administration of immunoglobulin (Ig; a protein the immune system normally

uses to attack foreign organisms) has been found safe and effective in the treatment of GBS.¹⁶³ The therapeutic dose is 0.4 g/kg/day for 5 days.⁷¹ Practice parameter recommendations made after a review of PE and IVIg studies are that PE should be administered in nonambulatory adults seeking treatment within 4 weeks of GBS onset or ambulatory adults within 2 weeks of onset. IVIg was recommended in nonambulatory adults within 2 weeks of onset. Outcomes for either approach were equivalent. For children with severe GBS, either treatment approach is an option.⁷¹

PROGNOSIS. The primary methods of managing GBS have helped to improve mortality rates, which can exceed 5%. Factors that predict a poor outcome include onset at an older age, a protracted time before recovery begins, and the need for artificial respiration. An important objective evaluation finding that predicts a poor outcome is significantly reduced evoked motor potential amplitude, which correlates with the presence of axonal degeneration. Although most persons recover, up to 20% can have remaining neurologic deficits. After 1 year, 67% of clients have complete recovery, but 20% remain with significant disability.⁴² Even after 2 years, 8% have not recovered.

SPECIAL IMPLICATIONS FOR THE THERAPIST**39-7****Guillain-Barre Syndrome****PREFERRED PRACTICE PATTERNS**

5F: Impaired Peripheral Nerve Integrity and Muscle Performance Associated with Peripheral Nerve Injury

5G: Impaired Motor Function and Sensory Integrity Associated with Acute or Chronic Polyneuropathies

6B: Impaired Aerobic Capacity/Endurance Associated with Deconditioning

6E: Impaired Ventilation and Respiration/Gas Exchange Associated with Ventilatory Pump Dysfunction or Failure

7A: Primary Prevention/Risk Factors Reduction for Integumentary Disorders

Physical therapy is initiated at an early stage in this condition to maintain joint ROM within the client's pain tolerance and to monitor muscle strength until active exercises can be initiated. During the ascending phase when the person is losing function and becoming weaker, he or she can become easily fatigued and overwhelmed. Focus is toward prevention of complications associated with immobilization.

Meticulous skin care is required by all staff members to prevent skin breakdown and contractures. A strict turning schedule is usually established by the nursing staff and should be followed by all other health care staff as well. After each position change, inspect the skin (especially the sacrum, heels, ankles, shoulders, and greater trochanter). Massage to pressure points stimulates circulation; family or other caregivers can be instructed to perform this on a regular basis.

Care in the intensive care unit (ICU) requires observation of arterial blood gas measurements. Because the

Continued.

disease results in primary hypoventilation with hypoxemia and hypercapnia, watch for Po_2 below 70 mm Hg, which signals respiratory failure. Report any signs of rising Pco_2 (e.g., confusion, tachypnea). Pulse oximetry may be used to monitor peripheral oxygen saturation (see Appendix B). Auscultate breath sounds, turn and position the person, and encourage coughing and deep breathing to maintain clear airways and prevent atelectasis. See also Special Implications for the Therapist: Atelectasis in Chapter 15. The therapist must also follow universal precautions to help prevent any respiratory infection for the client (see Appendix A). Respiratory support is needed at the first sign of dyspnea (in adults, vital capacity less than 800 ml; in children, less than 12 ml/kg of body weight) or decreasing Po_2 .

Ventilation is instituted when pulmonary function is compromised by loss of respiratory skeletal muscle control. Coughing and clearing of tracheal secretions becomes difficult. In addition, weakness of laryngeal and pharyngeal muscles makes swallowing difficult and increases the risk of aspiration. Early tracheostomy is indicated in people with clinical and EMG evidence of axonal involvement together with respiratory failure.

Clinical indications for weaning from the ventilator include improved forced vital capacity and improved inspiratory force concomitant with improved muscle stretch. Finally, the chest should be clear of atelectasis. Communication using a communication board or other method is needed during ventilatory support.

Exercise and Guillain-Barre Syndrome

When the person's condition stabilizes, a therapeutic pool or Hubbard tank can be used to initiate movement in a controlled environment. A major precaution during the early treatment phase is to provide gentle stretching and active or active-assistive exercise at a level consistent with the person's muscle strength. Overstretching and overuse of painful muscles may result in a prolonged recovery period or a lack of recovery. During the descending phase, when the paralysis slowly recedes and physical function returns, neuromuscular facilitation techniques (such as proprioceptive neuromuscular facilitation) may be integrated into the active and resistive exercises.

Deep muscular discomfort or pain in the proximal muscles may be reported by clients. Paresis or paralysis requires positioning and appropriate splinting, which can help alleviate muscle and joint pain. Bed cages may reduce dysesthesias that are present in the feet. Palliative modalities, such as hot packs and gentle massage, may also bring relief of musculoskeletal pain.

Foster and Mulroy report that the average length of stay (LOS) for individuals in a rehabilitation facility was 63 days. Longer LOS correlated with presence of muscle belly tenderness, extreme lower limb weakness as measured by manual muscle test, and functional independence measure (FIM) scores at admission. Although the presence of axonal involvement was not significantly related to LOS, it does affect severity of involvement and the need for ventilator and orthosis,

which tended to require longer stays.⁴⁸ The length of time to maximum impairment (respiratory compromise and motor involvement) has not been found to correlate with outcome. Generally, the shorter the time it takes for recovery to begin after maximum impairment has been reached, the less likely it is that long-term disability will occur.¹¹¹

Discharge Planning

When the person is discharged from therapy, recovery may not be complete. Impaired function may require the continued use of assistive devices and possibly even mobility equipment such as a wheelchair or scooter. The home may require modifications, which should be evaluated and planned for before discharge.

Post-Polio Syndrome/Post-Polio Muscular Atrophy

Overview

Poliomyelitis (polio) virus infection was virtually eradicated in the United States with the advent of the Salk vaccine in the 1950s and the Sabin vaccine in the 1960s. Clinically, the disease was characterized as one of three patterns: (1) an asymptomatic or (2) nonparalytic infection that produced gastrointestinal, flulike symptoms and muscular pain or (3) a paralytic infection that also began with flulike symptoms. The paralytic form generally developed within a week after the onset of the symptoms. The virus invaded and damaged motor cell bodies. The extent of the asymmetric paresis and paralysis that ensued depended on the degree of anterior horn cell involvement. When cell bodies were killed, motor axons underwent Wallerian degeneration and muscles rapidly atrophied. Of those persons developing acute paralysis, equal numbers (30%) recovered, had mild residual paralysis, or were left with moderate to severe paralysis. Ten percent died from respiratory involvement. Recovery was attributed to the recovery of some anterior horn cells, as well as collateral sprouting from intact peripheral nerves and to hypertrophy of spared muscle fibers.¹⁰

Polio was a unique neuropathy that created only focal and asymmetric motor impairments, rather than the typical distal, symmetric motor and sensory losses associated with other neuropathies. For decades it was considered a static disease; after the initial episode there was no further progression of the disease. The last major epidemics of polio occurred in the early 1950s; thus most of the people who had paralytic polio are at least 50 years old today. Most people had significant recovery of function and went on to live very productive lives.

Definition

Post-polio syndrome (PPS), or post-polio muscular atrophy (PPMA), refers to new neuromuscular symptoms that occur decades (average postpolio interval is 25 years) after recovery from the acute paralytic episode.¹²⁰

Incidence and Risk Factors

It is estimated that there are 1.63 million polio survivors in the United States and that one-fourth to one-half of them will develop PPS.⁶⁰ A previous diagnosis of polio is essential for this diagnosis. As well, the degree of initial motor involvement as measured by weakness in the acute stage is a factor in the development of PPS. These combine with long-term overuse of muscle that places increased demands on joints, ligaments, and muscle.

Etiology

PPS appears to be related to the initial disorder of the motor neuron cell body affected by the poliovirus. Much of the recovery of muscle strength that occurred after the axonal degeneration can be attributed to reinnervation of denervated muscle fibers by collateral sprouts from other nearby surviving axons. That is, surviving axons increased the size of their innervation ratio. For example, instead of one axon innervating 3000 muscle fibers in the quadriceps, one axon innervated 5000 fibers. Studies confirm that denervation progresses in patients with prior poliomyelitis in both clinically affected and unaffected muscles, and indicate that this progression is more rapid than that occurring in normal aging. Overall, there was a 13.4% reduction in motor-unit number and a 18.4% diminution in M-wave amplitude ($p < 0.001$). The rate of motor-unit loss was twice that occurring in healthy subjects aged >60 years.¹⁰⁴

Pathogenesis

Muscle biopsy and EMG both indicate ongoing muscle denervation. PPS seems to be an evolution of the original motor neuron dysfunction that began after the poliovirus affected the alpha motor neuron. PPS is manifested when the compensated reinnervation that occurred cannot maintain that muscle fiber innervation. The nervous system is pruning back axonal sprouts in this enlarged motor unit that it no longer has the metabolic ability to support; thus new denervation results. Symptoms are related to an attrition of oversprouting motor neurons that can no longer support these axonal sprouts.²²

Clinical Manifestations

Symptoms vary, but in general, muscle strength declines in all people, with periods of stability for 3 to 10 years in muscles that had previously been affected by polio and had fully or partially recovered. Administration of an index of post-polio sequelae has shown that pain, atrophy, and bulbar (respiratory and swallowing) problems are the three most prominent sequelae from poliomyelitis.⁷⁴ Affected persons have also reported myalgias, joint pain, increased muscle atrophy, and new weakness, as well as excessive fatigue with minimal activity, vasomotor abnormalities, and diminishing endurance. These all combine to contribute to a loss of function. Researchers report that the rate of strength deterioration is faster than would occur in normal aging. Deterioration in the lower extremity predisposes individuals to overuse of upper extremity musculature to compensate.⁸⁰

Typically, symptoms are related to the individual's activities of daily living: crutch walking, wheelchair pro-

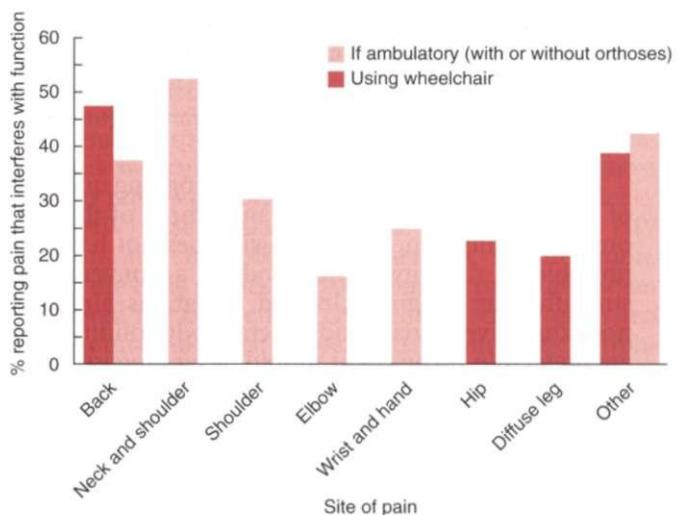


Figure 39-17

Location of pain reported in ambulatory and wheelchair-bound persons diagnosed with post-polio syndrome. (Data from Department of Physical Therapy, Institute for Rehabilitation and Research, Houston: An instructional course on physical therapy management of postpoliomyelitis: new challenges. Presented at the 65th American Physical Therapy Association Annual Conference, Chicago, June 1986.)

pulsion (Fig. 39-17). Pain is commonly located in the low back and joints of the upper extremity in women; it is worse at night and increases with physical activity and changes in climate.

MEDICAL MANAGEMENT

DIAGNOSIS. PPS is a clinical diagnosis requiring the exclusion of other medical, neurologic, orthopedic, or psychiatric disorders that could explain the new symptoms. Routine EMG can be used to confirm any new denervation, as can muscle biopsies. Single-fiber EMG and spinal fluid studies are rarely needed to establish a diagnosis.²²

TREATMENT. Medical management is aimed at symptomatic treatment and modification of lifestyle. Surgery for residual calcaneovalgus deformities at the ankle include triple arthrodesis.⁴⁰ Perimalleolar tendon transfers have been performed to compensate for triceps surae insufficiency.³¹

PROGNOSIS. PPS is a slowly progressive disorder with stable periods that last 3 to 10 years. A decline in functional status is reported to correlate with a poorer quality of life in individuals affected by PPS.⁸¹

SPECIAL IMPLICATIONS FOR THE THERAPIST

39-8

Post-Polio Syndrome

PREFERRED PRACTICE PATTERNS

5A: Primary Prevention/Risk Reduction for Loss of Balance and Falling

6B: Impaired Aerobic Capacity/Endurance Associated with Deconditioning

Continued.

6C: Impaired Ventilation, Respiration/Gas Exchange, and Aerobic Capacity/Endurance Associated with Airway Clearance Dysfunction

7A: Primary Prevention/Risk Reduction for Integumentary Disorders

Of importance to therapists is the ongoing question of the use of exercise in the management of this disorder. Partially denervated muscle does not have the physiologic capacity to respond to a conventional strengthening program. Instead, programs aimed at nonexhaustive exercise and general body conditioning are preferable.⁶⁸ The client should never exercise to the point of fatigue, and vital signs are monitored before and after exercise to assess the client's response to even mild activity. Caution the client to stop if pain persists or weakness increases. Because individuals with PPS have decreased peak workloads and decreased oxygen uptake, functional exercises of submaximal intensity are stressed with the goal of maintaining and improving endurance and functional capacity. For those with relatively good strength, a program to improve aerobic fitness is appropriate; for those with weaker leg musculature, a generalized fitness program should be aimed at endurance and improving work capacity.¹⁷⁶ Additionally, clients with PPS may also benefit from lifestyle modifications, including energy conservation techniques (see Box 9-8). Late onset weakness, pain, and fatigue have been reported in individuals who had not developed the paralytic form of the disease.⁶⁰

Posturally induced mechanical strain and overuse have led to degenerative changes and pain, as well as unstable joints. For these deformities to be reversed, the therapist should explore the use of orthoses, especially for gait. Many clients who have developed PPS are former brace users and may have an aversion to orthoses, but the braces they formerly used were not the cosmetic lightweight braces that can be constructed today.

Herpes Zoster/Post-Herpetic Neuralgia

Varicella-zoster virus (VZV) is a common herpes virus that affects the nervous system. VZV is the virus that causes chickenpox in children. After recovery from that childhood disease, the virus is not eliminated from the body; it lies dormant within sensory ganglia of cranial and spinal nerves and can become activated later in life to cause herpes zoster (HZ), or shingles.

Incidence

Annually, approximately 1% of the adult population over age 80 years develops HZ each year¹²⁹ and of those, about 20% develop postherpetic neuralgia. Immunocompromised individuals are also at risk.

Pathogenesis

HZ primarily affects the sensory ganglia of the spinal cord or cranial nerves. When reactivated, the virus causes a generalized inflammatory response beginning in the

sensory ganglion and spreading along spinal and peripheral nerves to produce demyelination and degeneration.

Clinical Manifestations

The inflammation produces pain and tingling in the involved dermatome with a rash followed by development of vesicles (blisters) that burst and encrust in the same dermatome. The skin lesions last up to 1 month and disappear as the effects of the virus resolve. Thoracic and trigeminal dermatomes are involved most often. Occasionally, the inflammation may affect motor neurons and produce LMN signs and symptoms. The pain resolves over time, but in individuals that develop postherpetic neuralgia, it may linger for weeks or months. Postherpetic pain is possibly related to hyperirritable primary afferent nociceptors that provide input to an already synthesized CNS.¹²¹ The type of pain has been described as a constant aching or burning or a cutting or stabbing pain.

MEDICAL MANAGEMENT

DIAGNOSIS AND TREATMENT. The diagnosis is made by clinical presentation. The disorder is treated symptomatically unless there is widespread involvement. Oral anti-viral medications, such as Acyclovir, are used to control the response and accelerate the resolution of the pain, hypoesthesia, burning, and itching associated with the neuralgia. Although analgesic drugs may be prescribed to relieve pain, a randomized controlled trial using topical lidocaine patches, gabapentin, and controlled-released oxycodone shows better pain relief. Nortriptyline, a tricyclic antidepressant, also provides analgesia and may be tolerated better than other medications.⁷⁵

PROGNOSIS. For immunosuppressed clients, there is a greater risk of developing postherpetic neuralgia and painful dysesthesias as a complication of HZ. Postherpetic pain is very resistant to treatment. Signs of the disorder in immunocompetent persons resolve within a month, but the area that was affected may be partly insensitive. Up to 20% of people who experience HZ will experience a second attack. See further discussion in Special Implications for Therapists boxes in Chapters 8 and 10.

Trigeminal Neuralgia/Tic Douloureux

Trigeminal neuralgia (TN), or tic douloureux, is a disorder of the trigeminal (fifth cranial) nerve in which there are intense paroxysms of lancinating pain within the nerve's distribution.

Incidence

TN is not a common disorder (5 cases per 100,000). It typically occurs in women between the ages of 50 and 70 years.

Etiology

TN arises from many causes: herpes zoster, multiple sclerosis, vascular lesions, or tumors that can affect the nerve to produce the painful sensations. Many times it will be referred to as idiopathic because the cause remains undetermined. Physical triggers can elicit paroxysms of pain.

Pathogenesis

Researchers hypothesize that the pain is due to ectopic activity generated at the site of involvement. Demyelinated fibers become hyperexcitable. Light mechanical stimulation recruits nearby pain fibers causing them to discharge and create the sensation of intense pain.

Clinical Manifestations

The pain associated with TN has a sudden onset and has been described as sharp, knifelike, lancinating, and "like a lightning bolt inside my head that lasts for seconds to minutes." The sensation is typically restricted to the maxillary (V2) division of the nerve, but it may involve the maxillary and mandibular divisions together. Less likely is involvement of the ophthalmic (V1) division.

The painful sensation often occurs in clusters. Any mechanical stimulation, chewing, smiling, or even a breeze can trigger an attack. Clients avoid stimulating the trigger zone. Remissions occur between attacks, but these remission periods shorten and attacks become more frequent over the course of the disorder. In about 10% of the cases the pain occurs bilaterally.

MEDICAL MANAGEMENT

DIAGNOSIS. Subjective reports of pain in the typical pattern are the basis for the diagnosis. No impairment or loss of sensation or motor control is obvious on evaluation. The person can identify the trigger site. Skull radiographs, CT scans, and MRI are used to rule out tumors and vascular causes.

TREATMENT. The preferred treatment of TN is oral carbamazepine (Tegretol, an anticonvulsant). Pain can be controlled with appropriate dosage in about 75% of clients with TN. Side effects of this medication include blurred vision, dizziness, drowsiness, as well as hematologic changes (anemia) and altered liver function. In addition, because carbamazepine has teratogenic effects, it should not be used in the first trimester of pregnancy nor should it be used by nursing mothers.⁵² Other medications, such as phenytoin (Dilantin), are less effective but should be tried in those who cannot tolerate carbamazepine. Promising new medications to manage TN include pimozide, tizanidine hydrochloride, and topical capsaicin.²⁸

In persons whose pain is refractory to medications, neurosurgical procedures are advised. Radiofrequency rhizotomy is preferred over trigeminal nerve section or alcohol ablation. Microvascular surgery has also been used when small blood vessels have been found to constrict the trigeminal nerve near its root. This procedure provides immediate pain relief; however, it is a major and difficult surgery.

PROGNOSIS. The efficacy of evaluating treatments for TN is complicated by the fact that the disorder may remit spontaneously. Remissions that occur soon after onset of TN may last for years. For those who do not remit, TN can be managed medically in most cases. The Trigeminal Neuralgia Association provides information and support for persons with this diagnosis.

Human Immunodeficiency Virus Advanced Disease (Acquired Immunodeficiency Syndrome)

Peripheral neuropathy, disease- or drug-induced myopathy, and musculoskeletal pain syndromes occur most often in advanced stages of human immunodeficiency virus (HIV) disease but can occur at any stage of HIV infection and may be the presenting manifestation. During the early phases of HIV when the immune system has altered responsiveness, GBS tends to develop. When immuno incompetence is severe, distal symmetric peripheral neuropathies occur; however, other parts of the body may be affected such as the face or trunk. The polyneuropathies are predominantly sensory. Painful dysesthesias characterized by burning, tingling, contact sensitivity and proprioceptive losses begin in the soles and ascend. Upper extremity involvement rarely occurs.³⁶ In severe cases, secondary motor deficits. In the individual with HIV and newly acquired neuropathy with a strong major motor component, vasculitis may be the underlying etiology (see the section on Vasculitis in Chapter 12). Involvement of the upper extremities can occur, but this is less common and usually later in the disease progression.

Vasculitis

Vasculitis can occur as a primary inflammation and necrosis of blood vessel walls (polyarteritis nodosa) or as a secondary process associated with autoimmune responses (rheumatoid vasculitis or systemic lupus erythematosus vasculitis), infections (hepatitis C with vasculitis), toxins, or drug exposure. Vasculitis can involve blood vessels of any size, type, or location and can affect any organ system, including blood vessels that supply the PNS, as well as the CNS. However, because the watershed zones between major vascular supplies exist in the PNS, peripheral nerves are apt to sustain ischemia.¹⁰⁹ Vasculitis may range from acute to chronic. Distribution of lesions may be irregular and segmental rather than continuous.

Pathology

Immune (antibody-antigen) complexes to each disorder are deposited in the blood vessels resulting in varying symptoms, depending on the organs affected. In the case of vasculitic neuropathy, the formation of antibody-antigen complexes activates the complement cascade with generation of C3a and C5a (chemotactic agents that recruit polymorphonuclear [PMN] leukocytes to the vessel walls). Phagocytosis of the immune complexes takes place, and release of free radicals and proteolytic enzymes disrupt cell membranes and damage blood vessel walls. The complement cascade generates the formation of a complement membrane attack complex that also contributes to endothelial damage (see discussion in Chapter 6 and Fig. 6-15). The resulting damage to endothelial cells results in thickening of the vessel wall, occlusion, and ischemia to the affected nerves with axonal degeneration and the resultant neuropathy. Classification is usually according to the size of the predominant vessels involved (see Chapter 12). In either case, the resulting ischemia may affect peripheral nerves.

Symptomatic Presentation of Vasculitic Neuropathy. Symptoms of a vascular neuropathy reflect the distribution of the peripheral nerve involved. Onset is generally acute, and individuals complain of burning pain in the nerve's distribution. In addition motor weakness can be anticipated. Although a single nerve may be involved (mononeuritis), overlapping asymmetric polyneuropathies are relatively common.⁵⁶

Peripheral neuropathy is a well-known and frequently early manifestation of many vasculitis syndromes. The pattern of neuropathic involvement depends on the extent and temporal progression of the vasculitic process that produces ischemia. A severe, burning dysesthetic pain in the involved area is present in 70% to 80% of all cases. Other symptoms may include paresthesias and sensory deficit; severe proximal muscle weakness and muscular atrophy can occur secondary to the neuropathy. In the early phase, one nerve is affected and causes symptoms in one extremity (mononeuritis multiplex) but can involve other nerves as the disorder progresses. The therapist should watch for anyone with neuropathy who exhibits constitutional symptoms such as fever, arthralgia, or skin involvement. This may herald a possible vasculitis syndrome and requires medical referral for accurate diagnosis. Early recognition of vasculitis can help prevent a poor outcome. Untreated or with a poor outcome to intervention, CNS involvement (e.g., encephalopathy, ischemic and hemorrhagic stroke, or cranial nerve palsy) can occur late in the course of vasculitis.

When corticosteroids (e.g., prednisone alone or sometimes in combination with other medications) are used (such as in the case of vasculitic neuropathy), the therapist must be aware of the need for osteoporosis prevention and attend to the other potential side effects from the chronic use of these medications (see the section on Corticosteroids in Chapter 5). Alternative methods of pain control may be offered in a rehabilitation setting such as biofeedback, transcutaneous electrical nerve stimulation (TENS), and physiologic modulation (e.g., using handheld temperature sensor to control ANS function; see section on Fibromyalgia in Chapter 7).

CANCER-INDUCED Paraneoplastic Neuropathies

A little over 50 years ago the symptoms of two individuals were reported whose autopsy revealed bronchial carcinoma. Both had developed a sensory neuropathy. Although subsequent reports of similar sensory neuropathies associated with other carcinomas have been reported, paraneoplastic syndromes can affect any portion of the nervous system (Table 39-9).

Etiology

In most individuals diagnosed with paraneoplastic neuropathy, the development of symptoms occurs subacutely or chronically over weeks to months and precedes the discovery of the tumor from months to years. The clinic features and electrophysiologic abnormalities indicate

that the cell body is the primary site of involvement. Large diameter neurons are preferentially affected.

Incidence

Numbers vary depending on how the disorder is defined, but estimates range from 10% to 50% that individuals with cancer will develop a paraneoplastic syndrome at some time during the course of their disease. Using a restrictive definition, paraneoplastic syndromes are rare.

Pathogenesis

The current theory is that an autoimmune response, initially directed against the cancer's antigen, subsequently attacks membrane receptors on or receptors within (anti-nuclear) neurons. See Chapter 30 for discussion of CNS neoplasms.

Clinical manifestations

The most common symptoms are numbness and paresthesias, initially asymmetric, but progressing to involvement of all extremities. Burning and aching or lancinating pain is common. Although individuals exhibit symptoms of areflexia, weakness is not common and when it occurs, generally is related to an inability to sustain the contraction secondary to impaired proprioceptive feedback. Many individuals with paraneoplastic neuropathy develop additional symptoms demonstrating a progressive involvement of central neural structures. This includes dysarthria, cerebellar ataxia (limb and truncal), ocular nystagmus, memory loss, and ANS involvement. When these central structures are involved, the diagnosis is termed *paraneoplastic encephalomyeloneuritis*.⁵⁷

MEDICAL MANAGEMENT

DIAGNOSIS. The differential diagnosis of paraneoplastic neuropathy is extensive and includes many disorders identified in this chapter that affect sensory nerve fibers or neurons. In addition to electrophysiology findings of severely reduced amplitude or absence of sensory nerve potentials, with normal to slightly slowed sensory nerve conduction velocities, nerve biopsies show nonspecific axonal degeneration and a reduction in myelinated fibers. Lumbar puncture and serum assays for antibodies may be included in the diagnostic workup. High serum titers for antibodies are suggestive of an occult tumor, but the sensitivity and specificity of these tests yields false positives and negatives. CT and MRI scanning are used to locate the tumor.⁵⁸

TREATMENT. Typical treatments for autoimmune disorders, such as immunosuppression using prednisone, cyclophosphamide, IVIg, or plasmapheresis, generally do not work with antinuclear antibodies because receptors are located within the nucleus of the neuron.

PROGNOSIS. The course is fairly stereotypical. Individuals deteriorate over weeks or months and then stabilize at a level of severe disability; for example, sensory polyneuropathies progress proximally, then ataxias develop and become progressively greater. Neurologic improvement is rare.

Table 39-9 Paraneoplastic Antibodies, Associated Carcinoma, and Symptoms that Develop

Antibody	Associated Carcinoma	Paraneoplastic Syndrome*	Antibody Reactions with Involved Region	Signs and Symptoms
Anti-Hu	SCLC (oat cell) SCLC	Paraneoplastic sensory/sensorimotor neuropathy Paraneoplastic encephalomyeloneuritis	Antibody affects neuronal nuclei in PNS and produces peripheral neuropathies (acute, subacute, or chronic). Multifocal disorder; antibody affects all neuronal nuclei in PNS and CNS and produces both peripheral neuropathies and cerebellar, brainstem, cerebral, and spinal signs. ANS involvement may occur.	Sensory neuropathy. Encephalomyeloneuropathy. Sensory neuropathy plus cerebellar ataxia, dysarthria, nystagmus, vertigo, confusion, areflexia.
	SCLC; lymphomas	Subacute motor neuropathy	Loss of anterior horn cells in spinal cord.	Impaired motor function; sensation is spared.
Anti-Yo	SCLC	LEMS	Antibodies directed against voltage-gated calcium channels that regulate ACh release in neuromuscular junction.	Proximal muscle weakness
Anti-Tr	Ovarian, breast, uterine	Pancerebellar syndrome, dysarthria, and nystagmus	Purkinje cell cytoplasm and deep cerebellar neurons produce subacute (weeks to months) cerebellar symptoms (limb and truncal ataxia, dysarthria, nystagmus).	Cerebellar ataxia
Anti-Ri	Hodgkin's lymphoma	Slow developing cerebellar syndrome	Purkinje cell cytoplasm	Cerebellar ataxia
Anti-amphiphysin	Breast, small cell lung	Opsoclonus-myoclonus	CNS nuclei: opsoclonus (involuntary conjugate multidirectional saccades)	Opsoclonus
Anti-VGC Anti-Ta	Breast SCLC Testicular	Stiff person syndrome LEMS Limbic encephalitis	— — Limbic and brainstem neuronal nuclei.	— — Proximal weakness

SCLC, Small cell lung carcinoma; PNS, peripheral nervous system; CNS, central nervous system; ANS, autonomic nervous system; LEMS, Lambert-Eaton myasthenic syndrome, ACh, acetylcholine.

*Paraneoplastic syndromes are associated with a variety of tumors and the antibodies that are produced affect both PNS, CNS, and ANS. Shaded chart has PNS involvement.

TOXINS

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-9

Polyneuropathy in Malignant Diseases

PREFERRED PRACTICE PATTERNS

- 5A: Primary Prevention/Risk Reduction for Loss of Balance and Falling
- 7A: Primary Prevention/Risk Reduction for Integumentary Disorders

In addition to toxic substances in the environment, some medications prescribed to treat medical conditions can be toxic to the PNS (Table 39-10).⁴

Lead Neuropathy

Definition

Toxic substances, such as lead, affect peripheral myelin or axons.

Table 39-10 Medications Toxic to Peripheral Nerves

Medication	Use
Doxorubicin (Adriamycin)	Cancer
Amiodarone	Irregular heartbeat
Chloramphenicol	Antibiotic
Cisplatin	Cancer
Dapsone	Skin diseases
Phenytoin (Dilantin)	Seizures and pain
Disulfiram (Antabuse)	Alcoholism
Ethionamide	Tuberculosis
Metronidazole (Flagyl)	Trichomonas infection
Gold	Rheumatoid arthritis
Isoniazid	Tuberculosis
Lithium	Manic depression and headache prevention
Nitrofurantoin (Furadantin)	Urinary tract infection
Nitrous oxide	Anesthetic
Penicillamine	Rheumatoid arthritis
Suramin	Cancer
Paclitaxel (Taxol)	Cancer
Vincristine	Cancer

Adapted from Asbury AK: Disorders of peripheral nerve. In Asbury AK, McKhann GM, McDonald WI: *Diseases of the nervous system: clinical neurobiology*, Philadelphia, 1986, WB Saunders.

Etiology and Risk Factors

Although lead has been virtually eliminated in urban environments, it may exist in third world countries or in some industries such as ceramics. The leading cause of lead neuropathy is the ingestion of lead from paint by children who live in old homes predating 1925. However, lead exposure may also occur after inhaling fumes from car batteries, and after drinking contaminated water or moonshine whiskey. Lead neuropathies also occur in workers in industries that use materials containing lead or who live near lead smelters. Most recently, the Consumer Product Safety Commission has identified inexpensive plastic miniblinds as a source of lead exposure. As the blind is exposed to sunlight, the plastic disintegrates and sheds dust that is high in lead.

Pathogenesis

Both the CNS and PNS can be affected. In the PNS, lead exposure initially causes segmental demyelination, but with prolonged exposure damage to axon cell bodies causes axonal degeneration.⁵²

Clinical Manifestations

Unlike most neuropathies, lead neuropathies primarily affect neurons innervating muscles in the upper extremity. After months of exposure, persons with a lead peripheral neuropathy will develop wristdrop.

MEDICAL MANAGEMENT

DIAGNOSIS, TREATMENT, AND PROGNOSIS. Diagnosis is based on the history, clinical examination, and motor NCVs, which will be slowed. If axonal degeneration has occurred, EMG will reveal fibrillation potentials, demonstrating loss of axonal innervation. Other tests to check

for concentration of lead in the body are urine evaluation and radiographs to reveal a lead line at the metaphysis in the iliac creases, long bones, and tips of the scapula.

Treatment consists of the removal of the source of the lead toxin along with the introduction of the chelating agent, edetate calcium disodium (EDTA), administered twice daily, to rid the body of lead. Symptomatic management consists of cock-up splints for the wristdrop. Recovery depends on the length of exposure and removal of the toxin.

Pesticides and Organophosphates

Etiology

Insecticides are used extensively worldwide in industry and agriculture. Some compounds have contaminated cooking oils, and outbreaks of organophosphate poisoning have been reported after ingestion. Parathion has been responsible for more accidental poisonings and deaths than any other organophosphate.

Pathogenesis and Clinical Manifestations

All organophosphate compounds inhibit cholinesterase activity, thus creating an acute cholinergic crisis. Acutely, organophosphate toxins affect systemic functions throughout the body; they are also capable of producing a less acute, more chronic neuropathy. Nausea and vomiting, diarrhea, muscle fasciculations, weakness, and paralysis, including sudden paralysis of the respiratory musculature, can occur after overstimulation at the neuromuscular junction. Death can result from vasomotor collapse that coincides with respiratory paralysis. Symptoms of peripheral nerve involvement appear within 1 to 4 days and because they arise quickly, may resemble GBS. A chronic peripheral neuropathy may persist for months or years or a delayed neuropathy may have its onset weeks after exposure.¹³⁸

MEDICAL MANAGEMENT

DIAGNOSIS. Overexposure to organophosphates will reduce cholinesterase activity of erythrocytes to less than 25% of normal. History and clinical evaluation may be accompanied by electrophysiologic studies to indicate the severity of the neuropathy (e.g., segmental demyelination or axonal degeneration or both).

TREATMENT. Insecticides should be washed from the skin and hair; if toxins have been ingested, emesis or lavage should be carried out. Acutely, atropine is given in doses every 10 minutes until the pupils are dilated, the skin flushed and dry, and the pulse rate rises. Neuromuscular paralysis can be reversed by injection of pralidoxime, a cholinesterase reactivator. Endotracheal intubation and ventilation may be required in the presence of respiratory paralysis. Strictly neuropathic management is aimed at symptomatic management.

PROGNOSIS. Recovery is based on removal from the toxin and the degree of involvement. If only segmental demyelination occurs, recovery will occur in weeks to months, but if axonal degeneration is present, recovery will take months to years.

MOTOR ENDPLATE DISORDERS

Myasthenia Gravis

Overview and Definition

Myasthenia gravis (MG) is the most common of the disorders of neuromuscular transmission. It is characterized by fluctuating weakness and fatigability of skeletal muscles.

Incidence

The incidence of MG is estimated at 1:200,000. Estimates from the National Myasthenia Gravis Foundation are that there are over 100,000 clients with MG and an additional 25,000 undiagnosed cases. MG can affect people in any age group, but peak incidences occur in women in their twenties and thirties and in men in their fifties and sixties. Overall, the ratio of women affected compared to men is 3:2.

Etiology

MG is an autoimmune disorder whose action takes place at the site of the neuromuscular junction and motor endplate.

Risk Factors

Disorders associated with an increased incidence of MG are thymic disorders such as hyperthyroidism, thymic tumor, or thyrotoxicosis. There is an association with diabetes and immune disorders such as rheumatoid arthritis or lupus. Exacerbations may occur before the menstrual period or shortly after pregnancy. Chronic infections of any kind can exacerbate MG. Five to seven percent appear to have a familial association.

Pathogenesis

In MG, the fundamental defect is at the neuromuscular junction. Receptors at the motor endplate normally receive acetylcholine (ACh) from the motor nerve terminal. An action potential occurs that leads to a muscle contraction. In MG the number of ACh receptors are decreased and those that remain are flattened, which results in decreased efficiency of neuromuscular transmission. The neuromuscular junction can normally transmit at high frequencies so that the muscle does not fatigue. Without ACh, the nerve impulses fail to pass across the neuromuscular junction to stimulate muscle contraction. The neuromuscular abnormalities in MG are brought about by an autoimmune response mediated by specific anti-ACh receptor antibodies. The antibodies may block the site that normally binds ACh, or the antibodies may damage the postsynaptic muscle membrane. There may be endocytosis (pinching off of regions of the cell's membrane) of the receptor site.

Although the cause of the autoimmune response in MG is not well understood, the thymus appears to play a role in the disease; 75% of persons with MG have abnormalities of the thymus (e.g., thymic hyperplasia or thymoma). Cells within the thymus bear ACh receptors on their surface, and may serve as a source of autoantigen to trigger the autoimmune reaction within the thymus gland when an immunologic abnormality causes a break-

down an autoimmune attack on acetylcholine (ACh) receptors.³³

Clinical Manifestations

Although MG encompasses a spectrum of mild to severe, its cardinal features are skeletal muscle weakness and fatigability. Repetition of activity causes fatigue, whereas rest restores activity. Other than weakness, neurologic findings are normal. A system of four major categories is used to classify MG: ocular, mild generalized, acute fulminating, or late severe.

The distribution of muscle weakness has a dichotomous pattern affecting only the ocular muscles, or a more variable, generalized pattern occurs. In approximately 85% of persons with MG, the weakness is generalized and affects the limb musculature. This fluctuating weakness is often more noticeable in proximal muscles.

Cranial muscles, particularly the eyelids and the muscles controlling eye movements, are the first to show weakness. Diplopia (double vision) and ptosis (drooping eyelids) are common early signs causing the person to tilt the head back to see (Fig. 39-18). Weak neck muscles may cause head bobbing in this position.

Chewing of meat produces fatigue, and the facial expression is one that seems to be snarling because the lips do not close. Speech tends to be nasal. Difficulty in swallowing may occur as a result of palatal, pharyngeal, and tongue weakness. Nasal regurgitation or aspiration of food is common.

MEDICAL MANAGEMENT

DIAGNOSIS. History and clinical observation of symptoms of weakness with continued use and improvement with rest are important in diagnosing MG. Several conditions that cause weakness of cranial, or somatic, muscles must also be considered. These include drug-induced myasthenia, hyperthyroidism, botulism, intracranial mass lesions, and progressive disorders of the eye. Lambert-Eaton syndrome is a presynaptic disorder of the neuromuscular junction that can cause symptoms similar to those of MG. Lambert-Eaton syndrome is an autoimmune disorder associated with neoplasm, most commonly small cell (oat cell) carcinoma of the lung, which is believed to trigger the autoimmune response.

The three methods used to diagnose MG are (1) immunologic, (2) pharmacologic, and (3) electrophysiologic testing.¹⁰⁵ Immunologic testing detects anti-ACh receptor antibodies in the serum. The presence of anti-ACh receptor antibodies is virtually diagnostic of MG, but a negative test does not exclude diagnosis of the disease. There is no correlation between the amount of anti-ACh receptor antibodies and the severity of the disease. However, in a person with MG a treatment-induced fall in the antibody level often correlates with clinical improvement.

The drug edrophonium (Tensilon) is used to demonstrate improvement in the myasthenic muscles by inhibiting acetylcholinesterase (AChE), an enzyme required for ACh uptake. Muscle strength and endurance are measured before and after administration of the drug. This test confirms that ACh uptake is part of the pathologic status; however, a control test of saline should also be used for comparison.



Figure 39-18

A. Facial weakness with myasthenia gravis is easily identified when the patient is asked to perform repeated facial movement. Note inability to fully open eyelids and the open jaw. **B.** Edrophonium (Tensilon) test can be used to confirm the diagnosis. Edrophonium chloride is a short-acting anticholinesterase that is injected intravenously. In myasthenia gravis, the facial weakness is rapidly relieved by this test. Similar responses occur elsewhere in the body. [From Goldman L, Ausiello D: *Cecil textbook of medicine*, ed 22, Philadelphia, 2004, WB Saunders.]

Electrophysiologic testing of myasthenic disorders demonstrates a normal EMG at rest. Specialized testing must be employed using repetitive stimulation to demonstrate a rapid decrement in the motor action potential's amplitude. Absence of sensory deficits and retention of tendon reflexes throughout the course of the disease also

tend to confirm the diagnosis of MG. Because respiratory impairment is a serious complication of MG, measurements of ventilatory function should be performed.¹⁵⁸

TREATMENT. AChE inhibitor medication provides for improvement of weakness but does not treat the underlying disease. Administration of this medication is tailored to the individual's requirements throughout the day. For example, a person with difficulty chewing and swallowing would take the medication before meals. Side effects of AChE inhibitors include gastrointestinal effects such as nausea and vomiting, abdominal cramping, and increased bronchial and oral secretions.

Surgical removal of the thymus is successful in 85% of persons with MG. Up to 35% of those undergoing thymectomy achieve a drug-free remission, although this may take years.

Immunosuppression using drugs, such as corticosteroids (prednisone) and azathioprine, are effective in nearly all persons with MG. Initially, high daily doses are begun and then followed by alternate-day high doses that are tapered slowly over a period of months. Unfortunately, adverse side effects are associated with high-dose steroids. These include cushingoid appearance, weight gains, hypertension, and osteoporosis (see Chapter 7).

Plasmapheresis is performed to remove substances that affect ACh receptors. However, plasmapheresis produces only short-term reduction in anti-AChE antibodies and is not effective for long-term symptom control.

PROGNOSIS. The course of MG is variable, typified by remissions and exacerbations, especially within the first year after onset. Symptoms often fluctuate in intensity during the day. This daily variability is superimposed on longer-term spontaneous relapses that may last for weeks. Remissions are rarely complete or permanent. This disorder follows a slowly progressive course. Onset of other systemic disorders and infections may precipitate an exacerbation of the disease and are the most common cause of a crisis. A myasthenic crisis is a medical emergency requiring attention to life-endangering weakening of the respiratory muscles. A myasthenic crisis requires ventilatory assistance. Treatment of a crisis occurs in the ICU because the client requires careful, immediate control of medications for survival.¹⁷⁸

When MG begins in children, it is important to establish the form it takes. Because AChE antibodies cross the placenta, 10% of newborns of mothers with MG develop a myasthenic reaction. Newborns with neonatal MG have a weak suck and cry and are hypotonic. Fortunately, this resolves in a few weeks.

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-10

Myasthenia Gravis

PREFERRED PRACTICE PATTERNS

4C: Impaired Muscle Performance

Physical and occupational therapy may be indicated as supportive care to assist the client with MG. In the acute care setting, the therapist must establish an accurate neurologic and respiratory baseline. Tidal volume,

vital capacity, and inspiratory force should be monitored regularly during treatment. Deep breathing and coughing should be encouraged. When eating, the person should be instructed to sit upright and to swallow when the chin is tipped slightly downward toward the chest and never with the neck extended because of the risk of aspiration. Finally, the client should never speak with food in the mouth.

The therapist must also be alert to signs of an impending myasthenic crisis (increasing muscle weakness; respiratory distress; or difficulty while talking, chewing, or swallowing). Make sure the client recognizes the side effects and signs of toxicity of AChE inhibitor medications. For those receiving a prolonged course of corticosteroids, report adverse side effects to the physician.

Plan therapy and teach the client to plan activities to coincide with periods of maximum energy (see Box 9-8 for energy conservation tips). The home should be arranged to help prevent unnecessary energy expenditure. Frequent rest periods help conserve energy and give muscles a chance to regain strength. The person with MG should avoid strenuous exercise, stress, and excessive exposure to the sun or cold weather. All of these can exacerbate signs and symptoms.

Researchers report that a strength training program eliciting maximal isometric contractions could be instituted in clients with mild-to-moderate MG. As long as participants were monitored for fatigue during periods of exercise, improvements were noted in all muscles.⁹³ After 3 months, participants' knee extensor muscles showed the most significant strength gains without adverse reactions. Recently, a cooling vest was worn to decrease core body temperature to determine whether pulmonary function and subjective perceptions of strength and fatigue would improve. All measures were improved in the majority of participants.¹⁰⁷

Because individuals diagnosed as having MG are placed on long-term corticosteroid medication, the treatment may induce a secondary condition: osteoporosis. These individuals should be encouraged to undergo dual energy x-ray absorptiometry (previously DEXA, now DXA) scan and to receive calcium supplements to counteract osteoporosis.⁹¹

The Myasthenia Gravis Foundation (800-541-5454) publishes educational materials that can be helpful to the client and family.

borne, (2) wound, (3) infant, and (4) unclassified.²⁹ Approximately 10 adult cases and 100 cases of infant botulism are reported each year in the United States.

Etiology and Pathogenesis

The anaerobic bacillus releases a protein neurotoxin that is heat-labile; it is destroyed by boiling food for 10 minutes. Therefore inadequate food preparation allows the neurotoxin to be ingested.

Infant botulism affects babies aged from 3 weeks to 9 months; the most common source of infant botulism arises from the ingestion of honey, which is why children of less than 1 year are not allowed to have honey.

Botulism is not always ingested orally. Some cases occur after wounds are contaminated with soil, in chronic drug abusers, after cesarean delivery, and may even occur when antibiotics are administered to prevent wound infection.

When the neurotoxin is ingested, digestive acids and proteolytic enzymes cannot destroy the molecules of the toxin and it is absorbed into the blood from the small intestine. Minute amounts of circulating toxin reach the cholinergic nerve endings at the motor endplate and bind to gangliosides of the presynaptic nerve terminals. Flaccid paralysis is caused by inhibition of ACh released from cholinergic terminals at the motor endplate. Inhibition of ACh release causes a symmetric paralysis with normal sensory and mental status.

Clinical Manifestations

Onset of symptoms develops 12 to 36 hours after ingestion of food containing the toxin. Signs and symptoms include malaise, weakness, blurred and double vision (diplopia), dry mouth, and nausea and vomiting. Progression is variable, but respiratory failure can occur in 6 to 8 hours. People may also report difficulty swallowing (dysphagia), dysarthria (slurred speech), and photophobia. Because the motor endplate is involved, there are no sensory changes. Motor weakness of the face and neck muscles progresses to involve the diaphragm, accessory muscles of respiration, and muscles controlling the extremities. Secondary effects from the flaccid paralysis, such as severe muscle wasting, pressure sores, and aspiration pneumonia, occur.

MEDICAL MANAGEMENT

DIAGNOSIS, TREATMENT, AND PROGNOSIS. A history suggesting a food source and toxin identification made by serum or stool analysis aids in the diagnosis. EMG testing demonstrates a decreasing amplitude and facilitation of muscle action potential after tetanic stimulation. Differential diagnosis includes disorders that also display a rapidly evolving flaccid paralysis, such as GBS, MG, and tick paralysis.

Immediate treatment is directed toward neutralizing the toxin using injectable trivalent ABE serum, an anti-toxin. Antitoxin prevents further binding of free botulism toxin to the presynaptic endings. If paralysis occurs because of wound botulism, care should include debridement and antibiotics.

BOTULISM

Definition and Incidence

Botulism is a rare, often fatal condition (20% mortality) caused by ingestion of a potent neurotoxin produced by *Clostridium botulinum*, which is found in improperly preserved or canned foods, as well as in contaminated wounds. The Centers for Disease Control and Prevention (CDC) recognizes four categories of botulism: (1) food-

Removal of unabsorbed toxin from the gastrointestinal tract is accomplished by gastric lavage and induced emesis. Finally, supportive measures should be instituted in the hospital; intubation and mechanical ventilation are needed when the individual's vital capacity is compromised.

If untreated, this disorder can be fatal within 24 hours of ingestion. Respiratory failure leads to death. In mild-to-moderate cases, a gradual recovery of muscle strength can take as long as 12 months after onset. After hospitalization, graded rehabilitation is instituted to treat muscle wasting, deconditioning, and orthostatic hypotension.

ABNORMAL RESPONSE IN PERIPHERAL NERVES

Complex Regional Pain Syndrome/Reflex Sympathetic Dystrophy/Causalgia

Reflex sympathetic dystrophy (RSD) is a syndrome, first described in 1864, that changes over time and varies by etiology. Now, the preferred terminology for the syndrome that develops after trauma is complex regional pain syndrome, type I (CRPS I). Early on, pain is greater than expected for the degree of tissue trauma that has been sustained. The pain spreads from localized to a regional distribution, characterized by a burning sensation that occurs spontaneously and at an intensity that does not correspond with the stimulus that elicited it. If the trauma that was sustained involves a major nerve and the clinical syndrome develops, it is causalgia, or CRPS type II (CRPS II).⁹⁹

Incidence

CRPS I may occur after 5% of all injuries. Because the diagnosis is often delayed, some very mild cases may resolve and others may progress to become a chronic, debilitating disorder. Although the average age of an individual with CRPS is in the mid-thirties, it has been reported in all age groups, including children as young as 3 years.

Etiology

RSD has its origin in a variety of conditions: it can follow surgery, such as arthroscopy; it can occur after an UMN lesion arising from traumatic brain injury, cerebrovascular accidents (creating a shoulder-hand syndrome), or destructive lesions of the CNS; or it can occur after LMN disorders from peripheral nerve injuries, neuropathies, and entrapments. CRPS I occurs without an overt nerve injury, and CRPS II is associated with peripheral nerve trauma.

Pathology

An injury at one somatic level initiates sympathetic efferent activity that affects many segmental levels. CRPS is thought to represent a reflex neurogenic inflammation. Facilitation of the sympathetic nervous system (SNS) and its neurotransmitters, catecholamines, activates primary

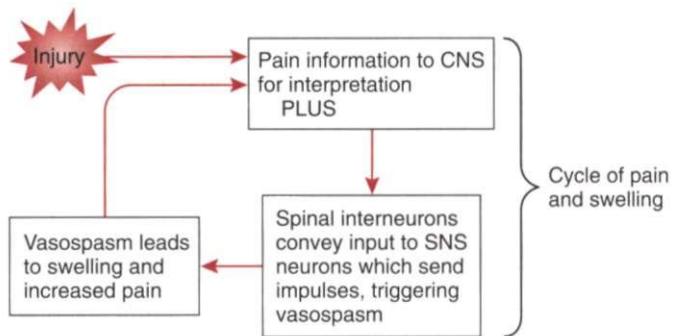


Figure 39-19

The exaggerated pain associated with sympathetic over activity occurs after minor trauma. Normally, the response of the sympathetic nervous system after injury causes cutaneous blood vessels to contract. This response shuts down appropriately within minutes to hours. In complex regional pain syndrome, the sympathetic nervous system functions abnormally and causes vasospasm, which creates cycles of swelling and pain. Initially, vasodilation occurs that increases skin temperature. Later in the course of the disorder, symptoms consist of cyanosis and coldness in the involved extremity.

afferent nociceptors to create the sensation of pain. Thermal dysfunctions are related to either the inhibition of SNS vasoconstriction or facilitation of the SNS causing excessive vasoconstriction (Fig. 39-19). Clinical studies have shown abnormal SNS reflexes that indicate CNS dysfunction exists as well.¹⁷⁴

Clinical Manifestations

CRPS has overlapping but identifiable clinical stages (Table 39-11). Although sensory impairments are often most the hallmark of CRPS, movement disorders also occur. Motor symptoms may precede the appearance of other impairments by weeks or months or may appear on the contralateral extremity in a mirror fashion but most often they occur concomitantly with autonomic changes and pain.

The primary clinical features of CRPS I are pain, ANS dysfunction, edema, movement disorders including inability to initiate movement, weakness, tremor, muscle spasms, dystrophy, and atrophy.⁶² The pain that occurs is disproportionate to the pain that would be expected. Even tactile stimulation may be perceived as pain (allodynia).⁷⁹ All contribute to functional impairments. Despite the fact that three stages of CRPS were originally identified and are still referred to, the course of this disorder is more unpredictable than the stages imply.⁷⁹ Individuals typically remain in a specific stage for 6 to 8 months; however, some may progress rapidly to and through the next stage. As the condition progresses, symptoms may spreading proximally and even spread to affect other extremities. In a few cases, the entire body may become involved.⁹⁹

Three abnormal vasomotor patterns have been identified; these relate to the temperature and color of the extremity and the acuity of CRPS. Other vasomotor changes include changes in the nails in which they become thick, brittle, and ridged.

Table 39-11 Complex Regional Pain Syndrome: Progressive Clinical Stages

Stage	Time Period	Classic Signs and Symptoms
Stage I (acute inflammation): denervation and sympathetic hypoactivity	Begins up to 10 days after injury; lasts 3-6 months	Pain: more severe than expected; burning or aching character; increased by dependent position, physical contact, or emotional disturbances. Hyperalgesia (lower pain threshold, increased sensitivity), allodynia (all stimuli are perceived as pain), and hyperpathia (threshold to pain is increased, once exceeded, sensation intensity increased more rapidly and greater than expected). Edema: soft and localized. Vasomotor/thermal changes: affected limb is warmer. Skin: hyperthermia and dry . Increased hair and nail growth. Pain: worsens and is constant, burning, and aching. Allodynia, hyperalgesia, and hyperpathia almost always present,
Stage II (dystrophic): paradoxic sympathetic hyperactivity	Occurs 3-6 months after onset of pain, lasts about 6 months	Edema: becomes hard, causing joint stiffness, Vasomotor/thermal changes: neither warm, nor cold. Skin: thin, glossy, cool (vasoconstriction) and sweaty. Thin, ridged nails. X-rays reveal osteoporosis and cystic and subchondral bone erosion Pain spreads proximally, occasionally to entire skin surface or plateaus.
Stage III (atrophic)	Begins about 6-12 months after onset; may last for years, or may resolve and reoccur	Edema: continues to harden. Vasomotor/thermal changes: SNS regulation is decreased on affected extremity, affected limb is cooler. Skin is thin, shiny, cyanotic, and dry. Fingertips and toes on involved extremity are atrophic. Fascia is thickened; contractures may occur. X-rays demonstrate bony demineralization and ankylosis .

SNS, Sympathetic nervous system.

MEDICAL MANAGEMENT

DIAGNOSIS. Diagnosis of CRPS is based primarily on the clinical examination and history. A combination of diagnostic tests aimed at assessing secondary changes (radiographic examinations, thermographic studies, and laser Doppler flowmetry) may aid in establishing a diagnosis. Because of the evolutionary nature of CRPS, a correct diagnosis may be delayed, especially in children.³⁵

TREATMENT. Treatment for CRPS tends to be multifactorial and prolonged. Successful treatment depends on early diagnosis, treatment of the underlying cause, and aggressive and sustained physical therapy.⁶⁷ Although stellate ganglion blocks or sympathectomy are used to alleviate pain and early symptoms, this approach is based on weak evidence.⁹⁸ All of the following treatments have limited evidence for their effectiveness.⁴⁷ Acupuncture, corticosteroids, and NSAIDs have been used early in stage I. They provide pain relief in up to 20%. Amitriptyline has been used to facilitate sleep and relieve depression. Calcium channel blockers help to improve peripheral circulation through their effect on the SNS.

Long-term intrathecal baclofen is used to control symptoms of motor dystonia. Its use is supported by the fact that γ -aminobutyric acid (GABA)-ergic inhibition is involved in motor function.

Although external TENS units have been minimally effective, implanted dorsal column stimulation has been shown to decrease pain intensity and perception of pain in randomized trials. Health-related quality of life improved only in individuals receiving spinal cord stimulation. It is best for intractable pain in one extremity.⁹⁹

PROGNOSIS. CRPS is a complex syndrome with varying severity and disability. In many cases, the pain continues for years, or less frequently, it may remit, then recur after another injury. In some cases, malingering for secondary gain has been documented.¹⁸¹ Outcome measures for CRPS I typically concentrate on impairments, leaving measurement of disability, which is the most relevant to function, with few assessments.¹³⁸ Physical therapy is indicated, particularly as part of a program of pain control. Although the goal is to maintain function so that the individual can perform normal activities, a vigorous approach is not indicated. Current research is aimed at understanding physiologic processes and finding the most effective interventions.

SPECIAL IMPLICATIONS FOR THE THERAPIST 39-11**Complex Regional Pain Syndrome****PREFERRED PRACTICE PATTERNS**

4A: Primary Prevention/Risk Reduction for Skeletal Demineralization

4D: Impaired Joint Mobility, Motor Function, Muscle Performance, and Range Of Motion Associated with Connective Tissue Dysfunction

5G: Impaired Motor Function and Sensory Integrity Associated with Acute or Chronic Polyneuropathies

7B: Impaired Integumentary Integrity Associated with Superficial Skin Integrity.

Goals for physical therapy include educating the client and encouraging normal use of the involved extremity while minimizing pain. Although modalities are used to provide pain relief, the greatest success

occurs when they are administered during earlier stages of CRPS. External TENS units are reported to be minimally effective.³³ Recently, when TENS was applied contralateral to the lesion, high-frequency stimulation decreased mechanical allodynia and low-frequency stimulation decreased thermal allodynia in Sprague-Dawley rats.¹⁴⁹ When the lower extremity is involved, pool exercises are helpful for improving mobility when weight bearing on land is problematic.

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 181 cited references and other general references for this chapter.

CHAPTER 40

Laboratory Tests and Values

GLENN L. IRION • CATHERINE C. GOODMAN

Many clients entering the health care delivery system undergo a variety of diagnostic and laboratory tests. Laboratory values may confirm a suspected diagnosis, rule out a suspected diagnosis, or be used as a screening tool.

With the need for shortened lengths of stay and improved client outcomes, therapists in many hospitals are being consulted earlier in the course of the inpatient's treatment and for a "sicker" client base often with multiple medical conditions (comorbidities). At the same time that advances in medical technology are making it possible for earlier diagnosis, improved medical treatment is contributing to greater longevity for people with acute medical conditions.

In order to provide the best plan of care and intervention for today's health care recipients, the therapist must understand test values and their variations, interpretations, and implications for therapy. Abnormal test results represent physiologic changes that may require modification of intervention or even contraindicate therapy intervention.²⁵ Neglecting to take these results into consideration before determining goals and designing intervention plans could be harmful and possibly fatal for some clients.⁶³

As members of a health care team, we are responsible for knowing a patient or client's health status, what we can do to improve it, and what might harm it. What the therapist learns from taking a history and performing a physical examination is supplemented by information found in laboratory test values.

Single threshold values listed in this text are not always clinically relevant but provide a general guideline. We will continually emphasize the following: in all cases, the therapist must make decisions based on the entire clinical picture and consultation with others rather than relying on a particular lab value. Treatment also depends on the clinical setting and medical treatment being received by the individual.

Abnormal values (i.e., out of the reference range) can be viewed as yellow (cautionary) or red (warning) flags, indicating that more questions should be asked before treating or before canceling treatment because of documented abnormal values. The therapist is advised to consider the person's physiology and weigh the risks and benefits of intervention. The therapist should have a rea-

sonable rationale for canceling therapy when values are not within the reference ranges.²⁵

Most of the time, abnormal values suggest the need to modify the treatment plan in order to treat in a safe and effective manner. Cancellation of treatment is advised when there is a critical (or panic level) lab value indicating a potentially life-threatening condition.

Monitoring vital signs is strongly encouraged in all patients/clients but especially when lab values are outside the reference ranges. More frequent rest periods, decreased exercise intensity during endurance training, or decreased resistance during strength training are examples of treatment modifications.²⁵

This chapter describes the purpose of laboratory tests, normal values, abnormal values, and potential interpretation of abnormal values. This chapter is organized from basic screening tests that may be done for nearly all patients/clients and proceeds to more specific systems and less frequently performed tests.

A reference web site is provided by the American Association for Clinical Chemistry (www.labtestsonline.org).¹ This web site will cover any additional lab tests the therapist might encounter, including the opportunity to enter a condition and determine which lab tests might be employed.

LABORATORY TESTS

As previously presented in this text, advances in medicine have resulted in a population that is living longer with a more complex pathologic picture. Orthopedic and neurologic conditions no longer present as singular phenomena but frequently occur in someone who has other medical pathologic findings.

We must be cognizant of the ways other conditions and diseases affect the individual's neuromusculoskeletal system and take the necessary steps to treat safely *and* effectively. For these reasons, routine monitoring of vital signs and evaluation of clinical laboratory data (when ever available) is advised in all clients regardless of age, condition, or diagnosis.⁷⁸

Laboratory values are a useful adjunct in evaluating a client's medical condition and revealing potential precautions for or contraindications to therapy, particularly

Table 40-1 Official "Do Not Use" List*

Do Not Use	Potential Problem	Use Instead
U (Unit)	Mistaken for "0" (zero), the number 4 (four) or "cc."	Write "unit"
IU (International Unit)	Mistaken for IV (intravenous) or the number 10 (ten).	Write "International Unit"
Q.D., QD, q.d., qd (daily)	Mistaken for each other.	Write "daily"
Q.O.D., QOD, q.o.d., qod (every other day)	Period after the Q mistaken for "1" and the "O" mistaken for "I."	Write "every other day"
Trailing zero (X.0 mg)†	Decimal point is missed.	Write X mg
Lack of leading zero (.X mg)	Decimal point is missed.	Write 0.X mg
MS, MSO ₄ , and MgSO ₄	Can cause confusion between morphine sulfate and magnesium sulfate.	Write "morphine sulfate" or "magnesium sulfate"

*Applies to all orders and all medication-related documentation that is handwritten (including free-text computer entry) or on preprinted forms.

†Exception: A "trailing zero" may be used only where required to demonstrate the level of precision of the value being reported, such as for laboratory results, imaging studies that report size of lesions, or catheter/tube sizes. It may not be used in medication orders or other medication-related documentation.

Additional Abbreviations, Acronyms and Symbols (For Possible Future Inclusion in the Official "Do Not Use" List)

Do Not Use	Potential Problem	Use Instead
>(greater than)	Misinterpreted as the number "7" (seven) or the letter "L"; confused for one another	Write "greater than"
>(less than)	Misinterpreted because of similar abbreviations for multiple drugs	Write "less than"
Abbreviations for drug names	Unfamiliar to many practitioners; confused with metric units	Write drug names in full
Apothecary units	Mistaken for the number "2" (two)	Use metric units
@	Mistaken for U (units) when poorly written	Write "@"
cc	Mistaken for mg (milligrams) resulting in one thousand-fold overdose	Write "ml" or "milliliters"
μ		Write "mcg" or "micrograms"

Data from The Joint Commission Official "Do not use list." Available at www.jointcommission.org. Accessed August 14, 2007.

exercise. For example, a low platelet level (e.g., 50,000/mm³) requires careful consideration of the planned intervention program. Consider the client with diabetes mellitus who is admitted to the hospital for a myocardial infarction (MI). Cardiac rehabilitation for this person in any setting (i.e., whether the facility has a formal cardiac rehabilitation program) requires careful monitoring of glucose levels before, during, and after exercise. However, this same person needing wound care for a diabetic neuropathic ulcer would not necessarily require blood glucose testing before the local application of wound management.

The number of possible lab tests that an individual may encounter can be overwhelming. Those tests addressed in this chapter were chosen because of their high volume in hospital use and their importance in clinical decision making for physical therapists in general.^{17,31}

Abbreviations

Recommended units for clinical laboratory data are provided in Box 40-1. The Joint Commission's official "do not use" list of abbreviations is listed in Table 40-1. The list was originally created in 2004 by The Joint Commission as part of the requirements for meeting National Patient Safety Goal (NPSG) requirement 2B, which required a standardized list of abbreviations, acronyms, and symbols that are not to be used throughout the organization.

Box 40-1

UNITS FOR CLINICAL LABORATORY DATA

g	gram
ng	nanogram
mg	milligram
ml	milliliter
L	liter
dl	deciliter (100 ml)
pg	picogram
mm ³	cubic millimeter
mmol	millimole
U	unit
IU	international unit
mU	milliunit
μg	microgram
μU	microunit
μm	micron
mEq	milliequivalent

APACHE

The acute physiology and chronic health evaluation (APACHE), a system for prognosis development for critically ill patients, has been developed using a number of lab and other values. Based on data entered regarding admission diagnosis, age, health history, and the physiologic measurements taken during the first 24 hours, a predicted death rate is calculated. Length of stay in the intensive care unit (ICU) can also be predicted.

Measurements include body temperature, mean arterial pressure, heart rate, respiratory rate, partial pressure of arterial pressure, hematocrit, white blood cell (WBC) count, arterial pH, Glasgow coma scale, and serum bicarbonate, potassium, and creatinine.⁷⁰⁻⁸⁸ Newer variables (use of mechanical ventilation and thrombolytic therapy) and adjustment to the equations used for predictions have been used to generate the latest version (APACHE IV).⁸⁹

Purpose

Laboratory tests may be used by the physician for screening (searching for an occult disease process in an otherwise healthy person), diagnosis (identifying the cause of symptoms), or monitoring (following the progress of a disease).⁶³ A single test may be used differently in different people, depending on the need for information. For example, a glucose test may be used diagnostically or as a monitoring test.

Screening tests may be used on populations in an effort to find individuals at risk for certain diseases (e.g., those with high cholesterol who could benefit from treatment before disease manifestations become evident). Screening is also done for genetic or metabolic diseases to find individuals before disease occurs. State laws generally require routine screening in newborns for a number of disorders, notably phenylketonuria, sickle cell disease, and hypothyroidism.

Certain lab tests are very sensitive and specific for certain pathologic conditions, whereas others may only provide one piece of evidence suggesting a health problem without actually providing a certain diagnosis. For the therapist, laboratory values assist in deciding whether therapy can be provided at that time, should be scaled back, or should be more aggressive.¹⁷

Some lab values are clear contraindications for receiving therapy, whereas others are suggestive that therapy provided should be less physiologically demanding. The therapist must work with other members of the health care team to determine what aspects of therapy should be held until physiologic improvement, what should be modified, and what should be done in place of the prescribed treatment plan.³¹ For example, an individual who is short of breath with blood gas values that indicate no physiologic reserve for increasing metabolic demand should not undergo therapy that involves activity; other aspects may be addressed such as positioning, pressure relief, and educating caregivers. Note also that different physicians or facilities may adopt criteria for holding therapy that vary from those suggested in the text.

Limitations of Lab Testing

Although lab tests are generally reliable, a number of issues must be addressed. First, samples used for lab analysis may be contaminated, mishandled, or mislabeled, and testing materials and techniques may be flawed. Values obtained by tests reflect the status of the person at the time the sample is obtained.

The condition of the individual may fluctuate so that a sample taken at a given time does not reflect the per-

son's current condition, resulting in a false positive or false negative result. Results may be influenced by medications or drugs; sex; age; weight; physiologic changes, such as pregnancy; and fluid status. The range of values for a given test in a healthy person is known as the *reference range* or *expected value*, formerly known as the normal range. The reference range depends on the methods used for the test and must be compared against the reference range specific to that laboratory.

Reference ranges may vary among different laboratories; this variability is even more obvious in the values reported as reference ranges among various laboratory textbooks. The reference values or "normal" ranges provided are not meant to be memorized and applied as a standard to every case. The reference ranges provided in this chapter give the therapist a general idea of the values expected for each test, but interpretation of specific individual values must be done using the laboratory reference values (usually provided on most laboratory reports) not these figures.

Each laboratory will include a means of assessing the results—sometimes by placing L for low or H for high after a test result or by providing the range of reference lab values for the tests performed. Certain tests may have limited predictive value. The positive predictive value of a test depends on the prevalence of the disease in a population. The less prevalent the disease, the less accurate laboratory results may be.

A test may fail to produce a result that would indicate an abnormal condition that truly exists (false negative) or the results may falsely indicate that an abnormal condition exists (false positive). Statistically, as the number of tests performed on a single individual increase, the possibility of an incorrect conclusion also increases, whether the person is sick or not.⁴⁵ This phenomenon is purely related to chance because a significant margin of error arises from the arbitrary setting of limits for normal or reference values. Laboratory tests are frequently "rechecked" in order to ensure a higher degree of diagnostic accuracy.

BASIC METABOLIC PANEL

The most common lab tests constitute what are now known as the *basic metabolic panel* (BMP),³¹ *comprehensive metabolic panel*, and *hepatic function panel*. These three terms are based on current procedural terminology (CPT) codes.⁹ These replace a variety of other names, such as SMA-6, SMA-7, SMA-12, SMA-20, Chemistry Panel, Chem Screen, Chem-6, Chem-7, Chem-12, Chem-20, SMAC-6, SMAC-7, SMAC-12, and SMAC-20.

The BMP is a group of eight specific tests for electrolyte level, acid/base balance, blood sugar, and kidney status. The tests consist of serum concentrations of sodium, potassium, chloride, calcium, blood urea nitrogen (BUN), creatinine, glucose, and carbon dioxide. The BMP may be done as part of a routine physical examination as an outpatient, routine testing of inpatients, or when a physician suspects an abnormality that may be detected by one or more components of the BMP.

Table 40-2 Reference Values for Basic Metabolic Profile and Magnesium

Test	Reference Value	Critical Value
Sodium	Infant: 134-150 mEq/L Child: 135-145 mEq/L Adult, older: 135-145 mEq/L	Adult: ≤ 110 mEq/L
Potassium	Infant: 3.6-5.8 mEq/L Child: 3.5-5.5 mEq/L Adult, older: 3.5-5.0 mEq/L	Newborn: <2.5 or >8.1 mEq/L Adult: <2.5 or >6.6 mEq/L For the PT: <3.2 or >5.1 (see text explanation)*
Chloride	Infant: 95-110 mEq/L Child: 98-105 mEq/L Adult, older: 95-105 mEq/L	Adult: <80 or >115 mEq/L
Calcium	Infant: 10-12 mg/dL Child: 9-11.5 mg/dL Adult, older: 9-11 mg/dL	
BUN	Newborn: 3-12 mg/dL Infant: 5-18 Child: 5-18 Adolescent: — Adult female: 10-20 Adult male: 10-20	<7 mg/dL (tetany), >12 mg/dL (coma)
Creatinine	Newborn: 0.3-1.2 mg/dL Infant: 0.2-0.4 mg/dL Child: 0.3-0.7 mg/dL Adolescent: 0.5-1.0 mg/dL Adult female: 0.5-1.1 mg/dL Adult male: 0.6-1.2 mg/dL	
Glucose	70-110 mg/dL	
Carbon dioxide	20-29 mEq/L	
Magnesium	Infant: 1.4-2.9 mEq/L Child: 1.6-2.6 mEq/L Adult, older: 1.5-2.5 mEq/L	<0.5 or >3.0 mEq/L

Creatinine for older adult decreases with decreased muscle mass. BUN may be slightly higher than adult level. BUN/Creatinine normal ratio is 10:1 to 20:1 for all ages.

BUN, Blood urea nitrogen.

*Some facilities use a slightly higher reference range (5.1 up to 5.3).

Normal values for BMP are given in Table 40-2, along with possible causes and consequences of abnormal values. BMP may be used as a screening tool, especially for diabetes and kidney disease. The sample is obtained by venipuncture, preferably after 10 to 12 hours of fasting.¹

As an indicator of current status of electrolytes, acid/base balance, renal function, and blood sugar, significant changes in BMP values may indicate acute problems such as kidney failure, insulin shock, diabetic coma, and respiratory distress.¹ Changes in sodium, potassium, and calcium, in particular, alter the excitability of neurons, cardiac, and skeletal muscle and can produce weakness, spasms, altered sensation, and cardiac arrhythmias.³

Sodium

Sodium is a critical determinant of fluid volume in the body. Under normal circumstances, increases in the amount of sodium in the body lead to retention of water and a loss of sodium leads to loss of water in the body. Changes in plasma sodium concentration indicate a loss of homeostasis. Sodium concentration may be altered by excessive infusion or ingestion of water or excessive production of antidiuretic hormone. Sodium concentration may increase when excessive water is lost from the body such as in profuse sweating or decreased antidiuretic

hormone (ADH) production (diabetes insipidus). Increased fluid volume increases blood pressure and may increase cell volume. Neurons are especially vulnerable to cell swelling, leading to neurologic dysfunction, possibly progressing to coma or death.

Potassium

Potassium is particularly important for function of excitable cells (e.g., nerve, muscles, and heart). The heart muscle is most susceptible to potassium disturbances, and arrhythmias and cardiac arrest can result from hypokalemia or hyperkalemia. Abnormal values in either direction can lead to cardiac rhythm disturbance and muscle weakness or irritability. Potassium measurements provide useful information about renal and adrenal disorders and about water and acid-base imbalances. Potassium acts as a part of the body's buffer system regulated by its excretion through the urine.

SPECIAL IMPLICATIONS FOR THE THERAPIST

40-1

Potassium

Table 40-1 provides a specific range of critical values for potassium for the physical therapist. Potassium levels below 3.2 mEq/L or above 5.1 mEq/L may con-

traindicate physical therapy intervention because of the possibility of arrhythmia and tetany. Table 40-1 lists typical critical values for potassium levels in adults as less than 2.5 or more than 6.6 mEq/L. These values apply to medical treatment issues. For example, clients in chronic renal failure can usually tolerate potassium levels as high as 5.5 mEq/L. When the values reach the levels between 5.5 and above, the physician may begin to monitor the individual more carefully. Levels less than 2.5 mmol/L or greater than 6.6 mEq/L require immediate medical attention.

For the therapist, the upper value is 5.0 to 5.1. Although it has been difficult to provide evidence for this from the literature, the potassium values listed "for the FT" on Table 40-1 have been offered and confirmed by many physicians from a clinical perspective. Nevertheless, studies to verify this information are needed. Levels above these values suggest the need to evaluate the client carefully and confer with the medical staff. Most physicians intervene medically with the potassium level reaches the upper 5 levels.

Hypokalemia makes moving difficult and clients with hypokalemia should not be exercising. Using a narrower range is a safety issue for any compromised individual undergoing physical effort compared to the person on strict bedrest. Increased levels of potassium are not conducive to exercise and are associated with decreased muscle pH, inhibition of motor neurons, and decreased action potentials.³² It is supposed that patients/clients should be close to the normal range, or exercise is not going to be effective. In all cases, the therapist must make decisions based on the entire clinical picture and consultation with others rather than rely on a particular lab value. Treatment also depends on the clinical setting and the medical treatment being received by the individual.

In anyone with marginal potassium levels, the therapist must monitor vital signs closely, including palpating the radial pulse for a full minute for any signs of rhythm disturbance. If discharge plans are pending, the therapist may want to consider physically challenging the individual with activities that may stress them while still in the relatively "safe" environment of the health care facility before sending them home unsupervised. Close observation for signs of dizziness, muscle cramping or weakness, numbness and tingling, and balance instability potentially caused by potassium imbalance is advised.

Other Considerations

Although we know that exercise can worsen hyperkalemia, there has not been any research to show that a precise change in potassium level occurs with specific levels or types of exercise. There is current debate concerning the relationship between potassium and ventilation, but specific guidelines are not available.

Clients/patients who chronically have higher levels of potassium may be less susceptible to the effects of exercise and elevation of potassium, but this is supposition and has not been proven. Individuals with heart failure who are thereby more susceptible to

arrhythmias from hypokalemia because of the medications they are taking need close monitoring and tighter control (e.g., below 5.0).⁷⁵

Chloride

Chloride levels tend to change along with changes in sodium and water (H_2O). Bicarbonate ion ($HC0_3^-$) is a critical component of acid-base balance. $HC0_3^-$ acts as a buffer, preventing changes in plasma pH. Low $HC0_3^-$ occurs in conditions that produce metabolic acidosis such as diabetic ketoacidosis. Respiratory compensation for metabolic acidosis results in loss of carbon dioxide (CO_2) from the plasma, which in turn reduces the amount of HCCV from the plasma.

Bicarbonate works as buffer as a result of the equilibrium reaction of $CO_2 + H_2O$ yielding H_2CO_3 , which in turn is in equilibrium with $HCOf +$ hydrogen (H^+). Exhaling CO_2 is the equivalent of losing an equal number of H^+ . Conversely, slowing ventilation allows CO_2 and thereby H^+ to accumulate in the blood and lower pH. The renal system also contributes to pH regulation by altering the amount of H^+ that passes in the urine and by synthesizing HCCV.

Renal compensation is slower to correct pH, requiring several days, as opposed to the more rapid respiratory response. The ability to regulate pH can be compromised by either respiratory or renal disease. Hypoventilation allows carbon dioxide and thereby acid to accumulate. Renal disease decreases the ability of the kidney to selectively alter fluid concentration, usually resulting in acidosis. Table 40-3 provides lab values that indicate whether acidosis or alkalosis is metabolic or respiratory and whether it is compensated. Further discussion of acid-base balance in disease may be found in Chapter 5.

Magnesium

Magnesium, like calcium, is involved in regulation of excitable cells but is not part of the BMP and is ordered separately. Low magnesium also results in arrhythmias, weakness, muscle spasms, and numbness. Magnesium (see Table 40-2) may be reduced in diabetes; with the use of diuretics; as a result of chronic vomiting or diarrhea; and may be increased by renal failure, hyperparathyroidism, or hypothyroidism.

Blood Glucose

In addition to the BMP, blood glucose may be measured under particular conditions to diagnose a suspected alteration in glucose homeostasis. Reference values for glucose testing are shown in Table 40-4. Fasting blood sugar (FBS), as the name implies, is done after fasting (at least 8 hours). Not eating overnight should allow blood sugar to fall to normal, whereas a random measurement may be elevated by eating close to the time of the test.

Another test is the 2-hour postprandial blood sugar (PPBS); 2 hours should be sufficient time for blood glucose to return to normal following eating. Another test, the oral glucose tolerance test (OGTT) involves con-

Table 40-3 Laboratory Values in Acid-Base Disorders*

ARTERIAL BLOOD				
	pH (7.35-7.45)	PCO ₂ (35-45 mm Hg)	HCO ₃ ⁻ (22-36 mEq/L)	Signs
Metabolic Acidosis				
Uncompensated	<7.35	Normal	<22	Headache, fatigue; nausea, vomiting, diarrhea, muscular twitching; convulsions; coma, hyperventilation
Compensated	Normal	<35	<22	Increased respiratory rate
Metabolic Alkalosis				
Uncompensated	>7.45	Normal	>26	Nausea, vomiting, diarrhea, confusion, irritability, agitation; muscle twitching, muscle cramping, muscle weakness, paresthesias, convulsions, slow breathing
Compensated	Normal	>45	>26	Decreased respiratory rate
Respiratory Acidosis				
Uncompensated	<7.35	>45	Normal	Headache, diaphoresis, tachycardia, disorientation, agitation, cyanosis, lethargy, ↓ deep tendon reflex
Compensated	Normal	>45	>26	—
Respiratory Alkalosis				
Uncompensated	>7.45	<35	Normal	Rapid, deep respirations, light-headedness, muscle twitching, anxiety and fears; paresthesias, cardiac arrhythmia
Compensated	Normal	<35	<22	—

Modified from Goodman CC, Snyder TE: *Differential diagnosis for physical therapists: screening for referrals*, ed 4, Philadelphia, 2007, WB Saunders. PCO₂, Partial carbon dioxide pressure; HCO₃⁻, bicarbonate.

*See also Table 5-13.

Table 40-4 Blood Glucose Tests**Fasting Plasma (Blood) Glucose (mg/dl)**

Adults	70-100
Adults older than 60 yr	80-110
Children	60-100
Neonates	40-80

WHO Diabetes Criteria*: Interpretation of OGTT

Glucose Levels	Normal	IFG	IGT	DM				
Venous plasma (mmol/l) (mg/dl)	Fasting <6.1 <110	2 hr <7.8 <140	Fasting ≥6.1 & <7.0 ≥110 & <126	2 hr <7.8 <140	Fasting <7.0 <126	2 hr ≥7.8 ≥140	Fasting ≥7.0 ≥126	2 hr ≥11.1 ≥200
Hemoglobin A_{1c}				Normal reference range: 4.0%-6.0% 2.5%-5.9% 6.0%-7.0% Greater than 7.0%				
Adult								
Good glucose control								
Fair glucose control								
Poor glucose control								

OGTT, Oral glucose tolerance test; WHO, World Health Organization; IFG, impaired fasting glycemia; IGT, impaired glucose tolerance; DM, diabetes mellitus.

*WHO Diabetes criteria available at: www.who.org. Accessed August 14, 2007.

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

sumption of a fixed amount of glucose and measurement of blood glucose at fixed intervals afterward to determine how quickly blood sugar can be brought back to normal. A person with a normal response will have a modest elevation in blood glucose after 1 hour and a return to normal by 2 hours. Blood glucose in an individual with

either a lack of insulin or lack of insulin response will remain elevated after more than 2 hours.

A test for long-term glycemic control (ability to maintain a steady blood sugar concentration) is glycosylated hemoglobin (HbA_{1c}). The amount of glycosylated hemoglobin measured in the red blood cells (RBCs) depends

on the amount of glucose available in the bloodstream over the 120-day lifespan of the RBC, thereby reflecting the average blood sugar level for the 100- to 120-day period before the test.

The A_{1c} test determines the fraction of hemoglobin containing bound glucose and reflects the average blood glucose concentration over a number of weeks to months, as opposed to the snapshot view provided by blood glucose monitoring. The more glucose the RBC was exposed to, the greater the HbA_{1c} percentage. An important advantage of this test is that the sample is not affected by short-term variations such as food intake, exercise, stress, hypoglycemic agents, or compliance. The HbA_{1c} measurement is now used more frequently than the 2-hour PPBS in monitoring people with diabetes.

Oral hypoglycemic agents are usually recommended when A_{1c} levels are greater than 7.0%. People with HbA1c concentrations less than 5% have the lowest rates of cardiovascular disease and mortality.³⁶ See Chapter 11 for further details.

SPECIAL IMPLICATIONS FOR THE THERAPIST 40-2

Blood Glucose

The ideal range for blood glucose levels is between 80 and 120 mg/dl, but the therapist should be aware of the goal of medical management for each person. For example, a young person with insulin-dependent diabetes (type 1) may be working toward tighter control (e.g., 80 to 120 mg/dl), whereas an older adult with non-insulin-dependent diabetes (type 2) may be looking for more moderate control (e.g., up to 150 mg/dl). Ideally, blood glucose will remain close to 100 mg/dl; however, during periods of stress caused by illness or surgery, blood glucose is more likely to fluctuate. In addition, adjustments in medication and diet will require more careful monitoring of blood glucose.

Individuals with diabetes who are acutely ill or who are trying to establish a new regimen of diet and medication will need to be monitored more frequently than those with an established plan. Therapists need to recognize situations that may lead to hypoglycemia and hyperglycemia, recognize signs and symptoms of these conditions, and when to suggest blood glucose monitoring.

Although some people, especially middle-aged adults with type 2 diabetes, may be told that a higher blood glucose is acceptable, patients/clients need to be encouraged to maintain the tightest possible glycemic control. Disease manifestations and long-term health in both type 1 and 2 are directly related to the success of glycemic control.

In any age group, a blood glucose measurement over 120 mg/dl should be monitored closely. If the blood glucose level is 70 mg/dl or less, a carbohydrate snack should be given and the glucose retested in 15 minutes to ensure an appropriate level.

Insulin therapy can result in hypoglycemia (low blood sugar, also called an insulin reaction). Symptoms can occur when the blood glucose level drops to 70 mg/dl or less. In diabetes, an overdose of insulin,

illness, late or skipped meals, or overexertion in exercise may cause hypoglycemic reactions. The clinical picture may vary from a report of headache and weakness, to irritability and lack of muscular coordination, to apprehension, inability to respond to verbal commands, and psychosis.

It is important to note that clients can exhibit signs and symptoms of hypoglycemia when their elevated blood glucose level drops rapidly but to a level that is still elevated (e.g., 400 to 200 mg/dl). The rapidity of the drop is the stimulus for sympathetic activity-based symptoms; even though a blood glucose level appears elevated, affected persons may still have symptoms of hypoglycemia. However, usually people become symptomatic at a level of less than 70 mg/dl.

Insulin, Glucose Levels, and Exercise

Eating increases blood glucose, whereas insulin and exercise decrease it. Clients should not be engaged in treatment after receiving insulin and before eating. This sequence of events can lead to hypoglycemia (insulin reaction). Symptoms may develop when blood glucose drops to 70, but in some individuals symptoms may not become obvious until a lower value. Physical activity needs to be scheduled at a time when blood glucose is expected to be normal or higher and avoided when it is low. Therefore exercise should occur after eating and not after insulin administration.

Glucose needs to be monitored frequently with the initiation of a new exercise or other activity program, bearing in mind that exercise may affect blood glucose for 12 to 24 hours. Individuals who have been physically active will not need as close monitoring as those who have been sedentary. Close monitoring should continue until the effect of exercise on blood glucose is consistent. In conjunction with the client's endocrinologist, alterations in diet and medication may also be needed.

Symptoms are related to activation of the sympathetic nervous system and may vary among individuals. These symptoms may include headache, nervousness, irritability, decreased coordination, shaking, tachycardia, excessive shaking, and complaints of weakness and may progress to decreased responsiveness or psychosis. Signs of hypoglycemia may also occur if a person has a rapid drop in blood sugar, even if it is elevated (e.g., a rapid drop from 400 to 200 mg/dl). Hypoglycemia needs to be treated by offering rapidly absorbable carbohydrates such as orange juice, honey, and hard candy. Be certain that what is given is not sugar-free.

In addition to hypoglycemia, therapists should also be aware of the signs of diabetic ketoacidosis (DKA). This condition results when metabolism becomes dependent on generation of ketones because of diminished availability of glucose at the cellular level. Critical values for blood glucose levels vary for each individual. The person with blood glucose levels greater than 300 mg/dl should be monitored closely.

Continued.

In addition to the acidosis, the affected individual may become rapidly dehydrated because of osmotic effect of an excessive amount of glucose in the urine. A fruity, acetone smell on the breath, thready pulse, and Kussmaul's respiration are indicative of DKA. This condition is more likely to occur in type 1 diabetes but can occur in type 2. DKA must be treated as a medical emergency.

If uncertain whether the client is hypoglycemic or hyperglycemic (see Table 11-17), the health care worker is advised to administer fruit juice or honey. This procedure will not harm the hyperglycemic client but could potentially save the hypoglycemic client. (See also Special Implications for the Therapist: Diabetes Mellitus in Chapter 11.)

Blood Urea Nitrogen and Creatinine

BUN and creatinine (see Table 40-2) are used to evaluate kidney function in individuals with kidney failure, for differential diagnosis if kidney disease is suspected, to monitor treatment of kidney disease, and to monitor kidney function while clients are using certain drugs.¹ Creatinine is a normal waste product related to creatinine phosphate, a mechanism of regenerating adenosine triphosphate (ATP) in skeletal muscle. Normally, the amount of creatinine in the blood is kept at a normal level by clearance in the kidneys. Because release of creatinine into the blood from muscle remains constant, a rise in serum creatinine usually represents a decline in the kidney's capacity for excreting wastes.

The rise in creatinine levels is directly correlated with the amount of loss of nephron function. With aging, there is a decrease in lean body mass (muscle tissue), possibly resulting in decreasing creatinine values. However, serum creatinine may remain normal in an older person even with significant declines in creatinine clearance and renal function because of the decline in lean body mass.

Causes for elevated creatinine may include glomerulonephritis, pyelonephritis, acute tubular necrosis, obstruction by prostate disease or kidney stones, or decreased renal blood flow. Creatinine may also be elevated as a result of excessive release of creatinine caused by muscle injury.

BUN also rises with decreased renal function, caused in particular by decreased renal blood flow, as opposed to decreased glomerular filtration (creatinine). Because BUN reflects a balance of nitrogen added to the blood and excreted by the kidney, BUN may be elevated by increased protein catabolism or dietary intake of protein.

Gastrointestinal bleeding will increase BUN because of the breakdown of protein from the blood within the gastrointestinal tract. The synthesis of urea also depends on the liver. People with severe primary liver disease will have a decreased BUN. With combined liver and renal disease (as occurs in hepatorenal syndrome), the BUN can be normal, not because renal excretory function is

good but rather because poor hepatic functioning resulted in decreased formation of urea.

SPECIAL IMPLICATIONS FOR THE THERAPIST

40-3

Renal Function Tests

Changes in creatinine and BUN levels do not usually contraindicate physical or occupational therapy intervention. Clients with renal disease may have anemia, hypertension, decreased endurance, and general deconditioning. Any of these conditions can affect physical therapy intervention. Rising creatinine levels may indicate muscle-wasting resulting from an increase in corticosteroid dosage or from exercise beyond the person's physiologic capabilities. If the person is dehydrated, the serum BUN will be elevated. Dehydration with elevated BUN could be a cause for light-headedness or dizziness during exercise.

BUN levels along with other blood values are important to review before therapy sessions to allow for appropriate treatment interventions, as well as anticipated response to treatment. BUN in particular is evaluated in clients with burns (e.g., decreased renal function or fluid intake) and is aggressively addressed in the fluid resuscitation phase of burn management. There may be a noted decrease in mental status associated with abnormal BUN levels (5 to 20 mg/dL).

COMPREHENSIVE METABOLIC PANEL

The comprehensive metabolic panel (CMP) is composed of the BMP with the addition of tests for liver function. These additional tests may be conducted separately as the liver panel. The liver panel consists of bilirubin, total protein, albumin, and serum enzymes that are altered when liver function is compromised. These are aspartate aminotransferase (AST, formerly called SGOT), alanine aminotransferase (ALT, formerly called SGPT), lactate dehydrogenase (LDH), γ -glutamyltransferase (GGT), and alkaline phosphatase (ALP).

Hepatic Function Panel

The liver is one of the first organs exposed to bacteria and toxins in the bloodstream; when the liver is not functioning well, these substances may reach the heart and lungs. This is one reason why people with liver failure are at high risk of multiorgan dysfunction syndrome (MODS; also known as multiple organ failure syndrome [MOFS]) (see Chapter 5). Since no one liver function test can pinpoint the specific liver dysfunction, physicians rely on various tests and measures in conjunction with clinical observations and other diagnostic tests (Table 40-5).

Measuring transaminases (enzymes) released into the blood from liver cells when they are damaged provides information about liver function and, in particular, the amount of inflammation in the liver. For example, ALT is an enzyme that serves as a sensitive indicator of hepa-

Table 40-5 Laboratory Tests for Liver and Biliary Tract Disease

	Normal Range	Comment
Serum bilirubin		
Direct (conjugated)	0.1-0.3 mg/dl	Increased with obstruction
Indirect (unconjugated)	0.2-0.8 mg/dl	Increased with other problems
Total	0.1-1.0 mg/dl	Increased with cirrhosis; hepatitis, hemolytic anemia, jaundice, transfusion reaction
Urine bilirubin	0	—
Serum proteins		
Albumin (A)	3.5-5.5 g/dl	Decreased in liver damage, burns, Crohn's disease, SLE, malnutrition (e.g., anorexia nervosa) digoxin (digitalis) toxicity
Globulin (G)	2.5-3.5 g/dl	Increased in hepatitis
Total	6-8 g/dl	Decreased in liver damage (synthesis is impaired)
A/G ratio	1.5:1-2.5:1	Ratio reverses with chronic hepatitis or other chronic liver disease
Transferrin (iron levels)	250-300 mg/dl	Decreased in liver damage, increased in iron deficiency
Alpha-fetoprotein	6-20 ng/ml	Cancer associated antigen; made by fetus but not by healthy adults; value >1000 ng/mg indicates likely hepatocellular carcinoma
Serum enzymes		
AST	8-20 U/L	Increased in liver damage, released by liver when damage occurs to liver cells; increased with primary muscle diseases (e.g., myopathy)
ALT	5-35 U/L	Same as above
LDH	45-90 U/L	Same as above. Increased with metastatic disease osteosarcoma
GGT	5-38 U/L	Age- and gender-dependent elevated with significant liver disorder
Alkaline phosphatase	30-85 U/L	Increased with liver tumor, biliary obstruction, rheumatoid arthritis, hyperparathyroidism, Paget's disease of bone
Blood ammonia	<75 mcg/dl	Great variation in reported values because of methods used; increased in severe liver damage
Coagulation functions		
Prothrombin time	12-15 sec	Prolonged in liver damage; salicylate intoxication, intake of anticoagulants (warfarin), DIC
INR	0.9-1.1 (ratio)	Prolonged in clotting factor, deficiencies (e.g. hemophilia), leukemia, DIC, with administration of heparin
aPTT	30-40 sec; therapeutic level 2-2.5 times normal	May drop when spleen is enlarged from portal hypertension, decreased in DIC and burns; increased with inflammation (see table 40-6, 40-12)
Platelets	150,000-400,000/mm ³	

Modified from Goodman CC, Snyder TE: *Differential diagnosis for physical therapists: screening for referral*, ed 4, Philadelphia, 2007, WB Saunders. SLE, Systemic lupus erythematosus; AST, aspartate aminotransferase; ALT, alanine aminotransferase; LDH, lactate dehydrogenase; GGT, γ -glutamyl transferase; PT, prothrombin time; INR, international normalized ratio; DIC, disseminated intravascular coagulation; aPTT, activated partial thromboplastin time.

tocellular damage; it is the primary test for detecting hepatitis.

ALP is related to the bile ducts and is increased when they are blocked and may indicate gallbladder, liver, and bile duct disease¹ but may also be elevated from increased bone turnover in chronic renal failure.⁴⁶ ALP may be elevated in diseases other than liver injury. Increased levels of this enzyme may indicate hyperparathyroidism, Paget's disease of bone, or rheumatoid arthritis. It is also elevated in biliary obstruction or with hepatocytic carcinoma.

AST is found in the liver and also in the heart and skeletal muscles and historically had been used for dif-

ferential diagnosis of chest pain. Bilirubin is measured as either total bilirubin, or direct bilirubin and indirect separately to determine the cause of elevated bilirubin. Total bilirubin can be elevated by liver disease or other causes such as bile duct occlusion and hemolytic anemia. Levels of albumin and total protein reflect the ability of the liver to synthesize proteins.¹

ALT, AST, GGT, and LDH are elevated with injury to hepatocytes. LDH may be elevated by injury to other tissues, such as myocardial infarction, or by cancer cells. Therefore elevated LDH may raise the suspicion of metastatic disease, particularly osteosarcoma.

Blood Ammonia

Ammonia is an intermediate product of breaking down amino acids in proteins. Severe liver injury results in the inability to convert ammonia into urea to be excreted by the kidneys and accumulation of ammonia. Ammonia may also accumulate because of hepatic disease resulting in hepatic encephalopathy, including confusion, lethargy, dementia, daytime sleepiness, tremors, deterioration of fine motor skills, and speech impairment. Ammonia may be tested if hepatic encephalopathy or Reye's syndrome is suspected as a cause of unexplained mental status or coma. A combination of elevated ammonia and decreased glucose in a child is indicative of Reye's syndrome.

Other causes of elevated ammonia may include gastrointestinal bleeding and a genetic defect in the enzymes of the urea cycle.¹ Reference values and interpretations for the hepatic function panel and ammonia are given in Table 40-5. When liver dysfunction results in increased serum ammonia and urea levels, peripheral nerve function can also be impaired. Asterixis and numbness or tingling (misinterpreted as carpal or tarsal tunnel syndrome) can occur as a result of this ammonia abnormality causing intrinsic nerve pathologic findings (see further discussion in Chapter 17).

SPECIAL IMPLICATIONS FOR THE THERAPIST 40-4

Hepatic Function

Elevation of liver enzymes indicates hepatic dysfunction. Therapists should be aware of signs of hepatic disease such as altered behavior or mental status, fluctuating levels of consciousness, peripheral edema, ascites, right upper abdominal pain, and musculoskeletal pain.

Although ALT and AST are part of the hepatic panel, they may be elevated by muscle injury or disease. Measurement of serum creatine kinase (CK)-MM would then be required to determine the source of elevated ALT and AST. Likewise, serum albumin may be depressed because of malnutrition, rather than by hepatic disease. Hypothyroidism can also cause mild skeletal muscle injury resulting in mild AST and ALT elevations.

Nutrition and Wound Healing

Serum albumin levels in combination with other laboratory values (e.g., glucose levels, hemoglobin, and hematocrit) can be used to assess nutritional status (e.g., in the case of eating disorders or malnutrition for other reasons) and to monitor wound healing. Serum albumin levels correlate negatively with medical complications during rehabilitation and positively with mobility outcome.^{13,19}

The Agency for Health Care Policy and Research (AHCPR) guidelines for clinically significant malnutrition impairing wound healing include serum albumin less than 3.5 mg/dl and total lymphocyte count less than 1800/mm³.⁵ The therapist must take this information into consideration when setting up and carrying out an appropriate intervention plan.

Other Considerations

The client with liver dysfunction is at increased risk of infection requiring careful practice of Standard Precautions. The heart also tries to compensate for fluid shifts and alterations in vascular status as a result of liver dysfunction, necessitating monitoring of vital signs. Heart failure can occur when collateral circulation can no longer support body systems.

Coagulation factors are synthesized in the liver; therefore, hepatic disease may also lead to coagulation disorders. Precautions may become necessary with hepatic disease accompanied by impaired coagulation or reduced platelet count, especially with any intervention requiring manual therapy or the use of any equipment, including gait training belts, physical therapy modalities, and weight training devices.

COMPLETE BLOOD COUNT

The complete blood count (CBC) is a common laboratory test performed routinely in many clinical settings. Although the term *complete* is commonly used, different degrees of detail are available. The term *CBC* implies that red blood cells (RBCs; erythrocytes), WBCs (leukocytes), and platelets are counted from a sample of blood. CBC is an automated test that provides results regarding the concentration of RBCs, WBCs, and platelets.

Table 40-6 lists normal and abnormal values related to blood testing with a number of potential causes and the consequences of abnormal values. A simple count of RBCs, WBCs, and platelets may be sufficient for determining the appropriate level of mobilization and exercise. Reference values for the CBC are given in Table 40-7.

Red Blood Cells

RBC count (or a simpler means of assessing the capacity of the blood to carry oxygen such as hemoglobin [Hgb] concentration or hematocrit [HCT]) correlate with a person's endurance and orthostatic tolerance. A relative decrease in the capacity of blood to carry oxygen is termed *anemia*. Several additional tests may be required to determine the cause of anemia, including intrinsic factor, vitamin B12, and folic acid, which are necessary for erythropoiesis. Mean cell volume, mean cell Hgb, red cell distribution width (variation in RBC size), presence of immature cells (reticulocytes), and ferritin may be necessary to diagnose the cause of anemia.

Ferritin is an intracellular store of iron. Its value declines in anemia caused by chronic iron deficiency and severe protein depletion (e.g., burns or malnutrition). Elevation of ferritin is also used as an indicator of states of chronic iron excess such as hemochromatosis.¹

Men with essential hypertension may have a high prevalence of increased iron stores and metabolic

Table 40-6 Complete Blood Count (CBC)

Abbreviation	Measure of	Significance
Leukocytes (WBCs)	Total number of WBCs; fight infection and react against foreign bodies or tissues	Decreased: infection, bone marrow suppression or failure (e.g., following neoplastic chemotherapy/radiotherapy, bone marrow infiltrative diseases), AIDS, alcoholism, diabetes, autoimmune diseases; lowest in morning Increased: indicates infection, inflammation, tissue necrosis, leukemia, tissue trauma or stress (physical or emotional), burns, thyroid storm, dehydration
RBCs	Erythrocyte (red cell count)	Decreased: anemia, blood loss, dietary insufficiency of iron and vitamins essential in RBC production, chemotherapy, various disorders/disease (e.g. Hodgkin's disease, multiple myeloma, leukemia, SLE, rheumatic fever, endocarditis) Increased: polycythemia vera, dehydration, severe diarrhea, poisoning, pulmonary fibroses, high altitude, chronic heart disease
HCT	HCT is percentage of whole blood occupied by RBCs	Decreased: anemia caused by blood loss (e.g., gastrointestinal bleeding trauma), nutritional deficiency (e.g., folate, iron, vitamin B12), leukemia, hyperthyroidism, cirrhosis, hemolytic reaction (e.g., blood transfusion, chemicals or drugs, severe burns, prosthetic heart valve) Increased: erythrocytosis, polycythemia, severe dehydration, shock caused by severe dehydration or burns, cor pulmonale
Hgb	Hgb measures oxygen-carrying capacity of RBCs	Decreased: hemoglobinopathy (e.g., sickle cell disease), pregnancy, hyperthyroidism, some medications (e.g., antibiotics, antineoplastic drugs, aspirin, rifampin, sulfonamides), cirrhosis, severe hemorrhage, severe burns, systemic disease (e.g., Hodgkin's disease, leukemia, lymphoma, SLE, sarcoidosis) Increased: living in high altitudes, some medications (e.g., gentamicin, methyldopa [Aldomet]), COPD, congestive heart failure, dehydration, polycythemia vera
Platelets (thrombocytes)	Clotting potential	Decreased: anemia, use of antibiotics, toxic effect of many drugs (e.g., antiinflammatories, steroids), pneumonia and other infections, HIV infection, cancer chemotherapy, bone marrow involvement Increased: inflammation, infection, cancer, splenectomy, trauma, rheumatoid arthritis, heart disease, cirrhosis, recovery from bone marrow suppression

WBCs, White blood cells; RBCs, red blood cells; HCT, hematocrit; Hgb, hemoglobin; AIDS, acquired immunodeficiency syndrome; SLE, systemic lupus erythematosus; COPD, chronic obstructive pulmonary disease; HIV, human immunodeficiency virus.

Table 40-7 Complete Blood Count (CBC) Reference Values

Age	WBCs (cells/mm ³)	RBCs (10 ⁶ /mm ³)	ESR (mm/hr)	HCT (%)	Hgb (g/dl)
Newborn	18,000-40,000 (drops to adult levels in 2-3 wk)	5.5-6.0	—	Up to 60	17-19
Children	4500-14,500 (varies with age)	4.6-4.8 (varies with age)	1-13	30-49 (varies with age)	14-17
Adult men	4500-11,000	4.5-5.3	0.17*	37-49	13-18
Adult women	4500-11,000	4.1-5.1	1-25†	36-46	12-16
Pregnant women	4500-16,000	Slightly lower	44-114 (increases because of increase in serum globulins and fibrinogen)	Decreases in third trimester because of hemodilution	11-12

Data from Corbett JV: *Laboratory tests and diagnostic procedures with nursing diagnoses*, ed 7, Upper Saddle River, NJ, 2007, Prentice-Hall Health.
WBCs, White blood cells; RBCs, red blood cells; ESR, erythrocyte sedimentation rate; HCT, hematocrit; Hgb, hemoglobin.

*Upper limit for men after age 50 is 20.

†Upper limit for women after age 50 is 30.

abnormalities that are part of the insulin-resistance-associated hepatic iron overload syndrome (IRHIO).⁶⁰ In general, individuals with elevated ferritin are at increased risk for insulin-resistance syndrome.^{21,86} A major limitation to the test for ferritin levels is the fact that ferritin can be elevated in conditions that do not reflect iron stores such as acute inflammatory diseases, infections, and metastatic malignancies.

White Blood Cells

WBC count can be provided as a total, a count of individual types of leukocytes, or subtypes of leukocytes. WBCs may either increase or decrease in disease. In general, an increase suggests infection or other inflammatory response. WBC count may decrease as a result of bone marrow disease or chemotherapy for cancer or to prevent transplant rejection.

The primary therapy implications are related to the presence of infection with elevated leukocyte count (leukocytosis) or risk of patients/clients becoming infected with a low WBC count (leukopenia). In particular, neutropenia is a risk factor for nosocomial infection. Facility policy may require supply of individual equipment, air filtration systems, gowning, gloving, and facemasks.⁸⁴

Platelets

Platelet count is decreased by excessive bleeding, coagulation disorders, autoimmune disorders, or histocompatibility problems caused by transfusion of incompatible platelets. Indications for platelet count include unexplained bruising and long coagulation time.

Platelet count is decreased in bone marrow diseases, such as aplastic anemia, leukemia, multiple myeloma, and other cancer in the bone marrow. In addition, chronic bleeding, autoimmune disease, and factors that suppress cell production by the bone marrow (e.g., cancer or other chemotherapies) may be causes of a low platelet count (thrombocytopenia).⁸⁰

BLOOD TESTS

Tests may be conducted on characteristics and subpopulations of different cells to determine the causes of altered blood counts. Bone marrow disease may be suspected for a number of reasons, particularly a global decrease of blood cells (pancytopenia).

Aspiration of bone marrow may also be required when cancer involving the bone marrow is suspected.⁶⁹ Bone marrow aspiration or biopsy allows evaluation of blood formation (hematopoiesis) by showing blood elements and precursor blood cells, as well as any abnormal or malignant cells.

Tests of RBCs

Symptoms of anemia may be present in spite of normal RBC count, or the cause of anemia may need to be identified. Therefore more specific testing of RBCs may be

needed. These include tests of RBC size, shape, maturity, and the type and concentration of hemoglobin inside them.

Hematocrit

Hematocrit (HCT) is a simple test involving a small quantity of blood that can be obtained with a simple skin prick. The blood is drawn into a small pipette and placed into a centrifuge to determine the relative volume of RBCs expressed as the percentage of total volume occupied by RBCs. The blood then separates (based on weight) into packed RBCs, buffy coat consisting of WBCs and platelets, and serum. This test is a quick screen for anemia. A low hematocrit is indicative of anemia, but anemia could still exist in the presence of a normal relative volume of RBCs.

Hemoglobin

Fleomoglobin (Hgb) concentration usually provides the same information as hematocrit. However, certain disease states may allow normal numbers of RBCs, but result in reduced concentration of hemoglobin within individual cells. Therefore anemia could result with normal hematocrit but reduced hemoglobin concentration. HCT and Hgb concentration are frequently tested simultaneously. When done this way, the term *H & H* is generally used.

Mean corpuscular hemoglobin concentration (MCHC) is used to determine whether RBCs have reduced hemoglobin concentration within them. This test would not be necessary if HCT and Hgb concentration show the same changes from normal or both were normal.

Mean corpuscular volume (MCV) is also used in the differential diagnosis of anemia. Different disease states may increase MCV, such as vitamin B12 or folic acid deficiency (macrocytic anemia), or it may be decreased as in iron deficiency anemia (hypochromic anemia) or other causes of decreased cell volume (microcytic anemia).

Hgb levels of 12 to 16 g/dl have been considered normal, but more recent studies have shown that older adults with a low-normal value of 12 g/dl are more likely to have difficulty performing daily tasks. Mild anemia may be dismissed as "innocent" but cause significant functional problems. Difficulty walking, climbing stairs, or doing house or yard work may be an early sign of low-normal Hgb levels.¹⁰

Red Blood Cell Shape

The normal biconcave disc of RBCs may be altered in a number of diseases. The crescent shape of RBCs may be seen microscopically to confirm the diagnosis of sickle cell disease. A number of rare genetic diseases may also alter the shape of RBCs. For example, hereditary spherocytosis, as the name implies, allows red cells to take on a spherical shape.

Reticulocyte Count

Immature RBCs are termed *reticulocytes*. Increased numbers of reticulocytes in the blood indicate compensation of the bone marrow for RBC loss, typically as a result of bleeding. This condition is termed *reticulocytosis*.

Iron

Iron is required for the synthesis of hemoglobin. Lack of iron results in small, hypochromic (pale) RBCs that cannot carry as much oxygen as normal. Iron status is determined by serum transferrin receptor assay⁵⁹ and serum ferritin.⁶⁰ Iron deficiency anemia is discussed further in Chapter 14.

Vitamin B12 and Folic Acid

Both of these vitamins are critical to the production of RBCs. Deficiency results in production of large immature RBCs being released from the bone marrow. B12 is obtained from ingesting animal protein and requires intrinsic factor, which is produced by the gastric mucosa for absorption in the distal part of the ileum. When absorption of vitamin B12 is inadequate (e.g., because of a malabsorption syndrome or from lack of intrinsic factor) pernicious anemia may develop.

B12 shots may be recommended when serum levels are too low. Folic acid (folate), one of the B vitamins, is also necessary for normal function of RBCs and WBCs and for the adequate synthesis of certain purines and pyrimidines, which are precursors to deoxyribonucleic acid (DNA). As with vitamin B12, folate depends on normal absorption in the intestinal mucosa.

SPECIAL IMPLICATIONS FOR THE THERAPIST 40-5

Blood Tests

Complete Blood Count

HEMOGLOBIN AND HEMATOCRIT

HCT and Hgb concentration may be decreased for a large number of reasons. Some of these result in chronically low Hgb and HCT, whereas others, especially bleeding, lead to acute decrease in Hgb and HCT. For example, decreased Hgb may be the result of obvious or occult blood loss, decreased RBC production (e.g., lack of substrate such as iron, vitamin B12, or folate), myeloproliferative processes (i.e., leukemias), or increased RBC destruction (e.g., disseminated intravascular coagulation [DIC], splenic involvement, or sequestration of sickle cells in sickle cell disease). Increased Hgb may be found in cases of dehydration and polycythemia (see also Table 40-6). Guidelines for exercise are given in Tables 40-8 and 40-9.

Regardless of the cause, anemia produces decreased exercise tolerance in the forms of decreased aerobic capacity (intensity), decreased endurance (requiring more rest breaks), and orthostatic intolerance. With HCT less than 25% or Hgb concentration less than 8 g/dL, physically demanding intervention is not likely to be beneficial.

Low Hgb values (8 to 10 g/dL) typically result in decreased exercise tolerance, increased fatigue, and tachycardia, conditions that may contraindicate aggressive therapeutic measures, including strength and endurance training. Treating functional limitations is often important but the timing is crucial. For example,

activity tolerance is poor in anyone with hemoglobin values of less than 8 g/dL, and therapeutic intervention is limited (see Table 40-8). (See also Special Implications for the Therapist: The Anemias in Chapter 14.)

People with chronic anemia, however, are more likely to be able to perform some physical activity compared with individuals who have acute onset of anemia. Individuals with anemia may receive transfusions. Many facilities do not allow out-of-bed activity during transfusions, but others may allow careful lower level activity.

WHITE BLOOD CELL COUNT

The therapist should be aware of white cell count for two important reasons. An elevated WBC count is indicative of infection. The patient is likely to have a compromised exercise tolerance and may also have precautions related to the therapist's intervention, including contact precautions, requiring gloves, gowns, caps, masks, and shoe covers.

If the count is low, the client may be susceptible to opportunistic infections and severe complications. The importance of good hand hygiene practices cannot be overemphasized when treating these individuals. A decreased WBC count predisposes the person to infection. Special care must be taken to avoid transmitting bacteria, viruses, and fungi to the patient/client.

With a WBC of less than 1000/mm³ or a neutrophil count of less than 500/mm³, patients are usually required to wear a protective mask outside the hospital/facility room and have specialized equipment such as high efficiency particulate air (HEPA) filtration within the room. Handwashing and the use of alcohol hand sanitizer, use of patient-specific equipment, and disinfection of equipment that cannot be left in the patient's room are necessary.

Granulocyte colony-stimulating factor (G-CSF) and/or prophylactic antibiotics may be prescribed by the physician for clients with low neutrophil counts, especially before and during chemotherapy to keep the WBC levels acceptable. Even with this medical intervention, therapists should adhere carefully to Standard Precautions and also ensure that all equipment is disinfected according to Standard Precautions when working with this population.²⁰

PLATELETS

Platelets initiate the clotting sequence to plug damaged blood vessels. When the platelets are less than 15,000 to 20,000/mm³, serious bleeding can occur and platelet transfusions may be required. Platelet count may be decreased for a number of reasons, whether a result of bone marrow suppression, bleeding disorders, or other diseases. As platelet count falls below 150,000/mm³, the risk of spontaneous bleeding increases. At higher platelet counts, trivial trauma may lead to bleeding. Exercise guidelines related to thrombocytopenia are given in Table 40-9.

SPECIAL CONSIDERATIONS FOR THE ONCOLOGY PATIENT

Many questions have been raised about the blood counts and exercise recommendations made in this

Continued.

Table 40-8 Complete Blood Count: Exercise Guidelines (Adult)*

WBC count	<1000/mm ³	No exercise*; wear protective mask
	<5000/mm ³ or >10,000 with fever	No exercise permitted
	4,800-10,800 mm ³	Normal reference range; no activity restriction in healthy adults but some modifications may be needed in clients who are ill or during recovery after chemotherapy
HCT	>5000/mm ³	Light exercise: progress to resistive exercise as tolerated
	<25%	No exercise permitted
	>25%	Light exercise permitted
	30%-32%	Add resistive exercise as tolerated
Hgb	<8 g/dl	No exercise permitted
	8-10 g/dl	Light exercise permitted
	>10 g/dl	Resistive exercise permitted
Platelets	<20,000/mm ³	No exercise†
PT	Values ≥ 2.5 times the reference range	Physical and occupational therapy contraindicated
Clients receiving anticoagulant therapy (PT)	INR ≥ 2.5-3.0	Consult with physician (see text)

Modified from Garritan S, Jones P, Kornberg T, Parkin C: Laboratory values in the intensive care unit, Acute Care Perspective: Newsletter of the Acute Care/Hospital Clinical Practice Section, APTA, winter 1995.

WBC, White blood cell; HCT, hematocrit; Hgb, Hemoglobin; PT, prothrombin time; INR, International normalized ratio.

*These guidelines are only meant as a general recommendation (see text for further discussion and explanation). The therapist must make individual determinations depending on the client's age, general health status, and disease or condition present. For example, someone with an acute episode of urinary tract infection with altered WBC count and fever would be treated differently from someone with a chronic condition, such as diabetes Mellitus.

†See Table 40-9.

chapter. These concerns are directed at oncology patients but may be valid for others as well. The guidelines offered here are based on current clinical practice at various cancer centers around the United States and consensus of opinion from many clinicians. There are many variables and factors to consider when using these values. They are only guidelines—a best guess given the little amount of published evidence available at the current time. Also, as mentioned in each of the appropriate tables, the therapist must make individual determinations depending on the client's age, general health status, and disease or condition present.

More conservative treatment is considered when there is fever, known infection, a previous history of bleeding complication, or concern that overfatiguing the individual could lead to a decrease in immune function. Monitoring fatigue levels during and up to 8 hours after exercise may be warranted.^{48a}

At the present time, there are no known studies or reports on hemorrhage as a result of exercise related to blood counts. Anecdotal stories of individual patients have been related and there is always the concern for this complication. Low platelet counts alone as a risk factor for hemorrhage are important, but the combination of low platelet counts and fever raises the risk even more. This consideration leads us to instruct patients to limit Valsalva maneuvers and maximal exertion and avoid resistive exercises when platelet levels fall below 20,000 cells/mm³.

Again, these guidelines vary; some institutions use much lower levels based on the patient population

Table 40-9 Exercise Guidelines for Thrombocytopenia*

Platelet Count (cells/mm ³)	Exercise
≥150,000 (normal range: 150,000-450,000)	Normal activity (unrestricted)
≥50,000	Progressive resistive exercise (as tolerated) Swimming Low bench stepping Bicycling (no grade; flat only) AROM exercise
≥30,000	Moderate exercise Stationary bicycling Walking as tolerated Aquatic therapy Light exercise
≥20,000	AROM exercise only Walking as tolerated Aquatic therapy with physician approval Some advocate no exercise, others permit AROM exercise
<20,000	Restricted to activities of daily living; walking with physician approval

AROM, Active range of motion.

*These guidelines vary from institution to institution; the therapist should check with each facility for its specific guidelines. Some therapists working in oncology settings report a more liberal exercise guideline. For example, in some centers, restriction to AROM and activities of daily living is indicated only when platelet counts drop below 5000/mm³. See text for further discussion and explanation.