◀ **FIGURE 6.13 Sympathetic and Parasympathetic Divisions of the Autonomic Nervous System** Sympathetic outputs (left) arise from thoracolumbar spinal cord segments and synapse in paravertebral and prevertebral ganglia. Parasympathetic outputs (right) arise from craniosacral regions and synapse in ganglia in or near effector organs.

KEY CLINICAL CONCEPT

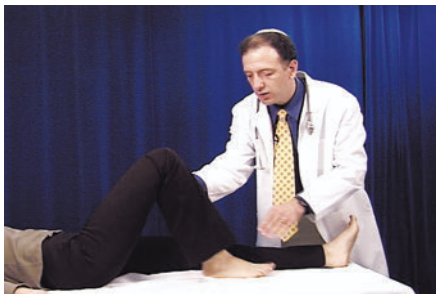
6.1 UPPER MOTOR NEURON VERSUS LOWER MOTOR NEURON LESIONS

The concept of upper motor neuron versus lower motor neuron lesions is very useful in clinical localization (see Figure 6.8). **Upper motor neurons** of the corticospinal tract project from the cerebral cortex to lower motor neurons located in the anterior horn of the spinal cord. **Lower motor neurons**, in turn, project via peripheral nerves to skeletal muscle. An identical concept of upper and lower motor neurons applies to the corticobulbar tract and cranial nerve motor nuclei.

Signs of **lower motor neuron lesions** include muscle weakness, atrophy, fasciculations, decreased tone, and hyporeflexia (Table 6.4; see also **neuroexam.com Video 48**). **Fasciculations** are abnormal muscle twitches caused by spontaneous activity in groups of muscle cells. An example of a benign fasciculation not associated with motor neuron damage is the eyelid twitching often experienced during periods of fatigue, caffeine excess, and eye strain (such as while reading too much neuroanatomy in one night). Signs of **upper motor neuron lesions** include muscle weakness and a combination of increased tone (see **neuroexam.com Videos 49** and **50**) and hyperreflexia sometimes referred to as **spasticity**. Additional abnormal reflexes seen with upper motor neuron lesions, such as **Babinski's sign** (see Figure 3.2), Hoffmann's sign, posturing, and so on, are discussed in Chapter 3 (see also **neuroexam.com Videos 58–60**). Note that with acute upper motor neuron lesions, flaccid paralysis with decreased tone and decreased reflexes may initially occur and gradually, over hours or even months, develop into spastic paresis. Spinal shock is an example of this process (see KCC 7.2).

Increased tone and hyperreflexia do not occur in experimental animals when a selective lesion is made in the corticospinal tract alone. It has therefore been hypothesized that spasticity is caused by damage to descending inhibitory pathways that travel closely with the corticospinal tract, rather than by damage to the corticospinal tract itself. Loss of these descending inhibitory influences may lead to increased excitability of motor neurons in the anterior horn, resulting in brisk reflexes and increased tone. Although this hypothesis fits available data, it has yet to be definitely proven in humans. ■

Atrophy? Fasciculations?



Lower extremity tone

TABLE 6.4 Signs of Upper Motor Neuron and Lower Motor Neuron Lesions

SIGN	UPPER MOTOR NEURON LESIONS	LOWER MOTOR NEURON LESIONS
Weakness	Yes	Yes
Atrophy	No[a]	Yes
Fasciculations	No	Yes
Reflexes	Increased[b]	Decreased
Tone	Increased[b]	Decreased

[a]Mild atrophy may develop due to disuse.

[b]With acute upper motor lesions, reflexes and tone may be decreased.

TABLE 6.5 Terms Commonly Used to Describe Weakness

TERM	DEFINITION	EXAMPLE	CLINICAL SYMPTOMS
DENOTING SEVERITY			
Paresis	Weakness (partial paralysis)	Hemiparesis	Weakness of one side of body (face, arm, and leg)
-plegia	No movement[a]	Hemiplegia	No movement of one side of body (face, arm, and leg)
Paralysis	No movement[a]	Leg paralysis	No movement of the leg
Palsy	Imprecise term for weakness or no movement	Facial palsy	Weakness or paralysis of face muscles
DENOTING LOCATION			
Hemi-	One side of body (face, arm, and leg)	Hemiplegia	No movement of one side of body (face, arm, and leg)
Para-	Both legs	Paraparesis	Weakness of both legs
Mono-	One limb	Monoparesis	Weakness of one limb (arm or leg)
Di-	Both sides of body equally affected	Facial diplegia	Symmetrical facial weakness
Quadri- or tetra-	All four limbs	Quadriplegia (tetraplegia)	Paralysis of all four limbs

[a]In upper motor neuron lesions causing paralysis or plegia there is no voluntary movement of the limb, but reflexes may be present.

KEY CLINICAL CONCEPT

6.2 TERMS USED TO DESCRIBE WEAKNESS

Weakness is one of the most important functional consequences of both upper and lower motor neuron lesions. Various terms are used in clinical practice to describe both the severity and distribution of weakness (Table 6.5). We will discuss localization of these different patterns of weakness in the next section. ■

KEY CLINICAL CONCEPT

6.3 WEAKNESS PATTERNS AND LOCALIZATION

Weakness can be caused by lesions or dysfunction at any level in the motor system, including the association and limbic cortices involved in volitional or motivational control of movement, the upper motor neurons of the corticospinal tract anywhere from cortex to spinal cord, the lower motor neurons anywhere from anterior horn to peripheral nerve, the neuromuscular junction, the muscles, and the mechanical functions of joints and tendons. The process of localizing lesions, as outlined in the sections that follow, requires that you identify the correct motor system level, side, and specific neuroanatomical structures affected. In the illustrations in this section, lesions are shown in red and deficits are shown in purple.

Unilateral Face, Arm, and Leg Weakness or Paralysis

OTHER NAMES: Hemiparesis or hemiplegia.

1. With No Associated Sensory Deficits Figure 6.14A

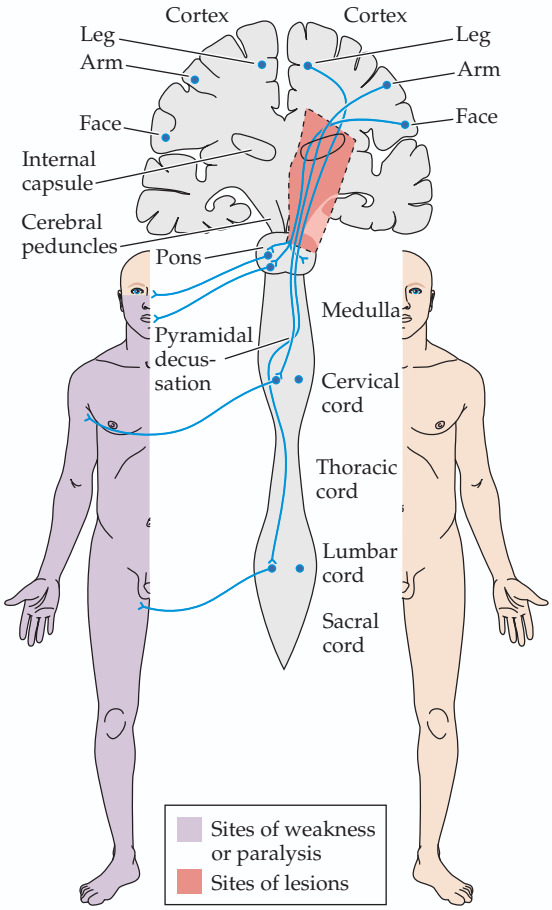
OTHER NAMES: Pure motor hemiparesis.

LOCATIONS RULED OUT: Unlikely to be cortical because the lesion would have to involve the entire motor strip, in which case sensory involvement is hard to avoid. Unlikely to be muscle or peripheral nerve because in that case coincidental involvement of the face, arm and leg, all on one side of the body, would be required. Not the spinal cord or medulla because in that case the face would be spared.

REVIEW EXERCISE

Cover the right two columns in Table 6.4. For each sign, state whether it is present, increased, or decreased with upper motor neuron lesions and with lower motor neuron lesions.

FIGURE 6.14A Pure Hemiparesis ▶



LOCATIONS RULED IN: Corticospinal and corticobulbar tract fibers below the cortex and above the medulla: corona radiate, posterior limb of the internal capsule, basis pontis, or middle third of the cerebral peduncle.

SIDE OF LESION: Contralateral to weakness (above the pyramidal decussation).

COMMON CAUSES: Lacunar infarct of the internal capsule (lenticulostriate branches of the middle cerebral artery or anterior choroidal artery; see Figures 10.7 and 10.9; see also Table 10.3) or of the pons (median perforating branches of the basilar artery; see Figure 14.21B,C; see also Table 14.8). Infarct of the cerebral peduncle (see Figure 14.21A) is less common. Demyelination, tumor, or abscess in these locations or in the corona radiata can also cause pure motor hemiparesis.

ASSOCIATED FEATURES: Upper motor neuron signs (see Table 6.4) are usually present. Dysarthria (see KCC 12.8) is common, giving rise to the name **dysarthria–pure motor hemiparesis**. Ataxia of the affected side may also occasionally be seen because of involvement of the cerebellar pathways (corticopontine fibers), giving rise to the name **ataxia-hemiparesis** (see Table 10.3; see also KCC 15.2).

2. With Associated Somatosensory, Oculomotor, Visual, or Higher Cortical Deficits Figure 6.14B

LOCATIONS RULED OUT: Unlikely to be below the medulla, for the reasons listed in the previous section.

LOCATIONS RULED IN: Entire primary motor cortex, including face, arm, and leg representations of the precentral gyrus, or corticospinal and corticobulbar tract fibers above the medulla (e.g, thalamocapsular lacune; see Table 10.3). The lesion can usually be further localized on the basis of other associated deficits.

SIDE OF LESION: Contralateral to weakness (above the pyramidal decussation).

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION: In addition to somatosensory, oculomotor, visual, or higher cortical deficits such as aphasia or neglect, there may be dysarthria or ataxia. Upper motor neuron signs are usually present as well.

COMMON CAUSES: Numerous, including infarct, hemorrhage, tumor, trauma, herniation, post-ictal state, and so on.

Unilateral Arm and Leg Weakness or Paralysis Figure 6.14C

OTHER NAMES: Hemiplegia or hemiparesis sparing the face; brachiocrural plegia or paresis.

LOCATIONS RULED OUT: Unlikely to be the corticospinal tract below the motor cortex above the medulla, because the corticobulbar tract fibers are located very close nearby and the face would thus usually be involved. Unlikely to be muscle or peripheral nerve because in that case coincidental involvement of both the arm and leg on one side of the body would be required. Not below C5 in the cervical cord because in that case some arm muscles would be spared.

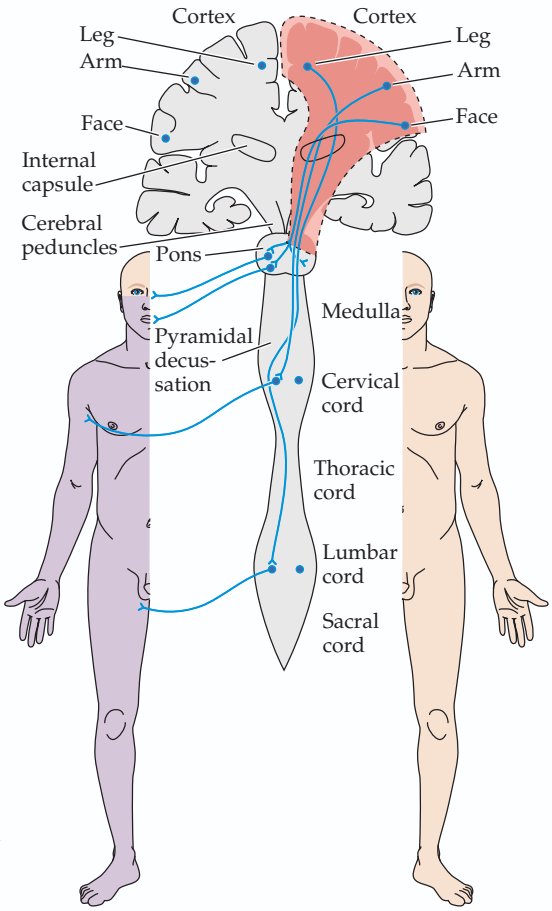
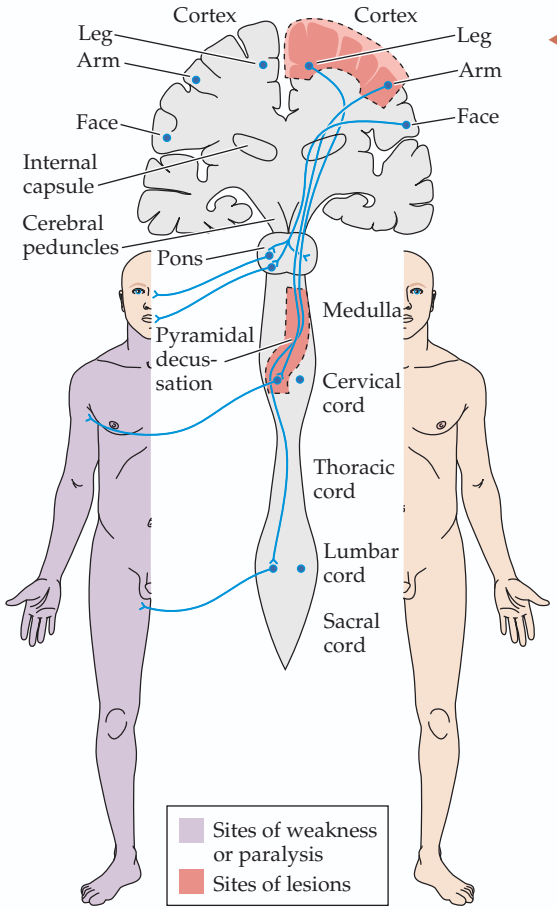


FIGURE 6.14B Hemiparesis with Additional Deficits ▶



◀ FIGURE 6.14C Hemiparesis Sparing the Face

LOCATIONS RULED IN: Arm and leg area of the motor cortex; corticospinal tract from the lower medulla to the C5 level of cervical spinal cord.

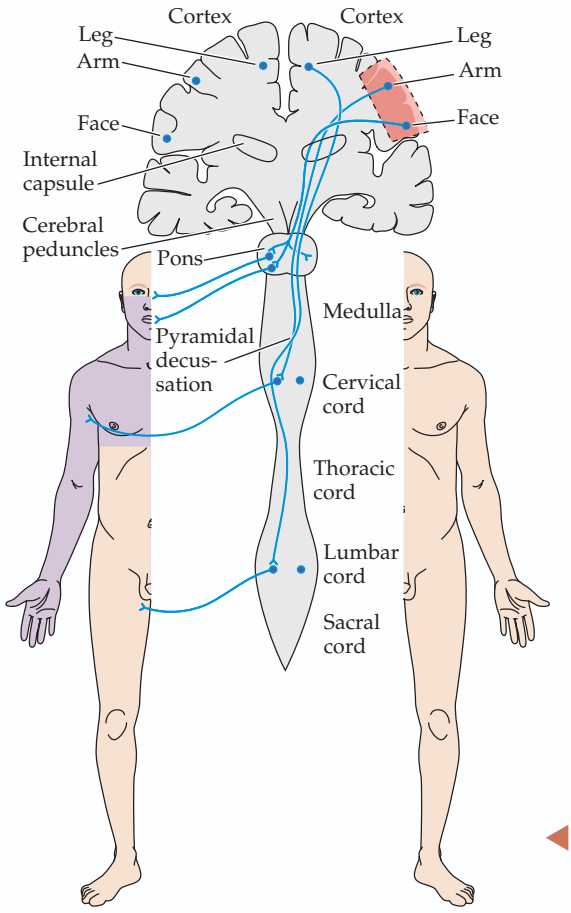
SIDE OF LESION: Motor cortex or medulla (above the pyramidal decussation): contralateral to weakness. Cervical spinal cord (below the pyramidal decussation): ipsilateral to weakness.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION: Upper motor neuron signs are usually present. Cortical lesions sparing the face are often in a watershed distribution, and they affect proximal more than distal muscles ("man in the barrel" syndrome; see KCC 10.2). Cortical lesions may be associated with aphasia (see KCC 19.6) or hemineglect (see KCC 19.9). In medial medullary lesions there may be loss of vibration and joint position sense on the same side as the weakness and tongue weakness on the opposite side (see Figure 14.21D; Table 14.7). In lesions extending to the lateral medulla, the lateral medullary syndrome may be present (see KCC 14.3; Table 14.7). In lesions of the spinal cord, the Brown–Séquard syndrome may be present (see KCC 7.4). High cervical lesions may involve the spinal trigeminal nucleus and tract (see Figure 12.8), causing decreased facial sensation.

COMMON CAUSES: Watershed infarct (anterior cerebral–middle cerebral watershed), medial or combined medial and lateral medullary infarcts, multiple sclerosis, lateral trauma, or compression of the cervical spinal cord. Occasionally, infarcts of the posterior limb of the internal capsule that are removed from the genu (see Figure 6.9B) may cause contralateral hemiparesis sparing the face.

Unilateral Face and Arm Weakness or Paralysis

Figure 6.14D



OTHER NAMES: Faciobrachial paresis or plegia.

LOCATIONS RULED OUT: Unlikely to be muscle or peripheral nerve because in that case coincidental involvement of the face and arm would be required. Uncommon (but not impossible) in lesions at the internal capsule or below because the corticobulbar and corticospinal tracts are fairly compact, resulting in leg involvement with most lesions.

LOCATIONS RULED IN: Face and arm areas of the primary motor cortex, over the lateral frontal convexity.

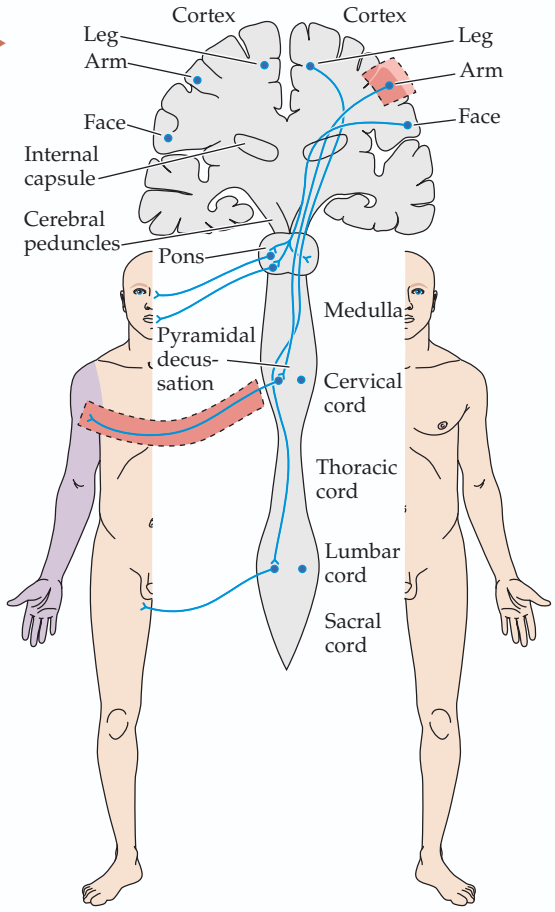
SIDE OF LESION: Contralateral to weakness (above the pyramidal decussation).

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION: Upper motor neuron signs and dysarthria are usually present. In dominant-hemisphere lesions, Broca's aphasia is common (see KCC 19.4). In nondominant-hemisphere lesions, hemineglect may occasionally be present (see KCC 19.9). Sensory loss can occur if the lesion extends into the parietal lobe (see KCC 7.3).

COMMON CAUSES: Middle cerebral artery superior division infarct is the classic cause (see Figures 10.1 and 10.5). Tumor, abscess, or other lesions may also occur in this location.

◀ FIGURE 6.14D Unilateral Face and Arm Weakness

FIGURE 6.14E Brachial Monoparesis ▶



Unilateral Arm Weakness or Paralysis Figure 6.14E

OTHER NAMES: Brachial monoparesis or monoplegia; there are specific names for different weakness patterns associated with peripheral nerve injuries (see Table 8.1; KCC 9.1).

LOCATIONS RULED OUT: Unlikely anywhere along the corticospinal tract (internal capsule, brainstem, spinal cord), because in that case the face and/or lower extremity would also likely be involved. Rare cases of foramen magnum tumors may initially affect one arm.

LOCATIONS RULED IN: Arm area of the primary motor cortex or peripheral nerves supplying the arm.

SIDE OF LESION: Motor cortex: contralateral to weakness. Peripheral nerves: ipsilateral to weakness.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION:

Motor cortex lesions: There may be associated upper motor neuron signs, cortical sensory loss, aphasia (see KCC 19.6), or subtle involvement of the face or leg. Occasionally, none of these are present. The weakness pattern may be incompatible with a lesion of peripheral nerves (see Table 8.1; see also KCC 9.1). For example, marked weakness of all finger, hand, and wrist muscles with no sensory loss and normal proximal strength does not occur with peripheral nerve lesions.

Peripheral nerve lesions: There may be associated lower motor neuron signs. Weakness and sensory loss may be compatible with a known pattern for a peripheral nerve lesion (see Table 8.1; see also KCC 9.1).

COMMON CAUSES:

Motor cortex lesion: Infarct of a small cortical branch of the middle cerebral artery, or a small tumor, abscess, or the like.

Peripheral nerve lesion: Compression injury, diabetic neuropathy, and so on (see KCC 8.3 and KCC 9.1).

Unilateral Leg Weakness or Paralysis Figure 6.14F

OTHER NAMES: Crural monoparesis or monoplegia; there are specific names for weakness patterns associated with various peripheral nerve or spinal cord lesions (see KCC 7.4 and KCC 9.1; see also Table 8.1).

LOCATIONS RULED OUT: Unlikely to be in the corticospinal tract above the upper thoracic cord (internal capsule, brainstem, cervical spinal cord) because in that case the face and/or upper extremity would usually also be involved. Rarely, cervical cord tumors can initially cause leg weakness only.

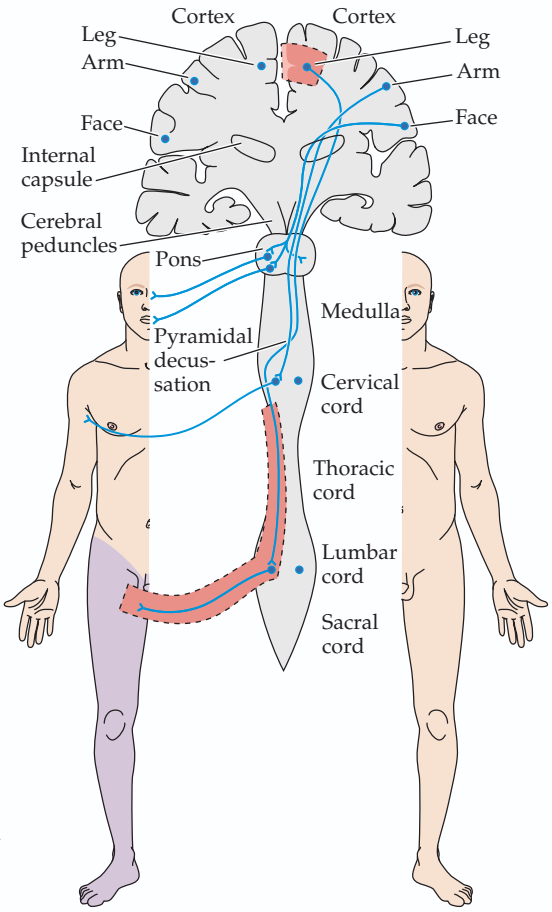
LOCATIONS RULED IN: Leg area of the primary motor cortex along the medial surface of the frontal lobe, lateral corticospinal tract below T1 in the spinal cord, or peripheral nerves supplying the leg.

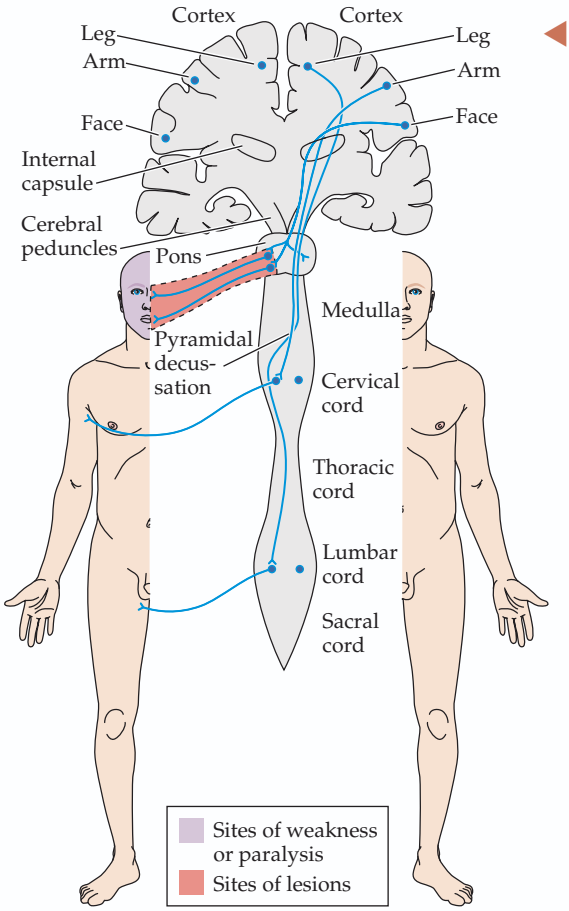
SIDE OF LESION: Motor cortex: contralateral to weakness. Spinal cord or peripheral nerves: ipsilateral to weakness.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION:

Motor cortex lesions: There may be associated upper motor neuron signs, cortical sensory loss, frontal lobe signs such as a

FIGURE 6.14F Crural Monoparesis ▶





◀ FIGURE 6.14G Facial Weakness (Lower Motor Neuron–Type)

grasp reflex, or subtle involvement of the arm or face. Occasionally, none of these are present. The weakness pattern may be incompatible with a lesion of peripheral nerves—for example, diffuse weakness of all muscles in one leg.

Spinal cord lesions: There may be associated upper motor neuron signs, a Brown–Séquard syndrome (see KCC 7.4), a sensory level, or some subtle spasticity of the contralateral leg. Sphincter function may be involved (see KCC 7.5). The weakness pattern may be incompatible with a lesion of peripheral nerves (see Table 8.1; KCC 9.1).

Peripheral nerve lesions: There may be associated lower motor neuron signs. Weakness and sensory loss may be compatible with a known pattern for a peripheral nerve lesion (see Chapters 8 and 9).

COMMON CAUSES:

Motor cortex lesion: Infarct in the anterior cerebral artery territory, or a small tumor, abscess, or the like.

Spinal cord lesion: Unilateral cord trauma, compression by tumor, or multiple sclerosis.

Peripheral nerve lesion: Compression injury, diabetic neuropathy, and so on.

Unilateral Facial Weakness or Paralysis Figure 6.14G,H

OTHER NAMES: Bell's palsy (peripheral nerve); isolated facial weakness.

LOCATIONS RULED OUT: Unlikely with lesions below the rostral medulla.

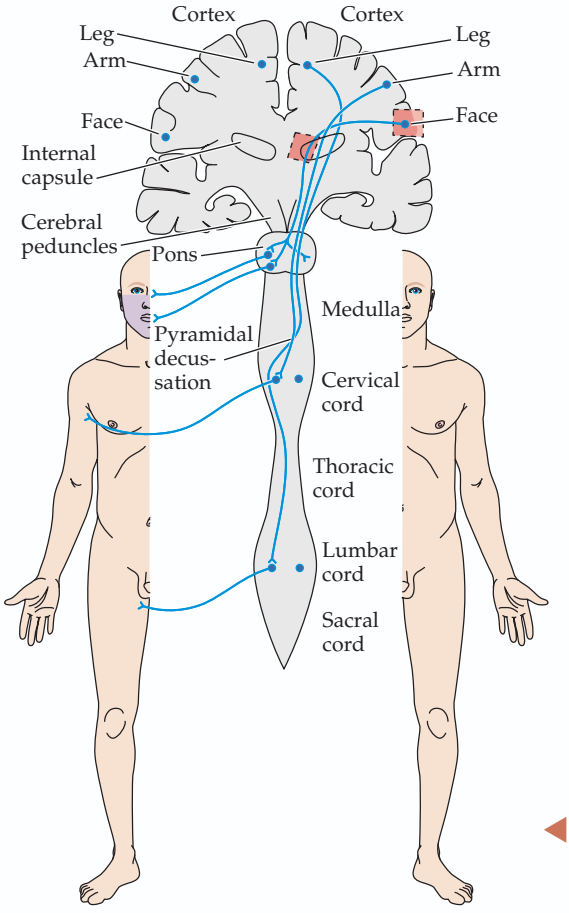
LOCATIONS RULED IN: Common—peripheral facial nerve (CN VII). Uncommon—lesions in the face area of the primary motor cortex or in the genu of the internal capsule (usually, lesions in these locations cause arm and leg involvement as well); facial nucleus and exiting nerve fascicles in the pons or rostral lateral medulla.

SIDE OF LESION: Facial nerve or nucleus—ipsilateral to weakness. Motor cortex or internal capsule—contralateral to weakness.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION:

Facial nerve or nucleus lesions (lower motor neuron; see Figure 6.14G): The forehead and orbicularis oculi are not spared (see Figure 12.13, lesion B). With facial nerve lesions (e.g., Bell's palsy), there may be hyperacusis, decreased taste, decreased lacrimation, and pain behind the ear on the affected side (see KCC 12.3). In facial nucleus lesions in the pons there are usually deficits associated with damage to nearby nuclei and pathways, such as CN VI, CN V, or the corticospinal tract (see Figures 12.11 and 14.21C; see also Table 14.8). In rostral lateral medullary lesions, a lateral medullary syndrome will be present. Interestingly, some authors report the forehead to be spared (upper motor neuron pattern) in facial weakness caused by medullary lesions.

Motor cortex or capsular genu lesions (upper motor neuron; see Figure 6.14H): The forehead is relatively spared (see Figure



◀ FIGURE 6.14H Facial Weakness (Upper Motor Neuron–Type)

12.13, lesion A). Dysarthria and unilateral tongue weakness are common. There may be subtle arm involvement. In cortical lesions, sensory loss or aphasia may be present.

COMMON CAUSES: Facial nerve: Bell's palsy, trauma, surgery. Motor cortex, capsular genu, pons, or medulla: infarct.

To summarize, only cases of isolated facial weakness of a lower motor neuron pattern, possibly with some hyperacusis, loss of taste, dry eye, or retroauricular pain, can be localized with certainty to the peripheral facial nerve. The presence of sensory loss or any other cranial nerve or motor abnormalities requires evaluation for a central nervous system lesion.

Note that facial weakness may be difficult to detect in cases in which it occurs bilaterally, called **facial diplegia**, since the weakness is symmetrical. Causes include motor neuron disease (see KCC 6.7), bilateral peripheral nerve lesions (such as in Guillain–Barré syndrome, sarcoidosis, Lyme disease, or bilateral Bell's palsy), or bilateral white matter abnormalities caused by ischemia or demyelination (such as in pseudobulbar palsy).

Bilateral Arm Weakness or Paralysis Figure 6.14I

OTHER NAMES: Brachial diplegia.

LOCATIONS RULED OUT: Unlikely to be in the corticospinal tracts because in that case the face and/or legs would also be involved.

LOCATIONS RULED IN: Medial fibers of both lateral corticospinal tracts (see Figure 6.10C); bilateral cervical spine ventral horn cells; peripheral nerve or muscle disorders affecting both arms.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION: A central cord syndrome or anterior cord syndrome may be present (see KCC 7.4).

COMMON CAUSES: Central cord syndrome: syringomyelia, intrinsic spinal cord tumor, myelitis. Anterior cord syndrome: anterior spinal artery infarct, trauma, myelitis. Peripheral nerve: bilateral carpal tunnel syndrome, or disc herniations.

Bilateral Leg Weakness or Paralysis Figure 6.14J

OTHER NAMES: Paraparesis or paraplegia.

LOCATIONS RULED OUT: Unlikely to be in the corticospinal tracts above the upper thoracic cord (internal capsule, brainstem, cervical spinal cord) because in that case the face and/or upper extremities would also be involved. Rarely, cervical cord tumors can initially cause bilateral leg weakness without arm involvement.

LOCATIONS RULED IN: Bilateral leg areas of the primary motor cortex along the medial surface of the frontal lobes; lateral corticospinal tracts below T1 in the spinal cord; cauda equina syndrome or other peripheral nerve or muscle disorders affecting both legs.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION:

Bilateral medial frontal lesions: Upper motor neuron signs may be present. There may also be frontal lobe dysfunction (see KCC 19.11), including confusion, apathy, grasp reflexes, and incontinence.

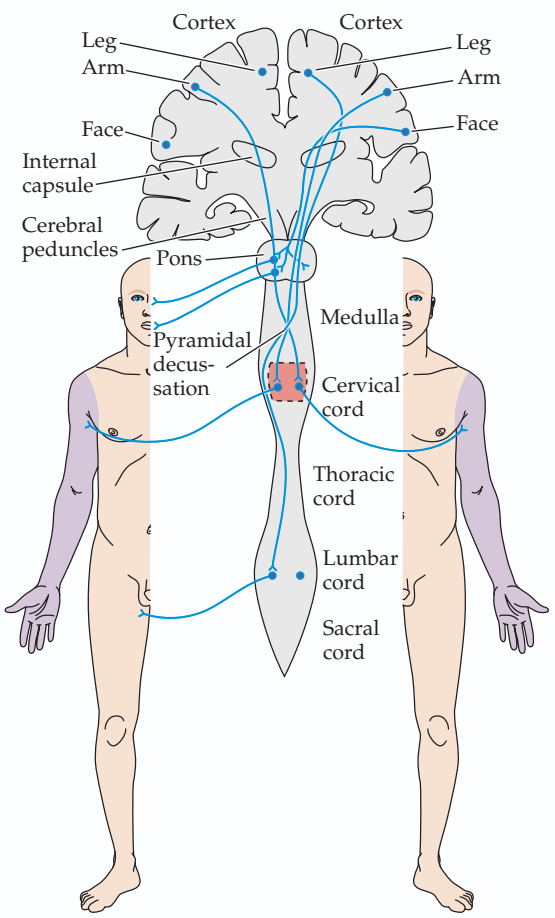


FIGURE 6.14I Brachial Diparesis

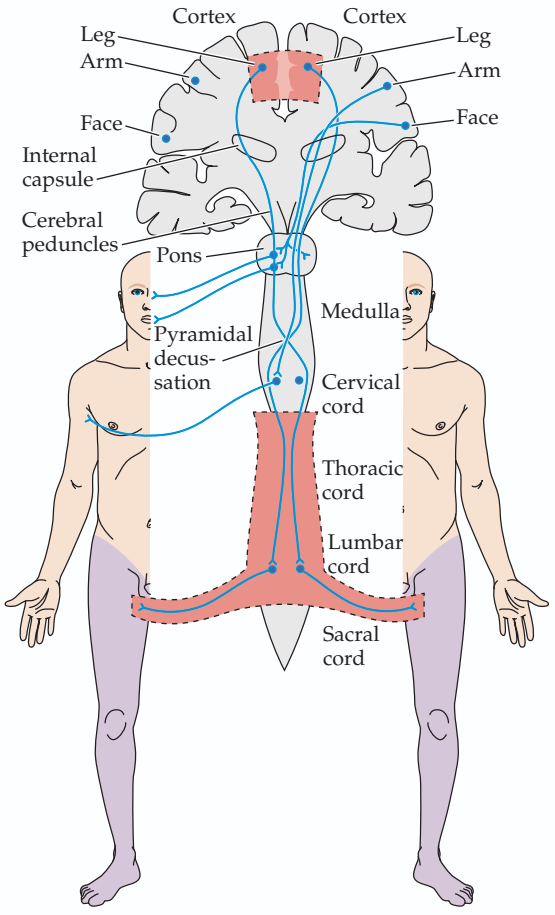


FIGURE 6.14J Paraparesis

Spinal cord lesions: Upper motor neuron signs (see Table 6.4), sphincter dysfunction, and autonomic dysfunction may be present. A sensory level (see Figure 8.4) or loss of specific reflexes (see Tables 3.6 and 3.7) may help determine the segmental level of the lesion.

Bilateral peripheral nerve or muscle disorders: Cauda equina syndrome is associated with sphincter and erectile dysfunction, sensory loss in lumbar or sacral dermatomes, and lower motor neuron signs (see KCC 8.4). Distal symmetrical polyneuropathies (see KCC 8.1) tend to preferentially affect distal muscles and may have associated distal "glove-stocking" sensory loss and lower motor neuron signs. Neuromuscular disorders and myopathies often (but not always) affect proximal more than distal muscles.

COMMON CAUSES: Note that spinal cord lesions are a common and serious cause of bilateral leg weakness.

Bilateral medial frontal lesions: Parasagittal meningioma (see KCC 5.8), bilateral anterior cerebral artery infarcts (see Figure 10.5), cerebral palsy (bilateral periventricular leukomalacia).

Spinal cord lesions: Numerous, including tumor, trauma, myelitis, epidural abscess (see KCC 7.2; Figure 7.10).

Bilateral peripheral nerve or muscle disorders: Cauda equina syndrome: tumor, trauma, disc herniation. Other peripheral nerve or muscle disorders (see KCC 8.1, 8.2, and 9.1): The lower extremities are often clinically affected before the arms in Guillain–Barré syndrome, Lambert–Eaton syndrome, numerous muscle disorders, and distal symmetrical polyneuropathies (caused by diabetes and other toxic, metabolic, congenital, and inflammatory conditions).

Bilateral Arm and Leg Weakness or Paralysis Figure 6.14K

OTHER NAMES: Quadriparesis, quadriplegia, tetraparesis, tetraplegia.

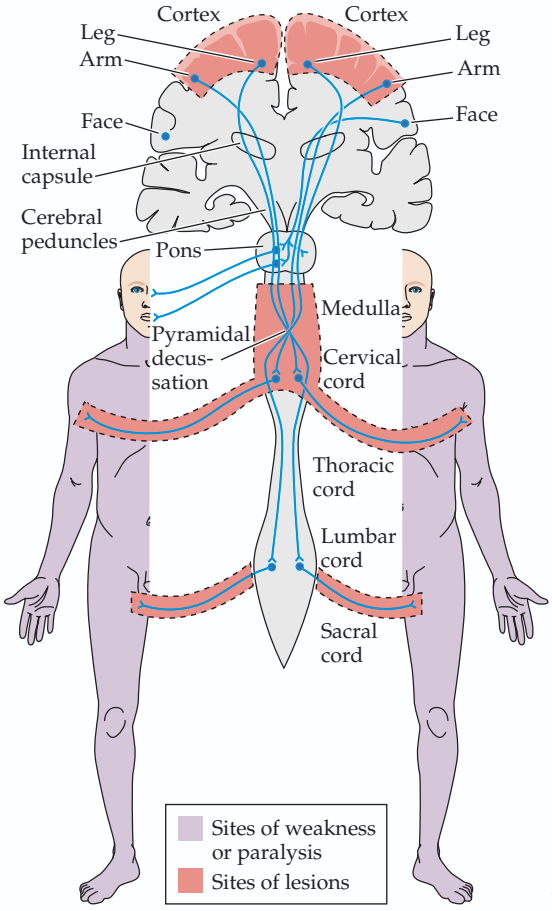
LOCATIONS RULED OUT: Unlikely to be below the motor cortex and above the medulla because the face would then be involved. Unlikely to be in the spinal cord below C5 because the arms would then be partly spared.

LOCATIONS RULED IN: Bilateral arm and leg areas of the motor cortex; bilateral lesions of the corticospinal tracts from the lower medulla to C5. Peripheral nerve, motor neuron, or muscle disorders severe enough to affect all four limbs usually also affect the face, although in some cases face involvement may be relatively mild.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION:

Bilateral motor cortex lesions: Cortical lesions sparing the face are often in a watershed distribution and affect proximal more than distal muscles ("man in the barrel" syndrome; see KCC 10.2; Figure 10.10). Upper motor neuron signs are usually present, and there may be associated aphasia, neglect, or other cognitive disturbances (see Chapter 19).

Bilateral upper cervical cord lesions: Upper motor neuron signs (see Table 6.4) are usually present. There may be a sensory level (see Figure 8.4), sphincter dysfunction (see KCC 7.5), or autonomic dysfunction (gastric paresis*, bladder atony, loss of erectile function, orthostatic hypotension). High cervical lesions may cause respiratory weakness and may involve the spinal trigeminal nucleus (see Figure 12.8), causing decreased facial sensation.



◀ FIGURE 6.14K Quadriparesis

Lower medullary lesions: Upper motor neuron signs are usually present. There may be occipital headache (see KCC 5.1), tongue weakness (see Figure 14.21D; see also Table 14.7), sensory loss, hiccups (see KCC 14.3), respiratory weakness, autonomic dysfunction, sphincter dysfunction (see KCC 7.5), or abnormal eye movements.

Peripheral nerve or muscle disorders: Lower motor neuron signs may be present in nerve disorders.

COMMON CAUSES:

Motor cortex lesions: Bilateral watershed infarcts (anterior cerebral–middle cerebral watershed) (see KCC 10.2).

Upper cervical cord and lower medullary lesions: Tumor, infarct, trauma, multiple sclerosis.

Peripheral nerve or muscle disorders: Numerous (see KCC 8.1, KCC 8.2, and KCC 9.1).

Generalized Weakness or Paralysis

LOCATIONS RULED OUT: Small focal or unilateral lesions do not produce generalized weakness. Lesions of the lower medulla or spinal cord spare the face or upper extremities.

LOCATIONS RULED IN: Bilateral lesions of the entire motor cortex; bilateral lesions of the corticospinal and corticobulbar tracts anywhere from corona radiata to pons; diffuse disorders involving all lower motor neurons, peripheral axons, neuromuscular junctions, or muscles. Bilateral ventral pontine ischemia due to basilar artery stenosis is an important cause of transient generalized weakness.

ASSOCIATED FEATURES ALLOWING FURTHER LOCALIZATION: Bilateral cerebral or corticospinal lesions may be associated with upper motor neuron signs. Lesions of the peripheral nerves may be associated with lower motor neuron signs. Sensory loss, eye movement abnormalities, pupillary abnormalities, autonomic disturbances, or impaired consciousness may be present, and these features help determine the location and nature of the lesion. Respiratory depression is common with severe generalized weakness.

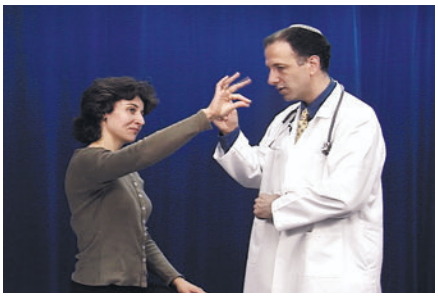
COMMON CAUSES: Global cerebral anoxia, pontine infarct or hemorrhage (locked-in syndrome, see KCC 14.1), advanced amyotrophic lateral sclerosis (see KCC 6.7), Guillain–Barré syndrome, myasthenia, botulism (see KCC 8.1), and numerous other diffuse neoplastic, infectious, inflammatory, traumatic, toxic, or metabolic disturbances.

General Comment

For patterns of weakness not described here, consider two or multiple lesions, unusual lesions, anatomical variants, or non-neurologic weakness as the cause. See also Chapters 8 and 9 for additional details about weakness caused by specific peripheral nerve lesions and Chapters 12 through 14 for weakness of extraocular muscles, jaw, neck, or tongue or of other specific muscles innervated by the cranial nerves. ■

*It is not known why spinal cord injury causes gastric paresis, since parasympathetics to the stomach travel via the vagus nerve and not from sacral spinal parasympathetics (see Figure 6.13).

Drift



Rapid hand movements

Romberg test

KEY CLINICAL CONCEPT

6.4 DETECTING SUBTLE HEMIPARESIS AT THE BEDSIDE

Sometimes patients have no obvious weakness or upper motor neuron signs, yet clinical suspicion warrants additional probing for more subtle deficits. The following tests can help detect mild corticospinal damage. See Chapter 3 and neuroexam.com for a review of the basic motor exam.

PRONATOR DRIFT: Patient holds arms extended, palms up, and closes eyes. Slight inward drifting rotation (pronation) of one forearm, or even a slight curling of the fingertips on one side, is abnormal (see **neuroexam.com Video 51**).

FINGER EXTENSORS: Patient holds fingers extended and resists while examiner tries to flex them (see **neuroexam.com Video 54**). This is an excellent test because corticospinal damage generally spares flexors relative to extensors, and finger extensors are relatively weak muscles with large cortical representation.

FINE MOVEMENTS: Patient rapidly taps index finger and thumb together; taps each finger to the thumb in sequence; rapidly pronates and supinates the hand either by holding it up and "screwing in a lightbulb" or by alternately slapping the palm and dorsum of the hand against the thigh; moves a coin from the palm to the fingers using one hand; taps the foot rapidly on the floor or bed (see **neuroexam.com Videos 52, 53, 62,** and **63**). The dominant hand or foot is normally only slightly faster at these tasks.

ISOLATED FINGER MOVEMENTS: Patient holds fingers abducted and extended and then moves one finger at a time.

SPASTIC CATCH: Feel for a subtle "catch" on one side compared to the other when holding the patient's hand in a handshake position and then rapidly supinating the patient's forearm (see **neuroexam.com Video 49**).

SUBTLE DECREASED NASOLABIAL FOLD: Observe patient's face carefully in several different settings, including rest, spontaneous smiling (see **neuroexam.com Video 40**), and grimacing during exam, not just during voluntary smile.

CAREFUL GAIT TESTING: Look for slight circumduction of one leg (the leg swings out in a circular arc with each step) or decreased arm swing. Also have the patient hop on each foot and walk on the toes (see **neuroexam.com Videos 68** and **69**).

FORCED GAIT: Patient walks on the outsides of the feet. Observe the hands carefully for subtle dystonic posturing on one side.

SILENT PLANTAR: If a normal flexor plantar response is present on one side, then a silent plantar response on the other side may represent a subtle Babinski's sign.

QUANTITATIVE TESTING: Under special circumstances, quantitative testing of motor power and speed may be helpful.

General Comment

Keep in mind that damage to other systems, such as the cerebellum, basal ganglia, or even peripheral nerves, can also produce abnormalities in some of these tests, making it important to interpret the results in the context of a complete neurologic exam. ■

KEY CLINICAL CONCEPT

6.5 UNSTEADY GAIT

Gait disorders can be caused by abnormal function of almost any part of the nervous system, as well as by some orthopedic conditions. Careful examination of gait is therefore one of the most sensitive tests of subtle neurologic dysfunction (see **neuroexam.com Videos 68** and **69**). Characteristic disorders of gait can be seen with lesions in specific systems, as described in Table 6.6. However, gait disorders alone often do not provide enough information for localization, and they must be analyzed in the context of a complete history and neurologic exam. In addition, in mild gait disorders only a few of the findings described in Table 6.6 may be present. ■

TABLE 6.6 Localization of Common Gait Disorders

NAME	LOCALIZATION	DESCRIPTION OF GAIT ABNORMALITIES	COMMON CAUSES
SPASTIC GAIT (see KCC 6.1)	Unilateral or bilateral corticospinal tracts	Unilateral or bilateral. Stiff-legged, circumduction, sometimes with scissoring of the legs and toe-walking (from increased tone in calf muscles), decreased arm swing, unsteady, falling toward side of greater spasticity.	Cortical, subcortical, or brainstem infarcts affecting upper motor neuron pathways; cerebral palsy; degenerative conditions; multiple sclerosis; spinal cord lesions
ATAXIC GAIT (see KCC 15.2)	Cerebellar vermis or other midline cerebellar structures	Wide based, unsteady, staggering side to side, and falling toward side of worse pathology. Subtle deficit can be detected with tandem (heel-to-toe, or "drunk walk") gait testing.	Toxins such as alcohol; medications; tumors of cerebellar vermis; infarcts or ischemia of cerebellar pathways; cerebellar degeneration
VERTIGINOUS GAIT (see KCC 12.6)	Vestibular nuclei, vestibular nerve, or semicircular canals	Looks similar to ataxic gait, wide based and unsteady. Patients sway and fall when attempting to stand with feet together and eyes closed (Romberg sign).	Toxins such as alcohol; infarcts or ischemia of vestibular nuclei; benign positional vertigo; Meniere's disease
FRONTAL GAIT (see KCC 5.7, 19.11)	Frontal lobes or frontal subcortical white matter	Slow, shuffling, narrow or wide based, "magnetic" (barely raising feet off floor), unsteady. Sometimes resembles Parkinsonian gait. Some patients can perform cycling movements on their back much better than they can walk, giving rise to the term "gait apraxia" in this condition.	Hydrocephalus; frontal tumors such as glioblastoma or meningioma; bilateral anterior cerebral artery infarcts; diffuse subcortical white matter disease
PARKINSONIAN GAIT (see KCC 16.1, 16.2)	Substantia nigra or other regions of basal ganglia	Slow, shuffling, narrow based. Difficulty initiating walking. Often stooped forward, with decreased arm swing, and "en bloc turning." Unsteady, with "retropulsion," taking several rapid steps to regain balance when pushed backward.	Parkinson's disease; other parkinsonian syndromes, such as progressive supranuclear palsy, or use of neuroleptic drugs

TABLE 6.6 *(continued)*

NAME	LOCALIZATION	DESCRIPTION OF GAIT ABNORMALITIES	COMMON CAUSES
DYSKINETIC GAIT (see KCC 16.1, 16.3)	Subthalamic nucleus, or other regions of basal ganglia	Unilateral or bilateral dancelike (choreic), flinging (ballistic), or writhing (athetoid) movements occur during walking and may be accompanied by some unsteadiness.	Huntington's disease; infarct of subthalamic nucleus or striatum; side effect of levodopa; other familial or drug-induced dyskinesias
TABETIC GAIT (see KCC 7.4)	Posterior columns or sensory nerve fibers	High-stepping, foot-flapping gait, with particular difficulty walking in the dark or on uneven surfaces. Patients sway and fall in attempts to stand with feet together and eyes closed (Romberg sign).	Posterior cord syndrome; severe sensory neuropathy
PARETIC GAIT (see KCC 8.3, 9.1)	Nerve roots, peripheral nerves, neuromuscular junction, or muscles	Exact appearance depends on location of lesion. With proximal hip weakness there may be a waddling, Trendelenburg gait. Severe thigh weakness may cause sudden knee buckling. Foot drop can cause a high-stepping, slapping gait, with frequent tripping.	Numerous peripheral nerve and muscle disorders
PAINFUL (ANTALGIC) GAIT	Peripheral nerve or orthopedic injury	Pain may be obvious based on patient's report or facial expression. Patients tend to avoid putting pressure on affected limb.	Herniated disc; peripheral neuropathy; muscle strain; contusions; fractures
ORTHOPEDIC GAIT DISORDER	Bones, joints, tendons, ligaments, and muscles	Depends on nature and location of the disorder. Peripheral nerve injury or spinal cord–related deficits may be present as well.	Arthritis; fractures; dislocations; contractures; soft tissue injuries
FUNCTIONAL GAIT DISORDER	Psychologically based	Can be hard to diagnose. Sometimes patients say they have poor balance, yet spontaneously perform highly destabilizing swaying movements while walking, without ever falling.	Conversion disorder; factitious disorder

KEY CLINICAL CONCEPT

6.6 MULTIPLE SCLEROSIS

Multiple sclerosis is an autoimmune inflammatory disorder affecting central nervous system myelin. The cause is unknown, although there is mounting evidence that T lymphocytes may be triggered by a combination of genetic and environmental factors to react against oligodendroglial myelin. Myelin in the peripheral nervous system is not affected. Discrete plaques of demyelination and inflammatory response can appear and disappear in multiple locations in the central nervous system over time, eventually forming sclerotic glial scars. Demyelination causes slowed conduction velocity, dispersion or loss of coherence of action potential volleys, and ultimately conduction block. Because dispersion increases with temperature, some patients have worse symptoms when they are warm. In addition to demyelination, recent studies have shown that some axons may be destroyed as well in multiple sclerosis plaques.

Prevalence is about 0.1% in the United States, with a higher worldwide prevalence in whites from northern climates, and about a 2:1 female-to-male ratio. Lifetime risk of developing multiple sclerosis goes up to 3–5% if a first-degree relative is affected. Peak age of onset is 20 to 40 years. Onset before age 10 or after 60 years of age is rare but not unheard of.

The classic clinical definition of multiple sclerosis is *two or more deficits separated in neuroanatomical space and time*. In practice, the **diagnosis** is based on the presence of typical clinical features, together with MRI evidence of white mat-

ter lesions, slowed conduction velocities on evoked potentials, and the presence of oligoclonal bands in cerebrospinal fluid obtained by lumbar puncture (see KCC 5.10). **Oligoclonal bands** are abnormal discrete bands seen on CSF gel electrophoresis. They result from the synthesis of large amounts of relatively homogeneous immunoglobulin by individual plasma cell clones in the cerebrospinal fluid (CSF). Oligoclonal bands are present in over 85% of patients with clinically definite multiple sclerosis, but they can be seen in about 8% of patients with other disorders as well. CSF with more than 50 white blood cells or with nonlymphocytes is unusual for multiple sclerosis. MRI findings suggestive of multiple sclerosis include multiple T2-bright areas, representing demyelinative plaques located in the white matter. The plaques tend to extend into the white matter from periventricular locations (resulting in "Dawson's fingers"), and they occur in both supratentorial and infratentorial structures. Acute plaques may enhance with gadolinium. The clinical features described here need not all be present to make the diagnosis of multiple sclerosis. In unusual or atypical cases of suspected multiple sclerosis it is essential to test for other inflammatory, infectious, neoplastic, hereditary, and degenerative conditions that can have similar clinical features.

Multiple sclerosis can affect numerous systems (Table 6.7). When patients first present with obvious symptoms, more subtle previous episodes can often be elicited in retrospect. About 50% of patients with a single episode of optic neuritis (see KCC 11.4) or transverse myelitis (see Table 7.4) subsequently develop multiple sclerosis. The course of multiple sclerosis is usually **relapsing–remitting** at the onset but may eventually evolve into a more refractory **chronic progressive** phase. Although severity of the disease varies from patient to patient, with good medical and neurologic care many patients with multiple sclerosis can now be expected to live a normal or near-normal life span despite their disability. Current therapies include a variety of immunomodulatory agents. Acute exacerbations are often treated with high-dose steroids, which can speed recovery in the short term but do not affect the overall course of the disease. For relapsing–remitting multiple sclerosis, the "first line" treatments are beta-interferon and copolymer (glatiramer acetate), which have a moderate effect on preventing exacerbations and delaying progression. "Second line" treatments for breakthrough relapsing disease include monoclonal antibodies such as natalizumab, rituximab, or campath and chemotherapeutic agents such as cyclophosphamide and mitoxantrone. There are currently no proven neuroprotective or neuoregenerative therapies for the more progressive phase of the disease, but this is an area of active investigation. It is also important to emphasize that multidisciplinary treatment of symptoms such as spasticity; pain; impaired bowel, bladder and sexual function; diplopia; dysphagia; and psychiatric manifestations can greatly improve a patient's quality of life. ■

TABLE 6.7 Common Symptoms and Signs in Chronic Multiple Sclerosis

FUNCTIONAL SYSTEM	PERCENT FREQUENCY
MOTOR	
Muscle weakness	65–100
Spasticity	73–100
Reflexes (hyperreflexia, Babinski's sign, absent abdominal cutaneous reflexes)	62–98
SENSORY	
Impairment of vibratory/position sense	48–82
Impairment of pain, temperature, or touch sense	16–72
Pain (moderate to severe)	11–37
Lhermitte's sign	1–42
CEREBELLAR	
Ataxia (limb/gait/truncal)	37–78
Tremor	36–81
Nystagmus (brainstem or cerebellar)	54–73
Dysarthria (brainstem or cerebellar)	29–62
CRANIAL NERVE/BRAINSTEM	
Vision affected	27–55
Ocular disturbances (excluding nystagmus)	18–39
Cranial nerves V, VII, VIII	5–52
Bulbar signs	9–49
Vertigo	7–27
AUTONOMIC	
Bladder dysfunction	49–93
Bowel dysfunction	39–64
Sexual dysfunction	33–59
Others (sweating and vascular abnormalities)	38–43
PSYCHIATRIC	
Depression	8–55
Euphoria	4–18
Cognitive abnormalities	11–59
MISCELLANEOUS	
Fatigue	59–85

Source: Rowland LP (ed.). 2000. *Merritt's Textbook of Neurology.* 10th Ed., Table 13.1. Lippincott Williams and Wilkins, Baltimore, MD.

KEY CLINICAL CONCEPT

6.7 MOTOR NEURON DISEASE

Several relatively uncommon disorders can selectively affect upper motor neurons, lower motor neurons, or both, producing motor deficits without sensory abnormalities or other findings. Most of these disorders are degenerative conditions referred to collectively as **motor neuron disease**. The classic example of motor neuron disease is **amyotrophic lateral sclerosis**, also known as **ALS** or **Lou Gehrig's disease**. ALS is characterized by gradually progressive degeneration of both upper motor neurons and lower motor neurons, leading eventually to respiratory failure and death. ALS has an incidence of 1 to 3 per 100,000 and is slightly more common in men, by a factor of about 1.5. Usual age of onset is in the 50s and 60s, although early-onset cases can be seen. Most cases occur sporadically, but there are also inherited forms that can have autosomal dominant, recessive, or X-linked transmission.

Initial symptoms are usually weakness or clumsiness, which *often begins focally* and then spreads to involve adjacent muscle groups. Painful muscle cramping and fasciculations are also common. Some patients present initially with predominantly bulbar complaints, such as dysarthria and dysphagia, or with respiratory symptoms. On neurologic examination, patients with ALS have weakness, with upper motor neuron findings such as increased tone and brisk reflexes, as well as lower motor neuron findings such as atrophy and fasciculations (see Table 6.4), sometimes best appreciated in the tongue muscles. A head droop is often present because of weakness of the neck muscles. Some patients have uncontrollable bouts of laughter or crying without the usual accompanying emotions, a finding known as pseudobulbar affect (see KCC 12.8). Sensory exam and mental status are typically normal. The extraocular muscles tend to be relatively spared. As the disease progresses, some patients can communicate only through eye movements. Electromyography (see KCC 9.2) shows evidence of muscle denervation and reinnervation in two or more extremities or body segments (for example head and arm, trunk and leg, arm and leg, etc.).

Unfortunately, there is no cure for this tragic disorder at present, and median survival from onset is 23 to 52 months. Riluzole, a blocker of glutamate release, has been shown to prolong survival by several months, and experimental trials with other agents are under way. Education of the patient and family about this disorder and implementation of a comprehensive program of medical and psychosocial services are imperative.

In evaluating patients with suspected ALS, it is important to test for other disorders that can, rarely, cause similar clinical findings. These include lead toxicity, dysproteinemia, thyroid dysfunction, vitamin B_{12} deficiency, vasculitis, paraneoplastic syndromes (see KCC 5.8), hexosaminidase A deficiency, multifocal motor neuropathy with conduction block, and other disorders. Cervical spine compression can occasionally produce a mixture of upper motor neuron signs (cord compression) and lower motor neuron signs in the upper extremities (nerve root compression). A cervical MRI is helpful to rule this out.

Some motor neuron disorders affect primarily upper motor neurons or primarily lower motor neurons. **Primary lateral sclerosis** is an example of an upper motor neuron disease, while **spinal muscular atrophy** affects lower motor neurons. Spinal muscular atrophy occurring in infancy is known as Werdnig–Hoffmann disease and usually leads to death by the second year of life. Much progress has been made recently in understanding the molecular basis of motor neuron disorders, offering some hope that we will have effective treatments for these devastating disorders in the near future. ■

CLINICAL CASES

CASE 6.1 SUDDEN ONSET OF RIGHT HAND WEAKNESS

CHIEF COMPLAINT

A 64-year-old man developed right hand weakness following cardiac arrest.

HISTORY

The patient had a history of hypertension and cigarette use but was otherwise healthy until the day of admission, when he suddenly collapsed in church. Family members at the scene administered immediate CPR, and when the ambulance arrived the patient received electrical defibrillation and promptly regained a normal cardiac rhythm. He was admitted to the cardiac intensive care unit and was found to have episodes of rapid atrial fibrillation. Several days after admission he was noted to have **weakness of the right hand**, and a neurology consult was requested.

PHYSICAL EXAMINATION

Vital signs: T = 98°F, P = 100, BP = 130/60.

Neck: Supple with no bruits.

Lungs: Clear.

Heart: Irregular rhythm, with a soft systolic murmur.

Abdomen: Normal bowel sounds; soft, nontender.

Extremities: Normal.

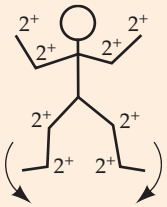
Neurologic exam:

MENTAL STATUS: Alert and oriented × 3. Language fluent, with intact naming, repetition, and reading. Able to recall 3/3 objects after 5 minutes.

CRANIAL NERVES: Normal, including no facial weakness.

MOTOR: Power 5/5 throughout, except for right hand and wrist: **Right wrist flexion, extension, and hand grip 3/5. Right finger extension, abduction, adduction, and thumb opposition 0/5.**

REFLEXES:



COORDINATION AND GAIT: Not tested.

SENSORY: Intact light touch, pinprick, joint position, and vibration sense. No extinction on double simultaneous stimulation.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. On the basis of the symptoms and signs shown in **bold** above, where is the lesion?
2. Given the relatively acute onset of the deficits and the presence of atrial fibrillation, what is the most likely diagnosis? What are some other possibilities?

Discussion

1. The key symptom and sign in this case is:
   - **Isolated right-sided weakness of wrist flexion and extension, finger flexion, extension, abduction, and adduction, and thumb opposition**

   Isolated hand weakness can be caused by a lesion in the primary motor cortex or in peripheral nerves (see KCC 6.3; Figure 6.14E). There are no upper or lower motor neuron signs to help localization in this patient. However, weakness of all finger, hand, and wrist muscles with no sensory loss and no proximal weakness cannot be explained by a peripheral nerve lesion (see KCC 8.3, 9.1; Table 8.1).

   The most likely *clinical localization* is left precentral gyrus, primary motor cortex, hand area.

2. Given the presence of cardiac disease including atrial fibrillation and the relatively acute onset of deficits, the most likely diagnosis is an embolic infarct (see KCC 10.4). An infarct of the left precentral gyrus hand area would be caused by occlusion of a small cortical branch of the left middle cerebral artery, superior division (see Figures 10.5, 10.6). Some other, much less likely causes of a lesion in the cortex in this setting include a small cortical hemorrhage, brain abscess, or tumor.

Clinical Course and Neuroimaging

A **head CT** (Image 6.1A–C, pages 258–259) showed an area of hypodensity representing a cortical infarct in the left precentral gyrus in approximately the hand area (compare to Figure 6.2). Additional workup revealed that the patient had a dilated heart and continued to be at risk for atrial fibrillation and recurrent emboli. He was therefore treated with anticoagulation therapy and antiarrhythmic drugs. By 10 days after the initial consult, his right hand strength had improved substantially, with wrist flexors and extensors 5/5 strength, finger flexors $4^+/5$, and finger extensors $4^-/5$.

CASE 6.2 SUDDEN ONSET OF LEFT FOOT WEAKNESS

CHIEF COMPLAINT

An 81-year-old woman presented to the emergency room because of left foot weakness.

HISTORY

The patient was previously healthy except for a history of hypertension and diabetes. On the morning of admission, as she got out of bed, she noticed difficulty when she first put her left foot on the floor. As she tried to walk, she felt that she was **dragging her left foot**. Nevertheless, she continued her usual morning activities, using a chair for support. Later in the morning, when the gait difficulty persisted, she called her children, who brought her to the emergency room. She had no other complaints except for a mild **right frontal headache**.

PHYSICAL EXAMINATION

Vital signs: Not recorded on admission.

Neck: Supple with no bruits.

Lungs: Clear.

Heart: Regular rate, with soft systolic murmur.

Abdomen: Benign, with normal bowel sounds.

Extremities: Normal.

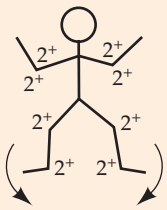
Neurologic exam:

MENTAL STATUS: Alert and oriented × 3. Speech fluent, with intact naming and comprehension.

CRANIAL NERVES: Normal, including no facial weakness.

MOTOR: No pronator drift. Normal tone. Power 5/5 throughout, except for left foot and leg***:*** **Left iliopsoas and hamstrings $4^+/5$, left ankle dorsiflexion and extensor hallucis longus 4/5.**

REFLEXES:



COORDINATION: Normal except for **slowing of heel-to-shin testing with left leg**.

GAIT: Not tested.

SENSORY: Intact light touch, temperature, joint position, and vibration sense.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. On the basis of the symptoms and signs shown in **bold** above, where is the lesion?
2. Given the sudden onset of symptoms in an elderly patient with diabetes and hypertension, what is the most likely diagnosis? What are some other possibilities?

Discussion

1. The key symptoms and signs in this case are***:***
   - **Isolated left-sided weakness and slowness of the iliopsoas, hamstrings, ankle dorsiflexors, and extensor hallucis longus**
   - **Right frontal headache**

   Isolated leg weakness can be caused by a lesion in the primary motor cortex, spinal cord, or peripheral nerves (see KCC 6.3; Figure 6.14F). There are no upper or lower motor neuron signs to help localization. However, weakness in both a femoral and sciatic nerve distribution with no sensory loss (see Table 8.1; KCC 8.3, 9.1) makes a peripheral nerve or spinal cord lesion less likely. In addition, the right frontal headache suggests a cranial localization (see KCC 5.1).

   The most likely clinical localization is***:*** right precentral gyrus, primary motor cortex, leg area.

2. Given the presence of diabetes and hypertension and the relatively acute onset of deficits, the most likely diagnosis is an embolic infarct (see KCC 10.4). An infarct of the right precentral gyrus leg area would be caused by occlusion of a cortical branch of the right anterior cerebral artery (see Figure 10.5). Some other, less likely causes of a cortical lesion in this setting include a small hemorrhage, brain abscess, or tumor. A spinal cord lesion or motor neuron disease is unlikely but possible.

Clinical Course and Neuroimaging

A **head MRI** (Image 6.2A–C, pages 260–261) showed increased T2 signal representing an infarct in the right primary motor cortex leg area. The strength in the patient's right foot gradually improved to the $4^+/5$ to 5/5 range by the time she was discharged home. A variety of tests (see KCC 10.4) showed no obvious cause for the stroke. She was therefore entered into an experimental trial for strokes of unknown cause comparing treatment with aspirin to warfarin (Coumadin). (The trial ultimately showed no difference in clinical effect between these treatments.)

CASE 6.3 SUDDEN ONSET OF RIGHT FACE WEAKNESS

CHIEF COMPLAINT

A 62-year-old man came to the emergency room with right facial weakness.

HISTORY

The patient awoke in the morning with a "funny feeling" in his right eye and thought he might have conjunctivitis. He looked in the mirror and noticed his right eyebrow drooping. He also thought his speech sounded slightly slurred, so he called his wife to confirm this. She told him to go to the emergency room, and he complied. Past medical history was notable for diabetes.

PHYSICAL EXAMINATION

Vital signs: T = 97°F, P = 80, BP = 160/80, R = 18.

Neck: Supple with no bruits.

Lungs: Clear.

Heart: Regular rate and rhythm, with no murmurs, gallops, or rubs.

Abdomen: Normal bowel sounds; soft, nontender.

Extremities: Normal.

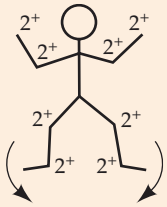
Neurologic exam:

MENTAL STATUS: Alert and oriented × 3. Speech fluent, with intact naming and repetition. Recalled 3/3 words after 5 minutes.

CRANIAL NERVES: Pupils 4 mm, constricting to 3 mm with light bilaterally. Visual fields full. Extraocular movements intact. Normal optokinetic nystagmus bilaterally. Intact pinprick sense, light touch sense, and graphesthesia in V_1, V_2, and V_3. Intact corneal reflex bilaterally. **Right eyebrow slightly depressed. Right lower face showed delay of movements with smile.** Taste on both sides of tongue intact in response to mustard or sweet preserves on a cotton swab. Hearing normal to finger rub. Normal gag and normal palate elevation. **Speech** sounded normal. (The patient felt it was still **mildly slurred**, but better than earlier in the day). Normal sternomastoid strength. Tongue midline.

MOTOR: No pronator drift. However, with pronation testing there was **trace curling of the right fingertips** (see KCC 6.4), with palms upward and eyes closed, that was not seen on the left side. Normal tone. Normal finger and toe taps. Power 5/5 throughout.

REFLEXES:



COORDINATION AND GAIT: Normal on finger-to-nose and heel-to-shin testing bilaterally. Normal reverse tandem gait. No Romberg sign.

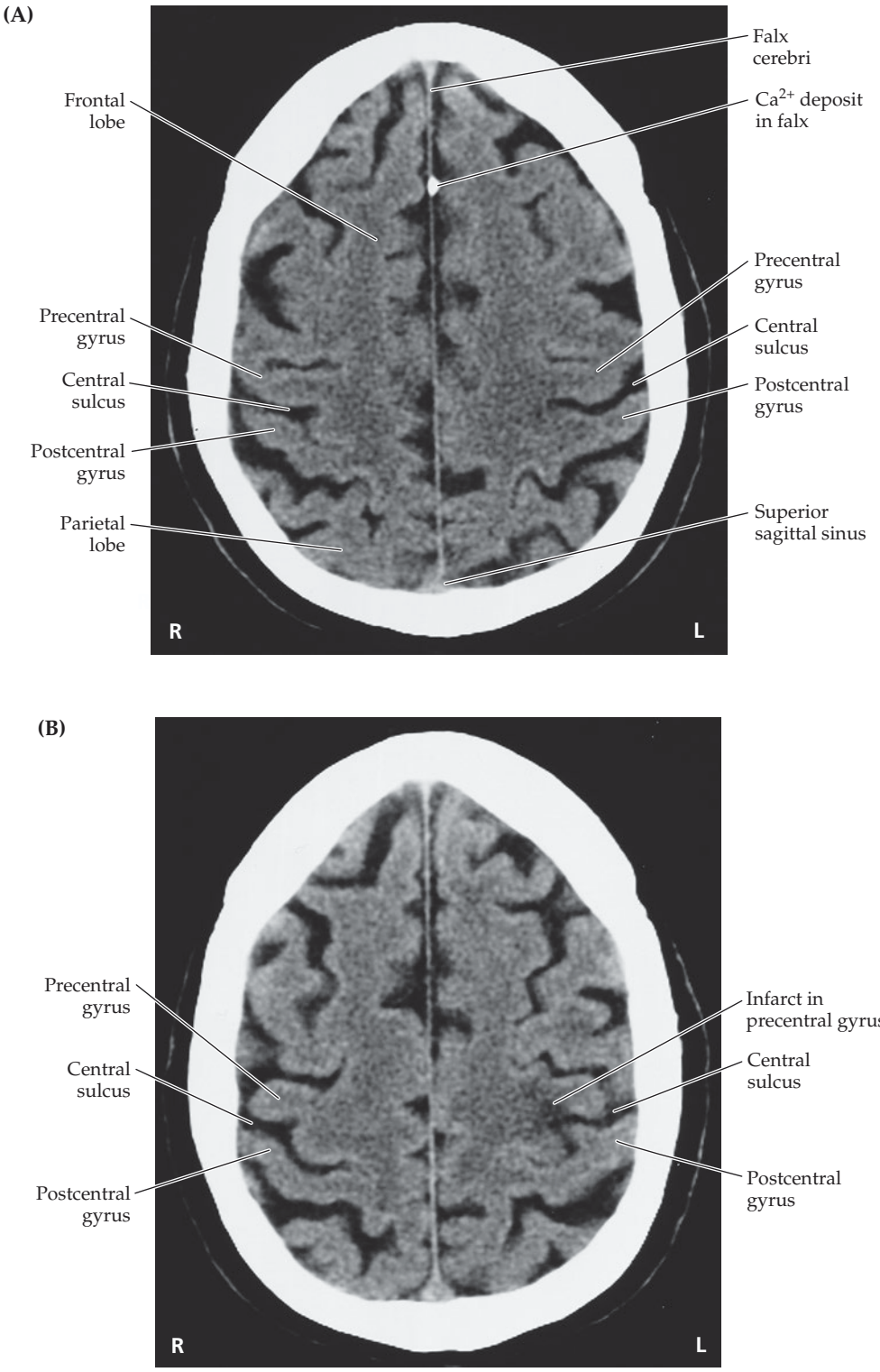
SENSORY: Intact light touch, pinprick, and vibration sense and graphesthesia.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. On the basis of the symptoms and signs shown in **bold** above, where is the lesion?
2. What is the most likely diagnosis? What are some other possibilities?

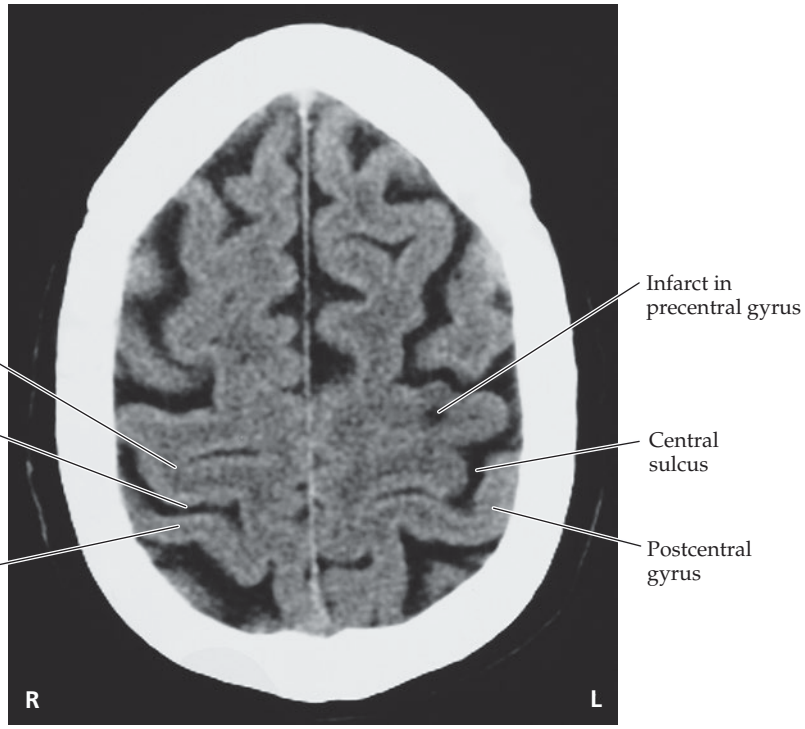
CASE 6.1 SUDDEN ONSET OF RIGHT HAND WEAKNESS

IMAGE 6.1A–C Infarct in Left Precentral Gyrus Hand Area (A–C) Head CT with sequentially higher horizontal slices. The infarct in the left precentral gyrus hand area is visible in (B) and (C). (Compare to the normal CT in the Neuroradiological Atlas, Figure 4.12.)



CASE 6.1 (*continued*)

(C)



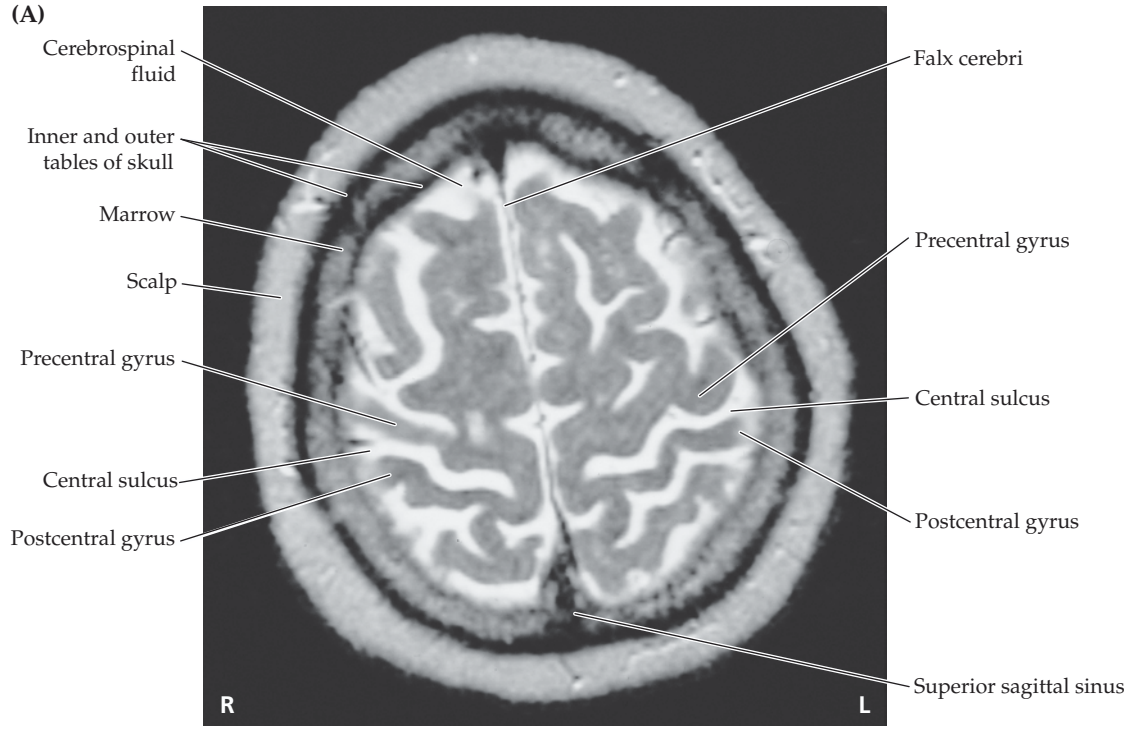
Discussion

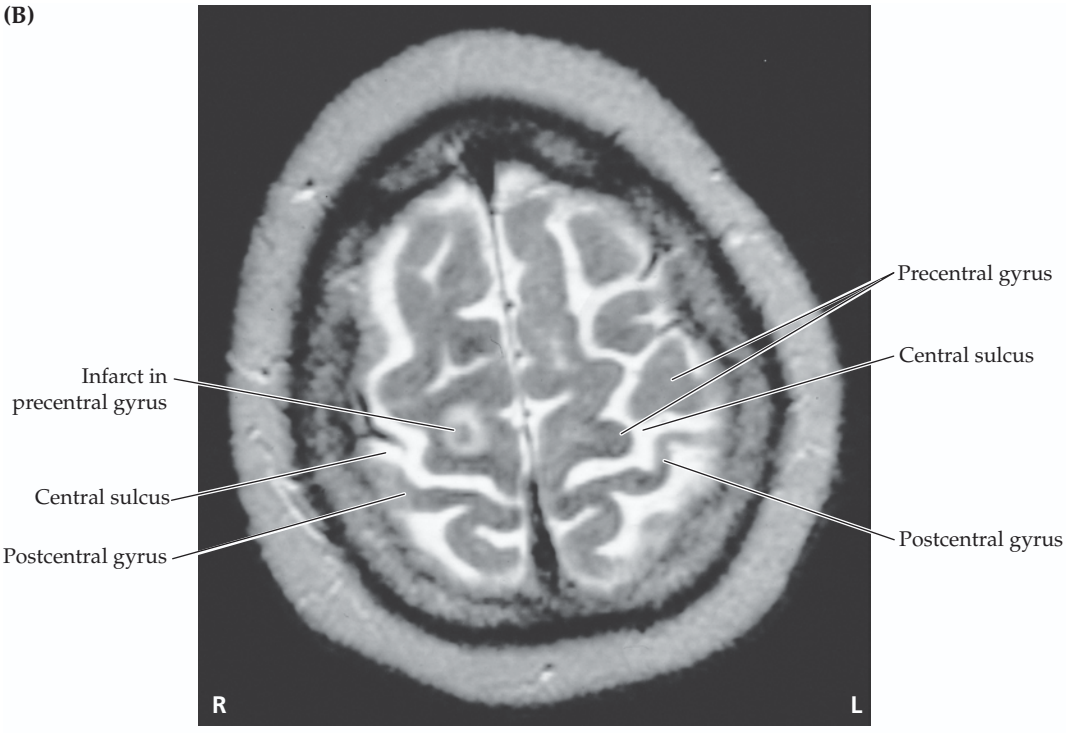
1. The key symptoms and signs in this case are:
   - **Right eyebrow slightly depressed; right lower face showed delay of movements with smile; speech mildly slurred**
   - **Trace curling of the right fingertips**

   Unilateral facial weakness without other significant deficits is most commonly caused by peripheral lesions of the facial nerve (see KCC 6.3; Figure 6.14G). However, it can occasionally be seen in cortical lesions or in lesions of the internal capsule genu (see Figures 6.10A, 6.14H). Our patient's main problem was right facial weakness, but he also had other subtle neurological findings. The presence of mild dysarthria and finger curling suggests minor involvement of the corticobulbar and corticospinal tracts, respectively. Thus, the lesion is most likely located in the left motor cortex face area (see Figure 6.14H), with slight impingement on adjacent structures or in the left capsular genu. One unusual feature of this case is the slight involvement of the eyebrow, which is normally spared in upper motor neuron–type facial weakness.
2. Given the presence of diabetes and the relatively acute onset of deficits, the most likely diagnosis is an embolic infarct (see KCC 10.4). An infarct of the left precentral gyrus face area would be caused by occlusion of a cortical branch of the left middle cerebral artery (see Figure 10.6). Some other, less likely causes of a cortical lesion in this setting include a small hemorrhage, brain abscess, or tumor.

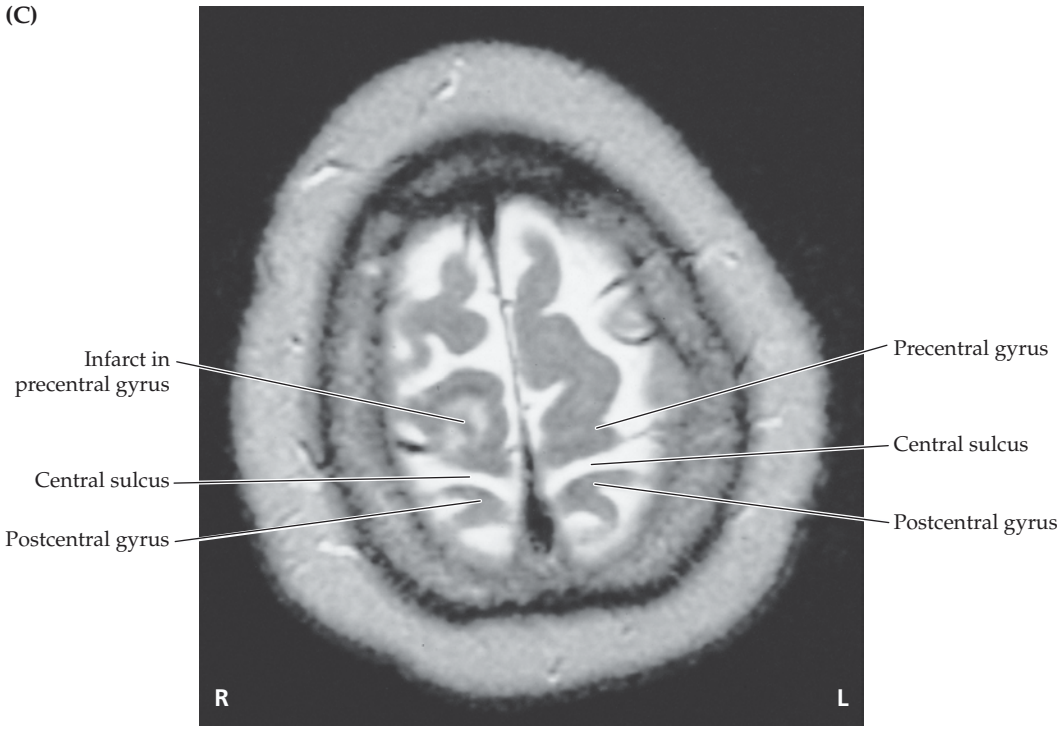
CASE 6.2 SUDDEN ONSET OF LEFT FOOT WEAKNESS

IMAGE 6.2A–C Infarct in Right Precentral Gyrus Leg Area (A–C) Sequentially higher axial (horizontal) T2-weighted MRI images. The infarct in the right precentral gyrus leg area is visible in (B) and (C). (Compare to the normal MRIs in the Neuroradiological Atlas, Figures 4.6B and 4.14.)





CASE 6.2 (*continued*)



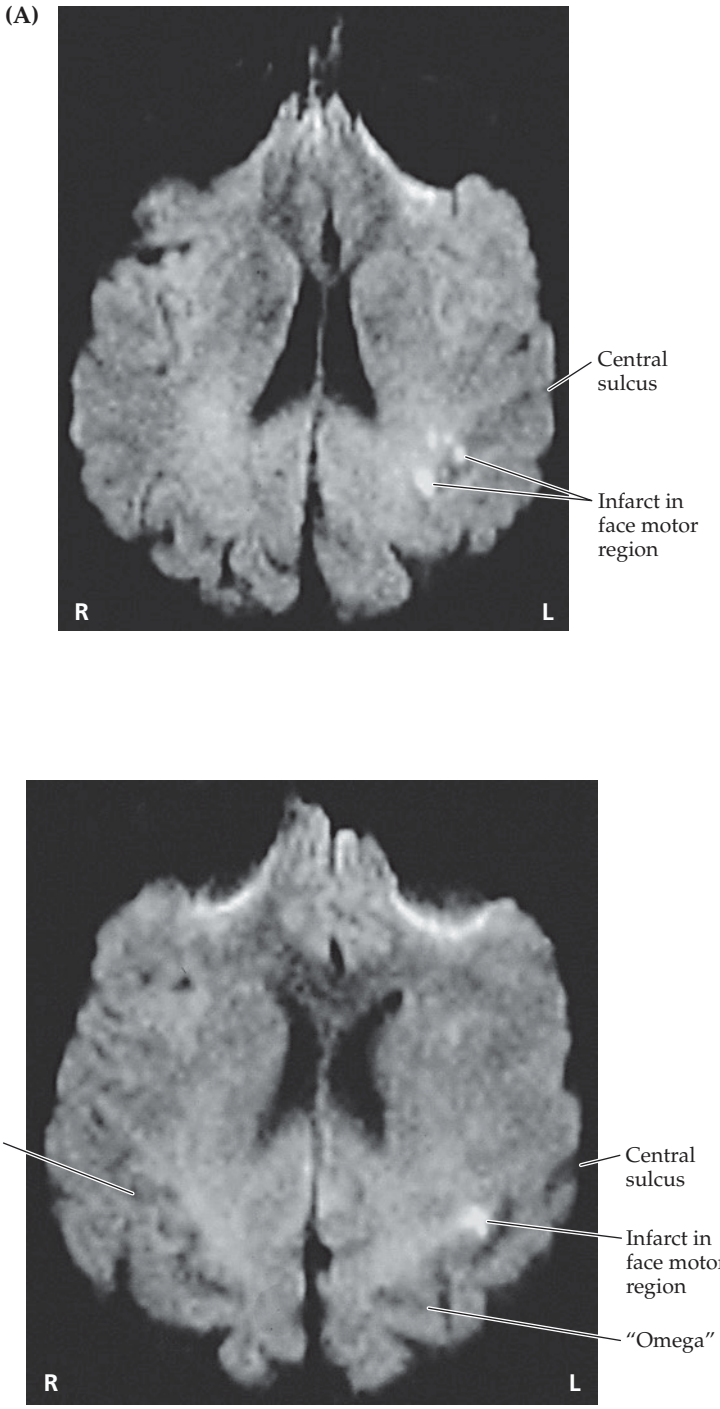
Clinical Course and Neuroimaging

T1- and T2-weighted MRI sequences done in the emergency room were normal. However, a **diffusion-weighted MRI** (see Chapter 4) done at the same time revealed several small areas of decreased diffusion (increased signal) in the left precentral gyrus (Image 6.3, page 262). The **"omega"** (or inverted omega) in the central sulcus, a landmark usually corresponding to the hand area on axial MRI sections (see Figures 4.11C, 4.13J), can be identified in Image 6.3B. Note that the diffusion changes are lateral to this, suggesting that they are in the face motor cortex.

Within a few hours of his arrival in the emergency room, the trace curling of this patient's right fingertips on pronation testing disappeared. He was admitted to the hospital, and by the next day the patient and his wife no longer thought that his speech was slurred. However, his right face remained mildly weak. Investigations for an embolic source (see KCC 10.4) were negative. He was discharged home on aspirin to reduce his risk of future strokes.

CASE 6.3 SUDDEN ONSET OF RIGHT FACE WEAKNESS

IMAGE 6.3A,B Infarct in Left Precentral Gyrus Face Area Diffusion-weighted MRI with (A) and (B) sequentially higher horizontal slices. The infarct is visible in the left precentral gyrus face area, just lateral to the omega-shaped bend in the central sulcus where the hand area is usually located.



CASE 6.4 PURE MOTOR HEMIPARESIS I

CHIEF COMPLAINT

A 31-year-old woman developed left face, arm, and leg weakness.

HISTORY

Three days prior to admission, while on a business trip, the patient noticed some difficulty walking, **veering slightly to the left and bumping into corners and walls on her left side**. The next day she had some **stuttering of her speech**, which subsequently resolved. She returned home, and on the morning of admission she noticed that her **left arm and hand were somewhat weak and clumsy**. She did not have any sensory symptoms, visual problems, headaches, or changes in bowel or bladder function. Her symptoms worsened in a warm meeting room and improved with a cold shower.

PHYSICAL EXAMINATION

Vital signs: T = 98.4°F, P = 85, BP = 132/81, R = 20.

Neck: Supple.

Lungs: Clear.

Heart: Regular rate with no murmurs.

Abdomen: Normal bowel sounds; soft, nontender.

Extremities: Normal.

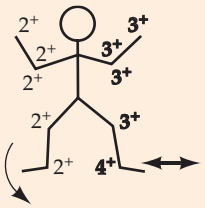
Neurologic exam:

MENTAL STATUS: Alert and oriented × 3. Recalled 2/3 words after 5 minutes. Speech fluent, with intact comprehension and repetition. No neglect on drawing a clock face or on line cancellation tasks. Normal abstraction and judgment.

CRANIAL NERVES: Normal except for a **decreased left nasolabial fold**. No dysarthria on exam. Fundi normal.

MOTOR: No pronator drift. **Tone slightly increased in left arm. Rapid finger tapping slower on the left. Power $4^+/5$ in left deltoid, triceps, iliopsoas, quadriceps, and hamstrings.** Power otherwise 5/5 throughout.

REFLEXES:



COORDINATION: Normal on finger-to-nose testing bilaterally.

GAIT: **Tends to veer to the left, especially with eyes closed. Decreased arm swing on the left. Unsteady tandem gait, falling to the left.**

SENSORY: Intact light touch, pinprick, temperature, vibration, and joint position sense.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. On the basis of the symptoms and signs shown in **bold** above, where is the lesion?
2. What is the most likely diagnosis? What are some other possibilities?

Discussion

1. The key symptoms and signs in this case are:
   - **Left face, arm, and leg weakness, clumsiness, slowness, increased tone, hyperreflexia, and equivocal Babinski's sign**
   - **Dysarthria**
   - **Unsteady gait, falling to the left, with decreased left arm swing**

   This patient has pure motor hemiparesis, with left face, arm, and leg upper motor neuron–type weakness and no sensory or cortical deficits such as neglect, aphasia, or other cognitive or visual disorders. Pure motor hemiparesis can be caused by lesions of the contralateral corticobulbar and corticospinal tracts, most commonly in the internal capsule or pons (see KCC 6.3; Figure 6.14A). Dysarthria (no longer present at time of exam but reported by history) can be caused by lesions in numerous locations (see KCC 12.8) but often accompanies pure motor hemiparesis, giving rise to the term "dysarthria-hemiparesis." Similarly, the unsteady gait could be caused by numerous lesions (see KCC 6.5) but is most easily explained by the patient's spastic left hemiparesis.

   The most likely *clinical localization* is right corticobulbar and corticospinal tracts in the posterior limb of the internal capsule or ventral pons.

2. Pure motor hemiparesis is usually caused by lacunar infarction (see Table 10.3) of the contralateral internal capsule or pons. However, given that the patient is a woman in her 30s with no vascular risk factors whose symptoms

worsen with warm temperature, the possibility that this is the first episode of multiple sclerosis should be seriously considered (see KCC 6.6). Other, less likely possibilities include a small tumor, abscess, or hemorrhage in the right internal capsule, cerebral peduncle, or ventral pons.

Clinical Course and Neuroimaging

A **head MRI** (Image 6.4A,B, page 266) showed increased T2 signal in the posterior limb of the right internal capsule. Note that there was enhancement with gadolinium, signifying breakdown of the blood–brain barrier. This is often seen with inflammatory lesions such as demyelinative plaques (see KCC 6.6), but it can also be seen a few days after infarcts. There were a few additional areas of increased T2 signal adjacent to the left frontal horn, suggesting possible prior episodes of demyelination.

An extensive workup for thromboembolic, demyelinative, inflammatory, infectious, and neoplastic disorders was done. All results were negative, except for two oligoclonal bands in the patient's cerebrospinal fluid (see KCC 6.6). Her left-sided weakness was improving by the time of discharge, 1 week after admission. Fortunately, she continued to improve and had no further problems over the following year. At a follow-up appointment 15 months after admission, her neurologic exam was entirely normal except for slight slowness of the left hand on testing of rapid alternating movements and 3^+ reflexes on the left side compared to 2^+ on the right. Her diagnosis remained uncertain, and she was subsequently followed periodically for the possible development of recurrent neurological signs.

CASE 6.5 PURE MOTOR HEMIPARESIS II

CHIEF COMPLAINT

A 74-year-old woman developed right face, arm, and leg weakness.

HISTORY

The patient was residing in a rehabilitation facility while recovering from an infection. She was doing well until one morning, when she suddenly developed **slurred speech and right-sided weakness**. An emergency neurology consultation was called. Medical history was notable for hypertension, coronary artery disease, and recent onset of atrial fibrillation.

PHYSICAL EXAMINATION

Vitals: T = 99.3°F, P = 84, BP = 110/70, R = 18.

Neck: No bruits.

Lungs: Clear.

Heart: Regular rate with no murmurs.

Abdomen: Normal bowel sounds; soft.

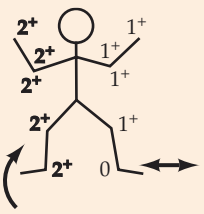
Neurologic exam:

MENTAL STATUS Alert and oriented × 3. Intact comprehension, repetition, and reading. Intact calculations.

CRANIAL NERVES: Pupils equal round and reactive to light. Visual fields full. Extraocular movements intact. Corneal reflex present bilaterally. **Decreased right nasolabial fold. Weak movements of the right face, but with only mild forehead involvement.** Gag reflex present, but with **decreased palate movement on the right**. **Speech slurred and dysarthric.** Normal sternomastoid strength. **Rightward tongue deviation.**

MOTOR: **Tone flaccid on right side,** normal on left. **Marked right hemiparesis, with power 2/5 in right deltoid, 0/5 in right triceps, biceps, and hand muscles. Power 2/5 in right iliopsoas and quadriceps and 0/5 in right foot.**

REFLEXES:



COORDINATION: Normal on the left; too weak to test on the right.

GAIT: Unable to stand.

SENSORY: Intact light touch, pinprick, and joint position sense. No extinction.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. On the basis of the symptoms and signs shown in **bold** above, where is the lesion?
2. What is the most likely diagnosis? What are some other possibilities?

Discussion

1. The key symptoms and signs in this case are:
   - **Right face, arm, and leg weakness, hyperreflexia, and Babinski's sign**
   - **Dysarthria, decreased right palate movement, rightward tongue deviation**

   Like the patient in the previous case, this patient has pure motor hemiparesis with dysarthria (dysarthria-hemiparesis). The reflexes are decreased on the left side, probably from a chronic neuropathy (see KCC 8.1), and the reflexes on the right are relatively increased, confirming that this is an upper motor neuron lesion. Again, there are no sensory or cortical deficits such as neglect, aphasia, or other cognitive or visual disorders. Pure motor hemiparesis can be caused by lesions of the contralateral corticobulbar and corticospinal tracts, most commonly in the internal capsule or pons (see KCC 6.3; Figure 6.14A). Control of right CN IX and X (right palate movement) and right CN XII (rightward tongue deviation) have been affected as well, also probably because of a contralateral corticobulbar tract lesion.

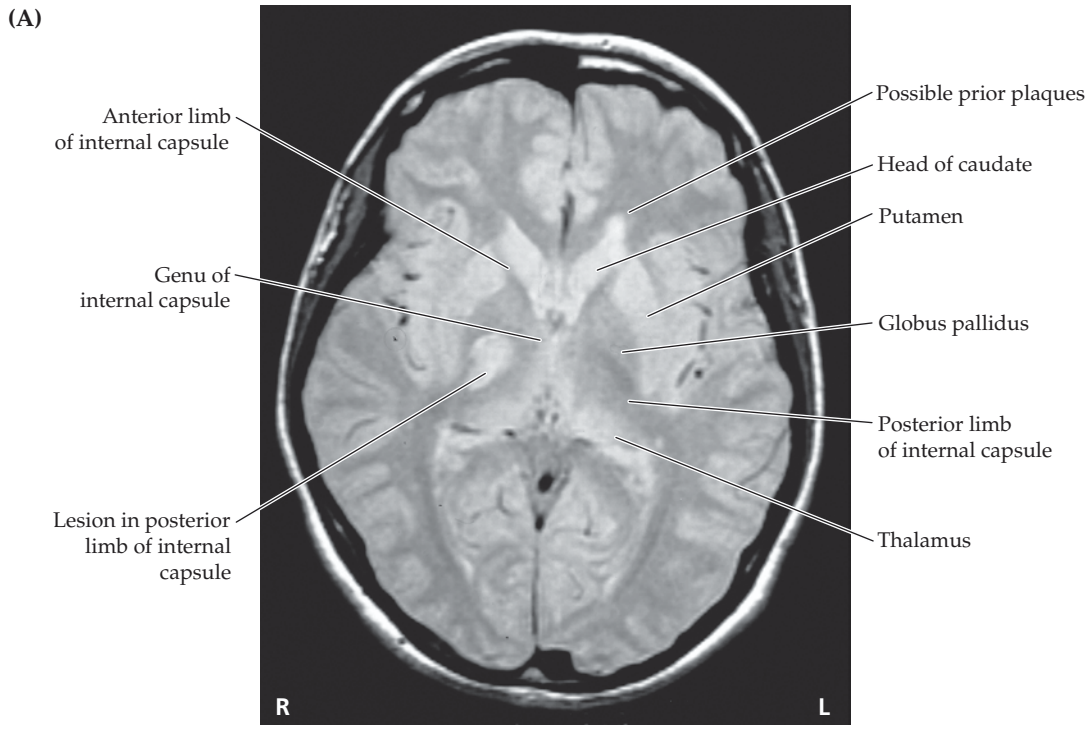
   The most likely *clinical localization* is left corticobulbar and corticospinal tracts in the posterior limb of the internal capsule or ventral pons.
2. Pure motor hemiparesis is usually caused by lacunar infarction (see Table 10.3) of the contralateral internal capsule or pons. This patient has multiple vascular risk factors, and lacunar infarction from small-vessel disease (see KCC 10.4) is the most likely diagnosis. Given the history of atrial fibrillation, an embolus to a small perforating vessel of the left internal capsule or pons should be considered as well.

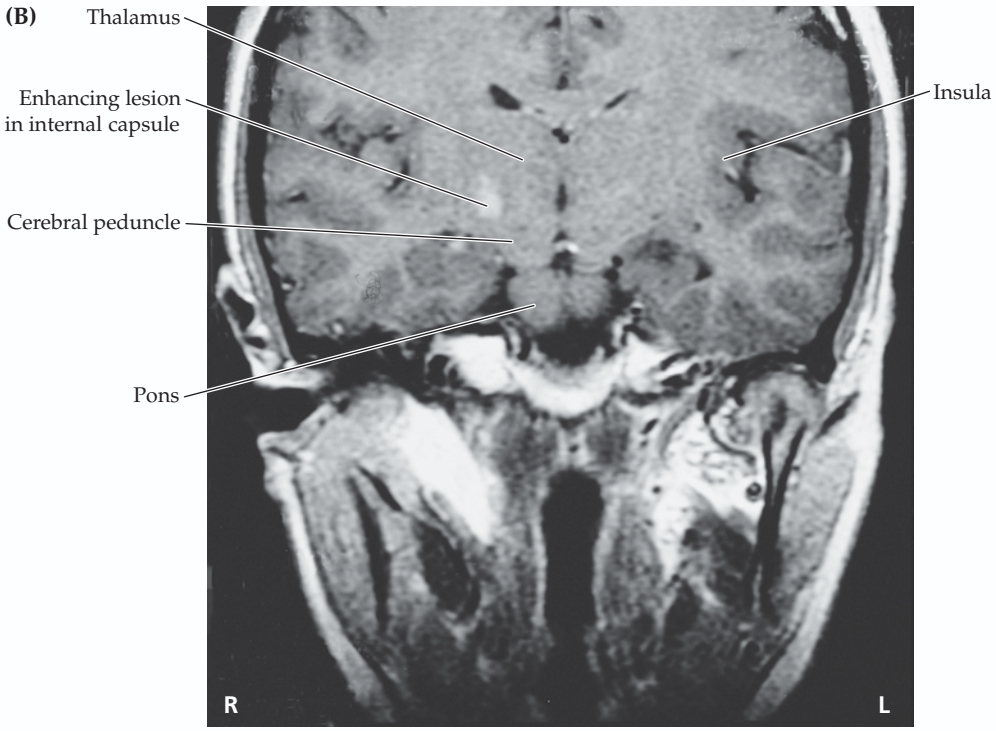
Clinical Course and Neuroimaging

The patient was transferred to a nearby hospital and started on anticoagulation therapy because of her history of atrial fibrillation. An **MRI scan** (Image 6.5, page 269) showed a T2 bright area in the left ventral pons consistent with lacunar infarction (see Figure 14.21B). A magnetic resonance angiogram (see Chapter 4) showed no significant narrowing of the circle of Willis vessels. The patient's hemiparesis had improved only slightly by the time of discharge, with power in the right arm and leg 3/5 proximally and 0/5 distally. Over the next year she had continued problems with dysarthria and swallowing difficulties, ultimately requiring a feeding tube for nutrition.

CASE 6.4 PURE MOTOR HEMIPARESIS I

IMAGE 6.4A,B Lesion in Posterior Limb of Right Internal Capsule MRI of the brain. (A) Axial (horizontal) proton density–weighted section. (B) Coronal T1-weighted section after intravenous administration of gadolinium contrast.





CASE 6.6 PROGRESSIVE WEAKNESS, MUSCLE TWITCHING, AND CRAMPS

CHIEF COMPLAINT

A 52-year-old right-handed man was referred to a neurologist for evaluation of weakness and difficulty walking.

HISTORY

The patient first noticed gait difficulty 6 months prior to the appointment. He felt "off balance" and over the next 2 months developed difficulty raising his feet off the floor while seated in a chair. A few months later his **leg weakness** had become worse, making it difficult to walk downstairs. In addition, his **arms and hands had become weak**, making it difficult for him to carry out his work as a carpenter. He also noticed constant **twitching of his arm and leg muscles** and painful **cramps in his legs**. He did not complain of diplopia, dysarthria, or dysphagia. There was no history of trauma or neck pain, and no history of toxin exposure. Family history was negative. Initial evaluation by his primary care physician included an MRI of the cervical spine, which was normal.

PHYSICAL EXAMINATION

Vitals: T = 98°F, P = 96, BP = 120/70, R = 18.

Neck: No bruits.

Lungs: Clear.

Heart: Regular rate with no murmurs.

Abdomen: Normal.

Extremities: Normal.

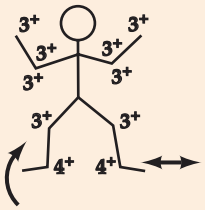
Neurologic exam:

MENTAL STATUS: Alert and oriented × 3. Intact naming, comprehension, and repetition.

CRANIAL NERVES: Pupils equal, round, and reactive to light. Extraocular movements intact. No nystagmus. No ptosis. Facial sensation intact. No facial weakness or asymmetry. Hearing good bilaterally. Tongue and palate midline, with no tongue fasciculations.

MOTOR: **Increased tone in bilateral lower extremities. Nearly continuous fasciculations in all four extremities. Atrophy present in the left hand interosseous muscles and bilateral foot intrinsic muscles. Weakness present bilaterally (see the table below), affecting the legs more than the arms and the right side slightly more than the left.**

REFLEXES: **Hoffmann's sign present bilaterally. Jaw jerk reflex present.**



COORDINATION: Finger-to-nose, heel-to-shin, and rapid alternating movements normal.

GAIT: **Required assistance to walk. Paraparetic and spastic gait.**

SENSORY: Intact light touch, pinprick, vibration, and joint position sense. No extinction.

LOCALIZATION AND DIFFERENTIAL DIAGNOSIS

1. Which of the symptoms and signs shown in **bold** above and in table below, are upper motor neuron signs? Which are lower motor neuron signs (see Table 6.4)? Could these findings be caused by cervical cord compression?
2. What is the most likely diagnosis? What are some other possibilities?

Results of Strength Testing

	ARM			WRIST		FINGER	
	DELTOID	BICEPS	TRICEPS	EXTENSORS	FLEXORS	EXTENSORS	GRIP
R	**4/5**	5/5	5/5	**4^+/5**	5/5	**4^+/5**	**4^+/5**
L	**4/5**	5/5	5/5	**5^-/5**	5/5	**4^+/5**	**5^-/5**

	NECK		LEG				
	FLEXORS	EXTENSORS	ILIOPSOAS	HAMSTRINGS	DORSIFLEXION	PLANTARFLEXION	QUADRICEPS
R	5/5	5/5	**4/5**	**4^+/5**	**3^-/5**	**5^-/5**	5/5
L	5/5	5/5	**4^+/5**	**4^+/5**	**3^-/5**	**5^-/5**	5/5

Discussion

1. As Table 6.4 indicates, weakness is both an upper motor neuron and a lower motor neuron sign. Fasciculations and atrophy are lower motor neuron signs. Increased tone, spastic gait, and hyperreflexia including Babinski's sign, Hoffmann's sign, and jaw jerk reflex are upper motor neuron signs.

   Cervical cord compression can cause upper motor neuron findings in the arms and legs, as well as lower motor neurons findings in the arms due to local nerve root compression. In this patient, however, lower motor neuron findings of fasciculations and atrophy were present in the lower extremities as well. In addition, a jaw jerk reflex was present, which is a sign of hyperreflexia produced by upper motor neuron dysfunction in the corticobulbar pathways well above the level of the cervical cord. Thus, this patient's findings result from diffuse upper and lower motor neuron dysfunction extending from the brain to the lumbosacral spinal cord.
2. Focal weakness progressing to become more diffuse with upper and lower motor neuron signs, muscle cramping, and fasciculations with no sensory deficits form the classic presentation of amyotrophic lateral sclerosis (see KCC 6.7). Also possible, but far less likely, are paraneoplastic motor neuron disease, hexosaminidase deficiency, lead toxicity, or a variety of other disorders listed in KCC 6.7.

Clinical Course

The diagnosis of probable ALS and its implications were discussed at length with the patient and his family. He decided to try treatment with riluzole and was enrolled in a comprehensive rehabilitation program. Additional testing included an EMG (see KCC 9.2), which showed evidence of denervation and reinnervation in all four extremities, compatible with the diagnosis of ALS. Other tests included serum protein electrophoresis, serum B_{12}, folate, and complete blood count, all of which were normal.

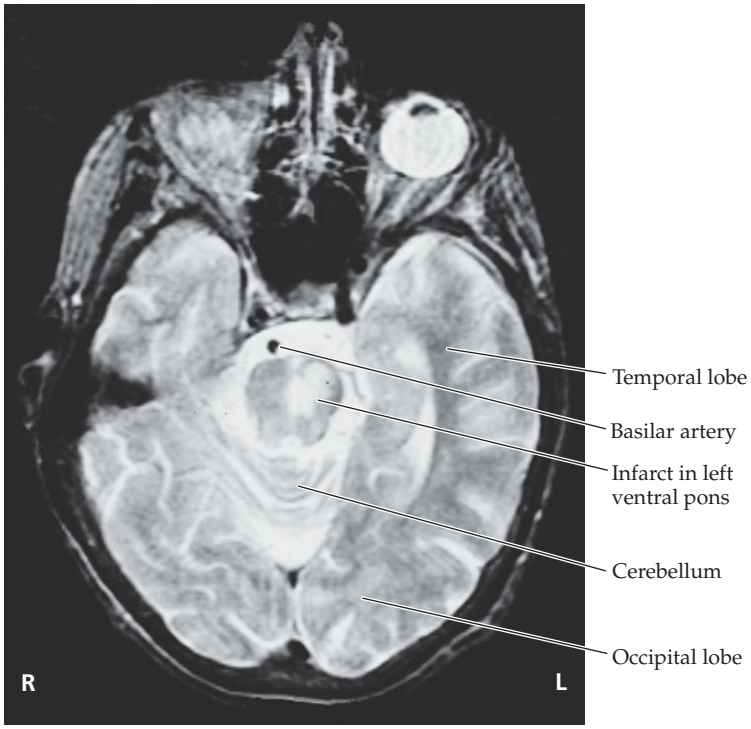
The patient was followed over the following months as his symptoms worsened. Within 1 year after initial symptoms he was wheelchair bound because of increasing weakness. By approximately 2 years into the illness, at his last follow-up appointment, he had developed profound dysarthria, dysphagia, and tongue atrophy with fasciculations, and 0/5 to 4^{-}/5 strength in his extremities. He continued to live at home with family supports and hospice care, and he died a few weeks later of respiratory failure.

Additional Cases

In other chapters, related cases can be found for the following topics: **weakness caused by corticospinal** and **corticobulbar dysfunction** (see Cases 5.1–5.4, 7.3, 7.4, 10.2, 10.4, 10.5, 10.7–10.9, 10.11, 10.12, 12.8, 13.7, 14.1–14.3, 14.5, 14.6, 18.3). Other relevant cases can be found using the **Case Index** located at the end of the book, and new cases are also available through the **Online Review and Study Guide**.

CASE 6.5 PURE MOTOR HEMIPARESIS II

IMAGE 6.5 Left Pontine Basis Infarct T-2 weighted axial (horizontal) head MRI showing infarct in the left ventral pons.



Brief Anatomical Study Guide

1. Motor and sensory pathways are **somatotopically organized**, with the cortical representations for the face located lateral to the hand and with the leg represented most medially (see Figure 6.2).
2. The **spinal cord** has **dorsal sensory roots**, **ventral motor roots**, **central gray matter**, and surrounding **white matter columns** (see Figure 6.3). The appearance of the spinal cord varies at different levels and is thickest at the **cervical enlargement** and **lumbosacral enlargement**, where nerves for the arms and legs, respectively, arise (see Figure 6.4). **Blood supply** for the spinal cord derives from the **anterior** and **posterior spinal arteries** (see Figure 6.5).
3. The **lateral corticospinal tract** is the most clinically important pathway in the nervous system, and knowledge of its anatomy is sufficient to localize many neurologic disorders (see Figures 6.8 and 6.11A). The lateral corticospinal tract originates mainly in the primary motor cortex of the **precentral gyrus**, descends through the **posterior limb of the internal capsule** (see Figure 6.10), down through the **cerebral peduncle** in the midbrain, and passes through the ventral pons to form fiber bundles along the

Brief Anatomical Study Guide (continued)

ventral medulla called the **pyramids** (see Figures 6.11A and 2.22A). The lateral corticospinal tract crosses to the opposite side at the **pyramidal decussation** located at the junction between the medulla and spinal cord—an essential piece of information for localizing lesions (see Figures 6.8, 6.11A, and 6.14). It then continues in the lateral spinal cord white matter to synapse onto motor neurons in the spinal cord **anterior** (**ventral**) **horn**.

4. Motor neurons projecting from the motor cortex to the spinal cord are called **upper motor neurons**; those projecting from the spinal cord to the muscles are called **lower motor neurons** (see Figure 6.8). **Upper motor neuron versus lower motor neuron signs** (see Table 6.4) often have important implications for determining whether patients are suffering from lesions of the central nervous system versus peripheral nerves.
5. **Patterns of weakness** can also be very useful for localizing lesions (see Figure 6.14).
6. Although the lateral corticospinal tract is clinically the most important, there are several additional descending motor pathways. Descending motor pathways are organized into **lateral motor systems**, such as the lateral corticospinal tract involved in **limb control**, and **medial motor systems**, which are involved in controlling **proximal trunk muscles** (see Table 6.3; see also Figures 6.6 and 6.11).
7. The **autonomic nervous system** generally controls homeostatic body functions that are not under voluntary control and has two main divisions (see Figures 6.12 and 6.13). The **sympathetic division** is involved in "fight-or-flight" functions such as increased heart rate and blood pressure and uses **norepinephrine** as its neurotransmitter on end organs. The **parasympathetic division** subserves "rest and digest" functions such as increased salivation and peristalsis, using **acetylcholine** as its peripheral neurotransmitter. Sympathetic (**thoracolumbar**) efferents arise from the **intermediolateral cell column** of the thoracic and upper lumbar spinal cord and synapse in paravertebral and prevertebral ganglia en route to their targets. Parasympathetic (**craniosacral**) efferents arise from brainstem and sacral spinal nuclei, synapsing in ganglia located in or near their end organs.

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