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CHAPTER

12 Vestibular System: Special Proprioception

The vestibular system is the primary sensory system that maintains the animal's balance, its normal orientation relative to the gravitational field of the earth. This orientation is maintained in the setting of linear or rotatory acceleration or deceleration or tilting of the animal. The vestibular system is responsible for maintaining the position of the eyes, neck, trunk, and limbs relative to the position or movement of the head at any time.

ANATOMY AND PHYSIOLOGY

Receptor

The receptor for special proprioception (SP)—the vestibular system—develops in conjunction with the receptor for the auditory system (special somatic afferent system). They are derived from ectoderm but are contained in a mesodermally derived structure. Together these receptors are the components of the inner ear. The ectodermal component arises as a proliferation of ectodermal epithelial cells on the surface of the embryo adjacent to the developing rhombencephalon. This structure is the otic placode, which subsequently invaginates to form an otic pit and otic vesicle (otocyst) that breaks away from its attachment to the surface ectoderm. This saccular structure undergoes extensive modification of its shape but always retains its fluid-filled lumen and surrounding thin epithelial wall as it becomes the membranous labyrinth of the inner ear. Special modifications of its epithelial surface at predetermined sites form the receptor organs for the vestibular and auditory systems.

Corresponding developmental modifications occur in the surrounding paraxial mesoderm to provide a supporting capsule for the membranous labyrinth. This fluid-filled ossified structure is the bony labyrinth contained within the developing petrous portion of the temporal bone.

These membranous and bony labyrinths are formed adjacent to the first and second branchial arches and their corresponding first pharyngeal pouch and first branchial groove. The first branchial groove gives rise to the external ear canal. The first pharyngeal pouch forms the auditory tube and the mucosa of the middle-ear cavity. The intervening

tissue forms the tympanum. The ear ossicles are derived from the neural crest of branchial arches 1 (malleus and incus) and 2 (stapes). These ossicles become components of the middle ear associated laterally with the tympanum (malleus) and medially with the vestibular window of the bony labyrinth of the inner ear (stapes).

Anatomically, the bony labyrinth in the petrous part of the temporal bone consists of three continuous fluid-filled portions (Figs. 12-1 and 12-2). These areas are the large vestibule and the three semicircular canals and the cochlea, which arise from the vestibule. Dilation in one end of each of the bony semicircular canals is the ampulla. All three continuous bony components contain perilymph, a fluid similar to cerebrospinal fluid (CSF), from which it may be derived. In the bony labyrinth are two openings: the vestibular and cochlear windows, which are named according to the components of the bony labyrinth in which they are located. Each opening is covered by a membrane, and the stapes is inserted in the membrane that covers the vestibular window.

The ectodermally derived membranous labyrinth consists of four fluid-filled compartments, all of which communicate (Fig. 12-3; see also Figs. 12-1 and 12-2). These compartments are contained within the components of the bony labyrinth and include the saccule and utriculus within the bony vestibule, the three semicircular ducts within the bony semicircular canals, and a cochlear duct within the bony cochlea. The endolymph contained within the membranous labyrinth is thought to be derived from the blood vessels along one wall of the cochlear duct and is absorbed back into the blood through the blood vessels surrounding the endolymphatic sac. The three semicircular ducts are the anterior (vertical), posterior (vertical), and lateral (horizontal). Each semicircular duct is oriented at right angles to the others. Thus rotation of the head around any plane causes endolymph to flow within one or more of the ducts. Each semicircular duct connects at both ends with the utriculus, which, in turn, connects with the saccule by way of the intervening endolymphatic duct and sac. The saccule connects with the cochlea duct by the small ductus reuniens.

Crista Ampullaris

At one end of each membranous semicircular duct is a dilation called the *ampulla*. On one side of the membranous ampulla, a proliferation of connective tissue forms a transverse ridge called the *crista* (see Figs. 12-1 through 12-3). It is lined on its internal surface by columnar neuroepithelial cells. On the surface of the crista is a gelatinous structure that is composed of a protein-polysaccharide material called the *cupula,* which extends across the lumen of the ampulla. This neuroepithelium is composed of two basic cell types: hair cells and supporting cells. The neurons of the vestibulocochlear nerve are derived from otic placode ectoderm. The dendritic zones of the neurons of the vestibular portion of the vestibulocochlear nerve are in synaptic contact with the base of the hair cells. These hair cells have on their luminal surface 40 to 80 hairs, or modified microvilli (stereocilia), and a single modified cilium (kinocilium). These structures project into the overlying cupula. Movement of fluid in the semicircular ducts causes deflection of the cupula, which is oriented transversely to the direction of flow of the endolymph. This deflection bends the stereocilia, which is the source of the stimulus by way of the hair cells to the dendritic zone of the vestibular neuron that is in synaptic relationship with the plasmalemma of the hair cell.

In one end of each semicircular duct is one membranous ampulla with its crista ampullaris. Because the three semicircular ducts are all at right angles to each other, movement of the head in any plane or angular rotation affects a crista ampullaris and stimulates vestibular neurons. These cristae function in dynamic equilibrium.

The vestibular neurons are tonically active, and their activity is excited or inhibited by deflection of the cupula in different directions. Each semicircular duct on one side is paired with a semicircular duct on the opposite side by their common position in a parallel plane. These synergistic pairs are the left and right lateral ducts, the left anterior and right posterior ducts, and the left posterior and right anterior ducts. When movement in the direction of one of these three planes stimulates the vestibular neurons of the crista of one duct, they are inhibited in the opposite duct of the synergistic pair. For example, rotation of the head to the right causes the endolymph to flow in the right lateral duct such that the cupula is deflected toward the utriculus and the cupula of the left lateral duct is deflected away from the utriculus. This action causes increased activity of vestibular neurons on the right side and decreased activity on the left side, resulting in a jerk nystagmus to the right side, which

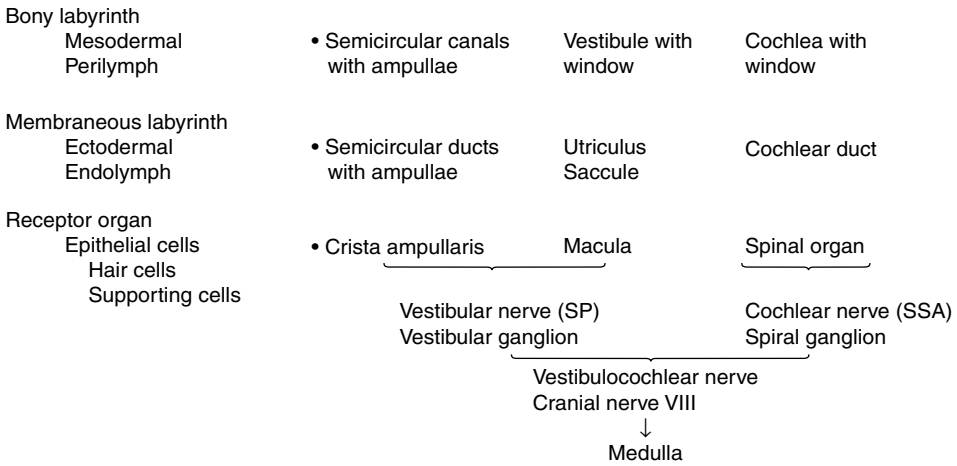

FIGURE 12-1 Components of the inner ear. *SP*, Special proprioception; *SSA,* special somatic afferent.

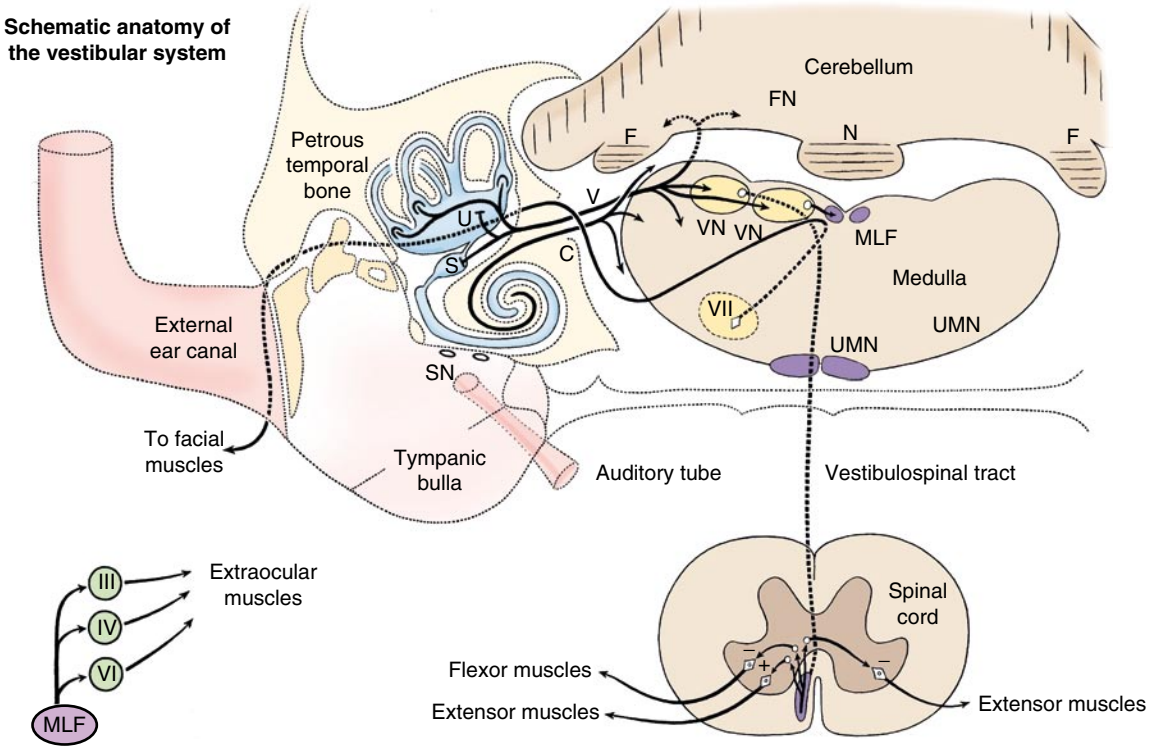

FIGURE 12-2 Schematic anatomy of the vestibular system. *III,* Oculomotor nucleus; *IV,* trochlear nucleus; *VI,* abducent nucleus; *VII,* facial nucleus; *C,* cranial nerve VIII–cochlear portion; *V,* cranial nerve VIII–vestibular portion; *F,* flocculus; *FN,* fastigial nucleus; *MLF,* medial longitudinal fasciculus; *N,* nodulus; *S,* saccule; *SN,* sympathetic neurons; *U,* utricle; *UMN,* upper motor neuron; *VN,* vestibular nucleus.

is an involuntary rhythmic oscillation of the eyes. The anatomic orientation of the stereocilia relative to the kinocilium on the surface of the crista is responsible for the difference in activity relative to the direction of the cupula deflection. Deviation of the stereocilia toward the kinocilium increases vestibular neuron activity. These receptors are not affected by a constant velocity of movement but respond to acceleration or deceleration, especially when the head is rotated.

Macula

The macula is the receptor found in the utriculus and saccule, which are located in the bony vestibule. These maculae are on one surface of each of these saclike structures (see Figs. 12-1 through 12-3). Each macula is an oval-shaped plaque in which the membranous labyrinth has proliferated. The surface of the macula consists of columnar epithelial cells. This neuroepithelium is composed of hair cells and supporting cells. Covering the neuroepithelium is a gelatinous material, the statoconiorum (otolithic) membrane. On the surface of this membrane are calcareous crystalline bodies known as *statoconia (otoliths)*. Similar to the hair cells of the cristae, the macular hair cells have projections of their luminal cell membranes—stereocilia and kinocilia—into the overlying statoconiorum membrane. Movement of the statoconia away from these cells is the initiating factor in bending the stereocilia to stimulate an impulse in the dendritic zones of the vestibular neurons that are in synaptic relationship with the base of the hair cells. The macula in the saccule is oriented in a vertical direction (sagittal plane), whereas the macula of the utriculus is in a horizontal direction (dorsal plane). Thus gravitational forces continually affect the position of the statoconia relative to the hair cells. These structures are responsible for the sensation of the static position of the head and linear acceleration or deceleration. They function in static equilibrium. The macula of the utriculus may be more important as a receptor for sensing changes in head posture, whereas the macula of the saccule may be more sensitive to vibrational stimuli and loud sounds.

Vestibulocochlear Nerve: Cranial Nerve VIII—Vestibular Division

The dendritic zone of the vestibular portion of cranial nerve VIII is in a synaptic relationship with the hair cells of each crista ampullaris and the macula utriculi and macula sacculi. The axons course through the internal acoustic meatus with those of the cochlear division of this nerve. The cell bodies of these bipolar-type sensory neurons are inserted along the course of the axons within the petrous portion of the temporal bone, where they form the vestibular ganglion (see Fig. 12-3). After leaving the internal acoustic meatus with the cochlear division of the vestibulocochlear nerve, the vestibular nerve axons pass to the lateral surface of the rostral medulla at the cerebellomedullary angle, which occurs at the level of the trapezoid body and the attachment of the caudal cerebellar peduncle to the cerebellum. The vestibular nerve axons enter the medulla between the caudal cerebellar peduncle and the spinal tract of the trigeminal nerve and terminate in telodendria at one of two sites. The majority of them terminate in the vestibular nuclei in the medulla and pons. A few course directly into the cerebellum by way of the

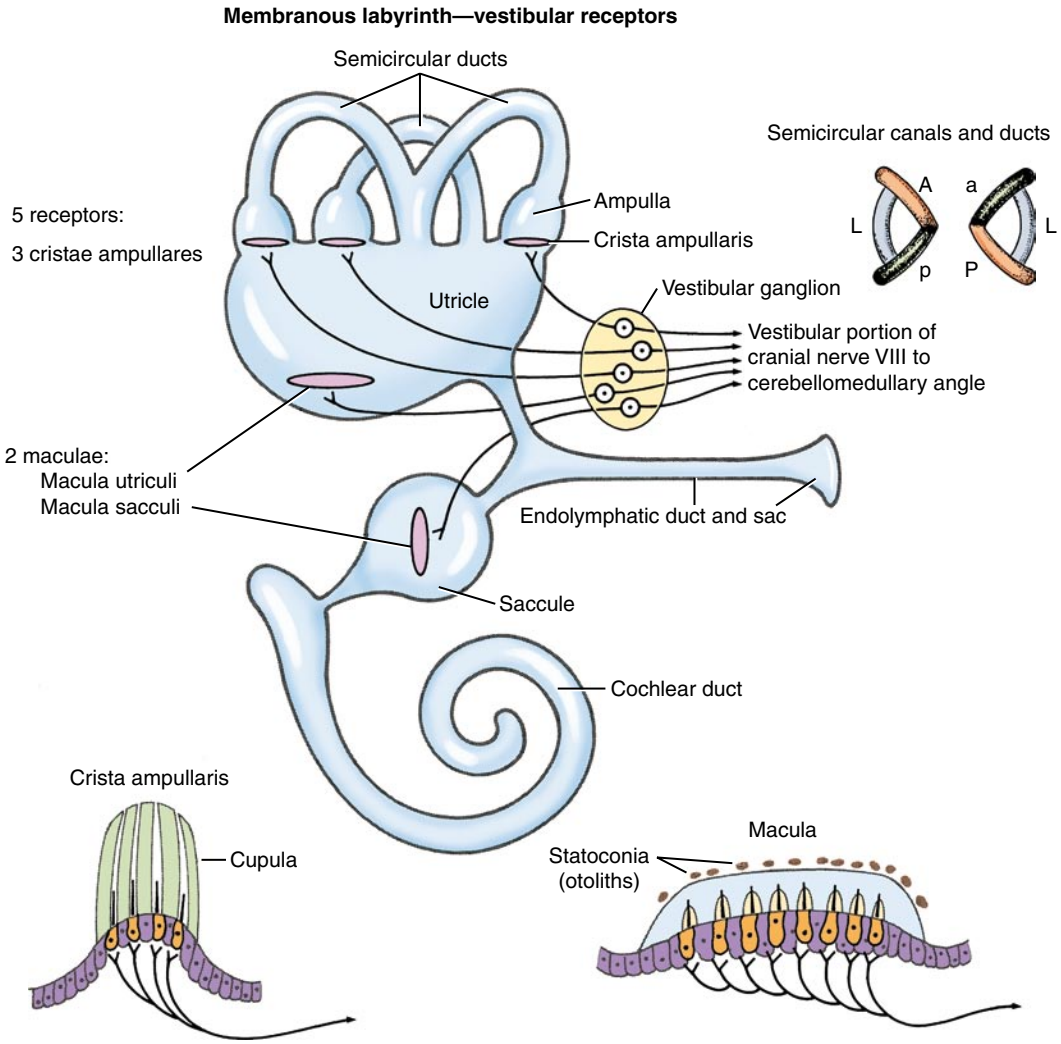

FIGURE 12-3 Special proprioception–vestibular system. Membranous labyrinth–vestibular receptors. *A,* Anterior–vertical plane; *L,* lateral–horizontal plane; *P,* posterior–vertical plane.

caudal peduncle and terminate in the fastigial nucleus in the cerebellar medulla and the cortex of the flocculonodular lobe. These latter axons form the direct vestibulocerebellar tract.

Vestibular Nuclei

On either side of the dorsal part of the pons and medulla adjacent to the lateral wall of the fourth ventricle are four vestibular nuclei (Fig. 12-4; see also Fig. 12-2). From the level of the rostral and middle cerebellar peduncles, they extend caudally to the level of the lateral cuneate nucleus in the lateral wall of the caudal portion of the fourth ventricle. The four nuclei are the rostral, medial, lateral, and caudal vestibular nuclei. They form a continuous column on each side of the pons and medulla. The rostral vestibular nucleus is located medial to the rostral and middle cerebellar peduncles, dorsal to the motor nucleus of the trigeminal nerve in the pons (see Fig. 2-11). The medial and lateral vestibular nuclei are located ventromedial to the confluence of the three cerebellar peduncles with the cerebellum (see Fig. 2-12). They are dorsal to the ventrolateral projection of the facial neurons. The medial nucleus continues caudally adjacent to the caudal vestibular nucleus in the dorsal medulla to the level of the lateral cuneate nucleus (see Fig. 2-13). The lateral vestibular nucleus is only located at the level of the confluent cerebellar peduncles (see Fig. 2-12). The caudal vestibular nucleus is caudal to the lateral vestibular nucleus and continues caudally to the level of the lateral cuneate nucleus. The caudal cerebellar peduncle is dorsolateral to the caudal vestibular nucleus. The spinal tract of the trigeminal nerve and its nucleus are ventrolateral to the caudal vestibular nucleus in the medulla. These vestibular nuclei receive afferents from the vestibular division of the vestibulocochlear nerve. From the vestibular nuclei are numerous projections, which can be grouped into spinal cord, brainstem, and cerebellar pathways (see Fig. 12-4).

Spinal Cord

The lateral vestibulospinal tract courses caudally in the ipsilateral ventral funiculus through the entire spinal cord. Its axons terminate in all of the spinal cord segments on interneurons in the ventral gray columns (see Fig. 2-17). These interneurons are facilitory to ipsilateral alpha and gamma motor neurons to extensor muscles, inhibitory to the ipsilateral

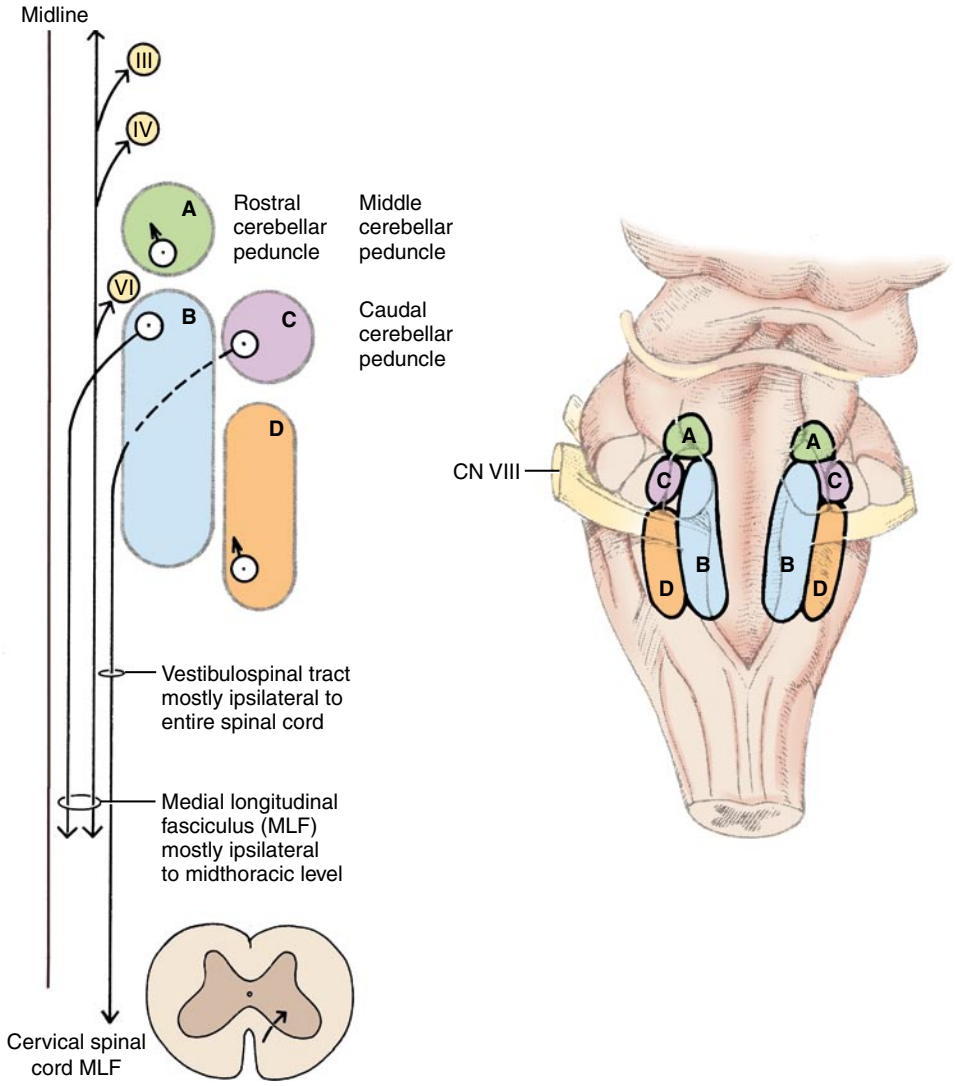

FIGURE 12-4 Vestibular nuclei and tracts. **A,** Rostral vestibular nucleus; **B,** medial vestibular nucleus; **C,** lateral vestibular nucleus; **D,** caudal vestibular nucleus.

alpha motor neurons to flexor muscles, and some interneurons cross to the opposite ventral gray column where they are inhibitory to the contralateral alpha and gamma motor neurons to extensor muscles (see Fig. 12-2). Thus the effect of stimulation of the neuronal cell bodies, the axons of which are in the vestibulospinal tract, is an ipsilateral extensor tonus and contralateral inhibition of this mechanism. The cell bodies of most of the axons in the lateral vestibulospinal tract are located in the lateral vestibular nucleus.

The medial vestibulospinal tract arises from cell bodies in the rostral, medial, and caudal vestibular nuclei and passes caudally in the ipsilateral ventral funiculus of the cervical and cranial thoracic spinal cord segments.[49] These axons terminate on interneurons in the ventral gray columns, which influence the activation of the alpha and gamma motor neurons that innervate primarily neck muscles. In addition, the medial vestibular nucleus projects axons into the medial longitudinal fasciculus, which courses caudally in the dorsal portion of the ventral funiculus through the cervical and cranial thoracic spinal cord segments.[35,36]

Through these spinal cord pathways, the position and activity of the limbs, neck, and trunk can be coordinated with movements of the head.

Brainstem

Neuronal cell bodies in the vestibular nuclei have three general terminations in the brainstem.

1. Axons course rostrally in the medial longitudinal fasciculus (MLF) to terminate in the motor nuclei of cranial nerves VI, IV, and III. Their purpose is to provide coordinated conjugate eye movements associated with changes in the position of the head. In most normal animals, this eye movement can be readily elicited by repeatedly moving the head from one side to the other and observing the jerk nystagmus that is produced. When the brainstem is severely contused by a head injury, these pathways may be disrupted, and eyeball movements cannot be elicited by changing the position of the head. This clinical sign usually indicates a poor prognosis because of the severity of the associated lesion.
2. Axons project into the reticular formation. Some of these axons provide afferents to the vomiting center located there. This pathway is involved with motion sickness.
3. We are all readily aware of any loss of our balance. Balance requires a pathway for conscious perception that involves a relay through a thalamic nucleus. This pathway is not well defined for the vestibular system. It may be closely

associated with the conscious pathway for the auditory system. Axons of neuronal cell bodies in vestibular nuclei course rostrally through the midbrain to terminate in the contralateral medial geniculate nucleus of the thalamus or some other thalamic nucleus. Synapse occurs here, and the axons of the cell bodies in that thalamic nucleus project by way of the internal capsule to the cerebral cortex, probably the cortex in the temporal lobe. Interference with this conscious pathway would explain the occasional observation of clinical signs of a vestibular system dysfunction after an acute prosencephalic lesion.

Cerebellum

Axons of neuronal cell bodies in the vestibular nuclei, in addition to some in the vestibular ganglia, project to the cerebellum through the caudal cerebellar peduncle and terminate mostly in the cortex of the flocculus of the hemisphere and the nodulus of the vermis (the flocculonodular lobe). These axons have collaterals that synapse in the fastigial nucleus, which is the most medial of the three nuclei in the cerebellar medulla (see Figs. 12-2 and Fig. 2-13).

Through these pathways the vestibular system functions to coordinate the position of the eyes, neck, trunk, and limbs with the position and movements of the head. The system maintains equilibrium during active and passive movement and when the head is at rest. Interference with the system results in varying degrees of loss of balance and abnormal head position.

CLINICAL SIGNS OF VESTIBULAR SYSTEM DISEASE

Vestibular system disease produces varying degrees of loss of equilibrium, causing imbalance and a unique quality of ataxia that is designated vestibular ataxia as opposed to general proprioceptive ataxia and cerebellar ataxia. Clinical neurologists think about and describe disorders of the vestibular system as peripheral or central. Only minor differences exist in the clinical signs of vestibular system dysfunction between lesions of this system in the petrous portion of the temporal bone (peripheral) or the vestibular nuclei on one side of the medulla or the vestibular components of the cerebellum (central). The determination of whether the vestibular system signs reflect a dysfunction of the peripheral or central components of the vestibular system is more dependent on recognition of clinical signs caused by the dysfunction of other systems located in the brainstem or cerebellum. As a rule, the most common diseases that affect the peripheral components of the vestibular system are less serious than those that affect the central components. We will first describe the clinical signs of vestibular system dysfunction as they would occur with a complete disruption of the vestibular receptors or vestibular nerve in the petrous portion of the temporal bone. These signs are the clinical signs of peripheral vestibular disease.

Unilateral Peripheral Vestibular Disease

Unilateral disease of the peripheral components of the vestibular system[9] is characterized by an asymmetric ataxia with loss of balance but with preservation of strength. No loss of general proprioception occurs in peripheral vestibular system disease. Therefore these patients know exactly where their limbs are in space, and no paresis is present, thus they can support weight well (normal lower motor neuron [LMN] activity) and move their limbs rapidly (normal upper motor neuron [UMN] activity) to prevent themselves from falling as a result of their balance loss. The clinical signs will be recognized on your observation of the posture and gait of the patient and on your examination of the posture and movement of the eyes.

Abnormal Posture and Vestibular Ataxia

Loss of coordination between the head and the neck, trunk, and limbs is reflected in a head tilt, with the more ventral ear directed toward the side of the vestibular system disorder. The degree of head tilt can vary from just a few degrees that may be difficult to recognize to nearly 45 degrees with the patient having difficulty standing up. To recognize the mild head tilt, you need to observe the patient's head from in front of the patient and with your head at the level of the head of the patient. The neck and trunk will lean, fall, or even roll toward the side of the lesion. The neck and trunk may be flexed laterally with the concavity directed toward the side of the lesion. The patient may tend to circle toward the affected side. These circles are usually small, which will appear as though the patient is falling in that direction. Animals that propulsively circle from prosencephalic lesions have no ataxia or other signs of vestibular system dysfunction and usually walk in wider circles. Occasionally, it may be possible to elicit mild hypertonia in the limbs on the side of the body opposite to the side of the vestibular system lesion. The asymmetry of the ataxia may be explained by the loss of tonic activity in the vestibulospinal tract on the side of the lesion, which removes facilitation of ipsilateral extensor muscles and a source of inhibition of contralateral extensor muscles. The unopposed activity of the contralateral vestibulospinal tract causes the neck and trunk to be forced toward the side of the lesion by excessive unopposed extensor muscle tonus. The entire body will lean, fall, or roll toward the side of the lesion. With peripheral vestibular system disorders, rolling is usually limited to the first 24 to 48 hours after a peracute onset of clinical signs. If the rolling persists longer than that, the lesion more likely involves the central components of the vestibular system. Frequently, the patient falls when it shakes its head. With only the vestibular system affected, these patients will make very rapid and short limb movements in their attempt to maintain their balance. As you evaluate a patient such as this one, you should ask yourself if this patient knows where its limbs are in space. The answer will be definitely *yes* if only the peripheral vestibular system is affected. Patients with vestibular ataxia use their eyes to help maintain their balance. Therefore blindfolding these patients usually makes their vestibular ataxia worse. This tactic is most helpful when you are not sure if the vestibular system is involved in the patient's clinical signs. Be cautious when you perform this test with large animals so that they do not fall and injure themselves or the observers. For horses and cattle, use a folded towel that is slipped under the halter so that it can be readily removed by pulling on one edge of the towel. *Never* tie the blindfold onto the halter. Cats often carry their tails elevated straight dorsally when they have a significant balance loss.

Normal Nystagmus

Nystagmus is an involuntary rhythmic oscillation of the eyes. Eye movements that are equal in each direction indicate a pendular nystagmus, which is uncommon, usually benign, and is associated with congenital visual system pathway abnormalities. Eye movements that are unequal, with a slow movement (slow phase) in one direction and a fast return (quick phase) of the eye to its starting position, indicate a jerk nystagmus, which can be normal or abnormal and reflect a dysfunction in the vestibular system. The direction of the nystagmus, by convention, is ascribed to the direction of the quick or fast phase of the jerk nystagmus. Both eyes are usually affected and usually in the same direction. This jerk nystagmus is a normal response to any rapid movement of the head. Stand over any normal dog and watch its eyes as you move the head in a horizontal-dorsal plane form side to side. You will observe a horizontal jerk nystagmus. As you move the head to the right, both eyes will repeatedly jerk quickly to the right with a slow return to the left. As you move the head to the left, the opposite will happen; both eyes will repeatedly jerk quickly to the left and slowly return to the right. This procedure is termed *normal vestibular* or *physiologic* nystagmus. Some textbooks refer to this response as vestibular-ocular nystagmus, or a doll's eye response. It evaluates not only the vestibular system, which is the sensory arm of this response, but also the medial longitudinal fasciculus in the brainstem and the abducent nerve innervation of the lateral rectus muscle that abducts the eye and the oculomotor nerve innervation of the medial rectus muscle that adducts the eye. If you flex and extend the neck so that the head moves up and down, the same eye movements will occur in a vertical direction. This event is a vertical jerk nystagmus. The quick phase of the nystagmus is always in the direction of the head movement. This response is a normal reflex in which the slow component is initiated by way of the vestibular receptors in the membranous labyrinth and the quick component involves a brainstem center related to the vestibular system. This reflex is important in maintaining visual fixation on stationary points as the body rotates.

Abnormal Nystagmus

When the head is held in its normal extended (neutral) position, or if held flexed laterally to either side or held fully extended at rest, no nystagmus will occur in the normal animal. It normally occurs only when you move the head. With dysfunction of the vestibular system, a jerk nystagmus may be observed. If it is observed when the head is held in its normal extended (neutral) position, it is called a resting or spontaneous nystagmus. If it is induced only by holding the head fixed in lateral flexion or full extension, it is called a positional nystagmus. These events are both forms of abnormal nystagmus. If you are suspicious of the possibility of a vestibular system disorder, looking for positional nystagmus when you place the patient on its back with its neck extended may be useful. Remember that it is normal for nystagmus to occur when you move the head! How do you explain this abnormal nystagmus? If you consider the existence of a continual bilateral stimulation of vestibular neurons that constantly reflects the position or movement of the head and that this provides a balanced tonic stimulation of the vestibular nuclei on each side and from there to the nuclei that innervate the extraocular muscles, then any interruption of this balanced tonic stimulation might result in an alteration at the nuclei of the neurons that innervate extraocular muscles that results in nystagmus. With peripheral vestibular diseases, the imbalance represents a loss of tonic stimulation of the vestibular nuclei from the affected side.

In disorders of the peripheral vestibular system, the abnormal resting or positional nystagmus is directed in a horizontal-dorsal plane or is rotatory but is always directed (quick phase) away from the side of the lesion or head tilt. To determine the direction of a rotatory nystagmus, observe the direction that the 12-o'clock position of the pupil moves during the quick phase. This direction does not change when the position of the head is changed. Occasionally, an abnormal positional nystagmus may appear vertical, especially when the patient is in dorsal recumbency. Previous theories suggested that vertical nystagmus only occurred with disorders of the central vestibular system, but we now believe this idea may be incorrect and oversimplified. Some patients with disorders of the peripheral vestibular system have almost a vertical nystagmus, but careful examination will usually reveal a slight rotatory component. We no longer use vertical nystagmus alone to distinguish peripheral from central vestibular system disease. With disorders of the central components of the vestibular system, the nystagmus may be horizontal, rotatory, or vertical. It may be directed toward or away from the side of the lesion, and it may change in direction with the head held in different positions. Thus the presence of a nystagmus that is directed toward the side of the lesion or head tilt or changes direction with changes in the position of the head are the only reliable features of the abnormal nystagmus that indicate a central involvement of the vestibular system. Many patients with central vestibular system disease will have abnormal nystagmus that is horizontal or rotatory and is directed to the side opposite to the side of the lesion and does not change its direction with changes in head position. Therefore, to determine a disorder of the central vestibular system, you must identify clinical signs of the central lesion that involve other neurologic systems, especially the UMN and general proprioception (GP) systems. Resting nystagmus is more common in acute disorders of the peripheral components of the vestibular system, and the rate of either resting or positional nystagmus tends to be more rapid than when the disorder is in the central components of the vestibular system. Some patients with severe resting nystagmus exhibit a slight head rotation that occurs simultaneously with the nystagmus corresponding to its rate and direction. In addition, a simultaneous eyelid blink may be seen concomitant with the nystagmus, which presumably is a reflex action. These latter two findings are very common in rabbits.

Normal nystagmus requires normal function of the vestibular system components, normal medial longitudinal fasciculus bilaterally, and normal general somatic efferent (GSE) neurons in the abducent, trochlear, and oculomotor nuclei. Abnormal nystagmus indicates a disruption in the normal bilateral balance of sensory information from the peripheral vestibular receptor and the activity of the central

components of the vestibular system. No normal or abnormal nystagmus can occur with bilateral loss of function in the peripheral vestibular system, its central components, the medial longitudinal fasciculus, or the GSE motor neurons of the abducent, trochlear, and oculomotor nuclei. Bilateral otitis interna is the most common cause of the complete absence of any normal or abnormal nystagmus.

Postrotatory Nystagmus

If an animal is rotated rapidly, as it accelerates, the labyrinth moves around the endolymph, which deflects the cupula of the crista ampullaris, stimulating the vestibular nerve and thus eliciting eye movements. The quick phase is in the direction of the rotation, but this aspect cannot be seen as the animal is moving. In time, the rotation of the endolymph reaches the same speed of rotation of the labyrinth. At this constant velocity, the cupulae are not deflected. Thus no rotatory stimulus reaches the vestibular nerve, and nystagmus does not occur. When the rotation is suddenly stopped, once again, a disparity occurs in the rotation of the labyrinth and the endolymph. The labyrinth is stationary, and the endolymph continues to flow for a short interval during which it deflects the cupulae. Vestibular neurons are stimulated, and nystagmus occurs. However, the direction of flow is opposite to that which occurred during acceleration, and the quick phase of the nystagmus is directed opposite to the direction of the rotation. The speed and duration of this postrotatory nystagmus are variable but should be approximately equal when the response to rotation is compared for both directions.

Vestibular system disease is suspected when a different response is elicited to spinning in one direction compared with the other. As a rule, when the patient is rotated in a direction opposite to the side of a peripheral receptor lesion, postrotatory nystagmus is depressed. This postrotatory test stimulates both labyrinths. However, the labyrinth on the outside of the rotation, on the side of the head opposite to the direction of rotation, is stimulated more because it is farther away from the axis of rotation, which may explain the abnormal postrotatory nystagmus that is observed with unilateral peripheral vestibular disease. On rotating the patient away from the side of the lesion, the diseased labyrinth is farthest from the axis of rotation. It cannot be stimulated properly because of the lesion, and a depressed postrotatory response may be observed.

This test can be performed only on patients that are small enough to be picked up and held with your elbows extended. It requires two people, the holder and the examiner. The holder directs the head of the patient away from his or her body and spins in a circle as rapidly as possible for 6 to 7 rotations and stops suddenly. The examiner immediately grasps the head of the patient and observes the eyes for nystagmus. The eyes of the holder will show the same postrotatory response. For some large dogs, you can secure them in a rotating desk chair and spin them with the chair. In most small animals, this postrotatory response can be readily elicited. We perform this test only when the clinical signs of a peripheral vestibular disorder are subtle and a need exists for more supportive information or in a patient that is suspected of having a bilateral peripheral vestibular system disorder in which no normal nystagmus will occur; it is not reliable for determining the side of the lesion.

Caloric Nystagmus

The vestibular receptors of each inner ear can be tested separately by using the caloric test. Irrigation of the external ear canal with ice-cold water or warm water for 3 to 5 minutes causes the endolymph to flow in the semicircular ducts. Using cold water, this test normally induces a jerk nystagmus to the side opposite to the ear being stimulated. If the peripheral receptor on the side being stimulated is nonfunctional because of a disease process, no nystagmus will be observed with this caloric test. Covering the patient's eyes may prevent voluntary repression of the response by fixation on an object in the environment of the visual field. This test is useful in humans who can be restrained in an adjustable chair that will permit not only the testing of an individual ear, but also individual semicircular ducts. Most animals need considerable physical restraint to perform this test, and, from personal experience, some normal dogs will not exhibit any nystagmus with prolonged irrigation of the ear canal with cold water. Thus this caloric testing is both unreliable and not practical in our animal patients. We avoid its use.

Strabismus

Strabismus is an abnormal position of the eye relative to the orbit or palpebral fissure that is a clinical sign of loss of innervation to the extraocular muscles and was described with the cranial nerves in Chapter 6. This strabismus is visible in all positions of the head. In the normal small animal, when the head and neck are extended in the tonic neck reaction, the eyes should elevate and remain in the center of the palpebral fissures. With disorders of any component of the vestibular system, this effect may not occur on the side of the lesion, resulting in a *dropped* or ventrally deviated eye that exposes the sclera dorsally. Occasionally, a slight ventral or ventrolateral strabismus is observed without head and neck extension but disappears when the head position is changed. This action will mimic an oculomotor nerve strabismus. However, when you move the head side to side to test for normal physiologic nystagmus, the affected eye will adduct and abduct well, indicating that cranial nerves III and VI are not impaired. This inconstant abnormal eye position is known as *vestibular* strabismus. You should look for this impairment when you hold the head and neck in extension because it may be the only clinical sign observed in mild disorders of the vestibular system. This vestibular strabismus will be on the same side as the lesion in the vestibular system.

In ruminants, it is normal for their eyes to not elevate completely when the head and neck are extended; therefore you expect to see some sclera dorsal to the cornea in these species, but it should be equal on both sides. Horses may exhibit a slight ventral deviation of the eyes when you try to extend their head and neck, but their size makes this observation difficult.

Postural Reactions

The vestibular system is the *only* system involved with movement of the animal that, when deficient, does not interfere with the performance of the postural reactions. Hopping, hemiwalking, placing, and paw or hoof replacement will all be normal. Only the animal's ability to right itself from a recumbent position may be altered, and this action toward the side of the lesion may be exaggerated. In the worst situation, the patient may continually roll in that direction.

The ability to perform these postural reactions (except for righting) is critical to determining whether the vestibular system disorder involves the peripheral or central components of the vestibular system. You need to repeat the hopping responses many times to be comfortable that they are normal in your patient with peripheral vestibular disease. In patients with severe loss of their ability to balance, holding them securely to perform these postural reactions may be difficult. With an acute onset of severe loss of balance, delaying or repeating this part of the neurologic examination after 24 hours may be necessary to allow time for the most severe clinical signs to abate enough so that you can handle the patient for this examination. The ground surface must not be slippery and should provide good traction for the patient. Be careful if you pick up one of these patients because severe disorientation will be initiated, and they will thrash their limbs to seek a supporting surface. If you suddenly pick up a cat with this disorder, you are in danger of being grasped by the struggling patient.

Vomiting as a continuous event is an uncommon clinical sign of vestibular system dysfunction in domestic animals. However, in approximately 25% of animals presented with an acute onset of vestibular system dysfunction, the owners will report observing an episode of vomiting at the onset of clinical signs.

Bilateral Peripheral Vestibular System Disease

When the peripheral components of the vestibular system are dysfunctional bilaterally, such as in a patient with bilateral otitis media-interna, no postural asymmetry is noted. Balance is lost to either side, resulting in the patient assuming a crouched posture closer to the ground surface. They can walk well but are often slow and cautious to prevent falling, especially when they move their heads suddenly. The most characteristic clinical sign is the presence of wide head excursions. When the patient moves its head to either side to look at objects in its environment, the movement is greater than normal, which gives the appearance that it cannot be stopped and the movement is prolonged. These wide head excursions occur to either side and to the same degree and may occasionally be accompanied by a brief staggering movement. Because no functional vestibular receptors or vestibular nerves exist, no stimulus exists to be projected into the brainstem and to the cranial nerves that move the eyes. Therefore no normal or abnormal nystagmus can be observed.

Central Vestibular System Disease

We have already indicated that the only clinical signs of dysfunction of the vestibular system that occur with disorders of the central components of the vestibular system and not with peripheral vestibular system disorders are the presence of an abnormal nystagmus that changes directions when the position of the head is changed and a horizontal or rotatory nystagmus directed toward the side of the head tilt and body deviation.[46] If the nystagmus is absolutely vertical, the disorder is most likely in the central components of the vestibular system. Be aware that what appears to be vertical may have a slight rotary component, which can occur with peripheral vestibular system disorders. The most reliable clinical sign that determines that a lesion exists in the pons or medulla affecting the vestibular nuclei is an ipsilateral postural reaction deficit or a recognizable spastic hemiparesis and ataxia from involvement of the UMN and GP systems adjacent to these nuclei here in the caudal brainstem. Clinical signs of cerebellar and cranial nerve dysfunction (except for the facial nerve) also implicate a cerebellar or pontomedullary location for the clinical signs of vestibular system dysfunction. Remember that facial paralysis and Horner syndrome can occur along with clinical signs of vestibular nerve dysfunction with diseases of the middle and inner ear in small animals and just facial paralysis in the horse and farm animals. Lesions that involve solely the vestibular nuclei on one side cause ipsilateral clinical signs similar to all the lesions that affect the peripheral components of the vestibular system with the patient's head tilt and loss of balance directed toward the side of the lesion.

Paradoxical Vestibular System Disease

Paradoxical vestibular system disease is a unique syndrome in which the head tilt and loss of balance are directed toward the side *opposite* to the central lesion, which usually involves the caudal cerebellar peduncle. An explanation for this paradox in the direction of the clinical signs of vestibular system dysfunction is based on the rule that the direction of the head tilt and balance loss will be toward the side of the *least* vestibular system activity. When we describe the physiologic anatomy of the cerebellum in Chapter 13, you will learn that the Purkinje neurons that form a single layer of cells in the cerebellar cortex are the only neurons that project their axons from the cerebellar cortex. These neurons are all inhibitory neurons that release gamma-amino butyric acid at their telodendria. Most of these neurons terminate via their telodendria on neuronal cell bodies in the cerebellar nuclei, which are located in the central portion of the cerebellum known as the cerebellar medulla. The neurons in these cerebellar nuclei comprise the majority of the efferent axons that leave the cerebellum to terminate in various brainstem nuclei. An exception to this rule is a small population of Purkinje neurons, most of which are located in the cortex of the folia of the flocculus in the hemisphere and the nodulus in the vermis. The Purkinje neurons of these cortical areas have axons that leave the cerebellum directly as a component of the caudal cerebellar peduncle. They terminate in the vestibular nuclei, where they are inhibitory to the activation of these neuronal cell bodies. A lesion in the caudal cerebellar peduncle interferes with this inhibition, resulting in excessive discharge of vestibular system neurons on that side. The imbalance in vestibular system activation between the two sides is recognized as a head tilt and loss of balance to the side opposite to this lesion because, as a rule, the direction of the head tilt and balance loss will be towards the side with the least activity of the vestibular system. This paradoxical syndrome is in contrast to lesions that cause a loss of activation of the neuronal cell bodies in the vestibular nuclei as seen in disorders of the peripheral components of the vestibular system or within the vestibular nuclei themselves.

Experimental studies support our clinical observations and proposed explanation.[25] Ablation of the caudal cerebellar peduncle dorsal to the medulla on one side will produce a head tilt and balance loss directed toward the side opposite to the lesion with the nystagmus directed toward the

side of the lesion. If the vestibular nuclei are included in this lesion, the head tilt and balance loss will be directed toward the side of the lesion, and the nystagmus will be toward the side opposite to the lesion, similar to disorders of the vestibular nerve or its receptors. Similarly, ablation of the flocculus and nodulus within the cerebellum will produce this paradoxical vestibular system syndrome, with the clinical signs directed toward the side opposite to this cerebellar lesion. However, experimental ablation of the fastigial nucleus, a source of activation of the vestibular nuclei, causes ipsilateral vestibular system signs.

In clinical practice, the side of this unilateral lesion will be determined on your neurologic examination by the side of the postural reaction deficit or the side of the hemiparesis and ataxia, which will be ipsilateral to the lesion. The caudal cerebellar peduncle lesion will be contralateral to the direction of the head tilt in paradoxical vestibular system disease. The caudal cerebellar peduncle lesion that causes the paradoxical vestibular system clinical signs also interferes with GP afferents that are entering the cerebellum. Their interruption will cause ipsilateral ataxia and a deficit in postural reactions. The lesions that affect the caudal cerebellar peduncle and cause the paradoxical vestibular system signs are variable and most commonly include infarcts, neoplasms, and inflammations, in our experience. Most of these lesions, when unilateral, also affect the UMN system to the ipsilateral neck, trunk, and limbs and ipsilateral GSE LMNs in cranial nerves.

Be aware that clinical signs of vestibular system dysfunction will occur if the dorsal roots of the first three cervical spinal cord segments are interrupted. This dysfunction has been observed in experimental animals in which these roots have been transected, presumably caused by the loss of GP afferents from neuromuscular spindles, which are critical for maintaining normal orientation of the head with the neck. Spinal cord lesions at this level that interrupt the spinovestibular tracts may have the same effect. We have observed temporary clinical signs of vestibular system dysfunction in three dogs after resection of extramedullary spinal cord tumors at the level of the C1 and C2 vertebrae, presumably from surgical trauma to these spinal cord segments. These clinical signs resolved in all three dogs within a 3- to 5-day period.

VESTIBULAR SYSTEM DISEASES

Dogs

CASE EXAMPLE 12-1

Signalment: 14-year-old male golden retriever, Sonny
Chief Complaint: Unable to stand up
History: The owners were reading at 7 PM when they heard a thrashing in their bedroom and found Sonny throwing himself around as he tried unsuccessfully to stand. They wrapped him in a blanket and brought him to the hospital, where he was examined and found unable to stand at that time. The video was made 6 hours after the sudden onset of these clinical signs, 5 hours after his hospitalization.
Examination: See **Video 12-1**. Note how rapidly this dog moves his limbs to maintain his balance and his normal rapid hopping responses. Also note the abnormal spontaneous right nystagmus.
Anatomic Diagnosis: Left peripheral vestibular system (membranous labyrinth, vestibular receptors, vestibular nerve portion of cranial nerve VIII, vestibular ganglion)
Differential Diagnosis: Benign idiopathic canine peripheral vestibular disease, otitis media-interna, ototoxicity

BENIGN IDIOPATHIC CANINE PERIPHERAL VESTIBULAR DISEASE

Benign idiopathic canine peripheral vestibular disease is the most presumptive clinical diagnosis in this patient based on the peracute onset, the age of the dog, and clinical signs limited to the peripheral components of the vestibular system predominantly on one side.[4,42] Whether the cochlear nerve or its receptors are also involved is unknown, given that you cannot reliably diagnose unilateral deafness without the use of electrodiagnostic equipment. Because this disorder is most prevalent in aged dogs, it is often termed *geriatric canine peripheral vestibular disease*. The cause of the disorder is unknown. Microscopic study of euthanized patients are uncommon because most dogs will spontaneously recover, the procedure is not routine in most necropsy laboratories, and the process of decalcification that is required makes recognition of subtle abnormalities difficult. The rapid recovery suggests that this disease may be a functional disorder, possibly an alteration in the production and absorption of endolymph that causes increased pressure within the membranous labyrinth. This theory has been proposed for the pathogenesis of Meniere disease in humans, which is an episodic disorder of the inner-ear components. Vestibular neuronitis is described in humans with an acute onset of clinical signs of a peripheral vestibular system dysfunction. Spontaneous recovery occurs. A herpesvirus-induced vestibular ganglionitis and an autoimmune inner-ear inflammation have also been proposed in humans. Paroxysmal positional vertigo (dizziness) in humans has been related to one or more statoconia that detach from the statoconiorum membrane and lodge in one of the semicircular ducts. Recovery is associated with specific head position adjustments to dislodge the statoconia. Many of the acute peripheral vestibular diseases of humans are not well understood.[11,17]

The idiopathic canine disorder is rarely observed before 5 years of age. The clinical signs are usually peracute in onset and rapidly improve to near complete resolution by 1 to 3 weeks from the onset. Residual clinical signs are uncommon. A few dogs may have a persistent head tilt. However, recurrences occasionally occur after a variable period of weeks to months. The onset of clinical signs can occur at any time of the year, which differs from a similar clinical syndrome that is seen in cats.

With this rapid spontaneous recovery and without knowing the cause of this disorder, no basis exists for specific treatment. In the first 24 to 48 hours when the clinical signs are severe and incapacitating, treatment with diazepam (Valium) or, to a lesser extent, meclizine (Antivert) may decrease the intensity of the clinical signs. Diazepam or similar drugs are used in a variety of vestibular system disorders in humans. In the past, this disorder was incorrectly diagnosed as a stroke, a brain infarction, which often resulted in the unnecessary

euthanasia of the patient. This practice is inexcusable with the present level of veterinary education. Severe clinical signs of vestibular system dysfunction often accompany the development of cerebellar ischemic lesions or infarcts (stroke), but the neurologic examination should support the anatomic diagnosis of a cerebellar disorder.[18,20] In addition, the clinical signs of this predominantly cerebellar disorder may resolve spontaneously or at least improve remarkably. If you are presented with a dog within a few hours of the peracute onset of the clinical signs of a peripheral vestibular disorder, the patient's severe disorientation may make performing a complete neurologic examination impossible. Evaluation of the postural reactions are critical to making the correct anatomic diagnosis. If your anatomic diagnosis of the location of the vestibular system disorder is dependent on the results of your postural reaction testing, we recommend confining the patient to a cage and reevaluating the patient over the next 12 to 24 hours before proceeding with ancillary procedures. Magnetic resonance (MR) imaging to date has been normal in the few patients with this peripheral vestbular system disorder that have been imaged. As MR imaging technology improves and we gain more experience, abnormalities may possibly be found, especially if an inflammatory disorder is present.

Otitis media-interna is your greatest concern in the differential diagnosis when the clinical signs are limited to the peripheral components of the vestibular system.[44] Facial paralysis and Horner syndrome often occur with otitis media-interna in small animals but *never* occur with the benign idiopathic disorder.[3] The peracute onset of severe clinical signs of peripheral vestibular system dysfunction is less common in otitis media-interna. Imaging procedures are the most reliable in supporting the diagnosis of otitis media-interna.

Ototoxicity should be supported by a history of exposure to drugs that affect inner-ear function.[27,32,50,51] Degeneration of the vestibular or cochlear labyrinthine receptors or both may occur with high levels of aminoglycoside antibiotics. These drugs include streptomycin, amikacin, kanamycin, neomycin, gentamycin, and vancomycin. Streptomycin most often affects the vestibular system receptors in cats. The other antibiotics more often affect the cochlear receptors, but both types of receptor are susceptible to degeneration from any of these antibiotics. Clinical signs are usually unilateral but occasionally bilateral clinical signs occur. Spontaneous recovery will occur only if the diagnosis is made promptly and the exposure period is short before drug removal.

Hypothyroid-induced ischemic neuropathy of the vestibulocochlear nerve is a rare cause of acute clinical signs of a peripheral vestibular system disorder. This diagnosis is supported by clinical laboratory findings of a primary hypothyroidism and severe hyperlipidemia. The ischemic neuropathy may be a result of hypothyroid-induced atherosclerosis or increased blood viscosity involving the labyrinthine artery. This pathogenesis has yet to be confirmed. It is not known if the rapid recovery that follows thyroid supplementation is due to the treatment or spontaneous recovery.

In the southeastern part of the United States where the blue tail lizard is common, many veterinarians believe that acute peripheral vestibular system dysfunction occurs in cats shortly after they eat the tail of this lizard.[1] Additional clinical signs include vomiting, trembling, salivation, and hyperirritability from more diffuse involvement of the nervous system. A few deaths have occurred. Further careful studies of this presumed toxicity are necessary. We have no experience with this unique disorder.

See the following videos for other examples of benign idiopathic canine peripheral vestibular disease.

Video 12-2 shows Iris, a 13-year-old spayed female Norwich terrier who was videoed 24 hours after her sudden onset of severe disorientation, inability to stand, and frequent rolling to the right side. During the videotaping, I (Alexander de Lahunta) could not get the left pelvic limb to hop, but this feature was normal a few hours later. The last portion of the video was made 2 months after the first and shows Iris completely recovered without any treatment.

Video 12-3 shows Sonny, a 12-year-old spayed female mixed breed with a sudden onset of what the owner described as seizure-like activity based on eye shaking and eyelid twitching. However, Sonny was still well aware of her environment, including recognition of the owner. The video was made 18 hours after the onset of clinical signs. Repeating the hopping responses many times was necessary on Sonny before I (AD) was comfortable the responses were normal in this dog with the severe disorientation.

Video 12-4 shows Jute, a 13-year-old female border collie 4 days after a sudden onset of a left head tilt and loss of balance. Initially she could not stand without assistance.

CASE EXAMPLE 12-2

Signalment: 4-year-old castrated male golden retriever, Bozo
Chief Complaint: Head tilt and tearing
History: Eight days before the examination, the owner noticed excessive tearing on the right side of Bozo's face. Four days later, the dog had developed a right head tilt.
Examination: See **Video 12-5**. Note the lack of a right palpebral reflex but the retraction of the eye with the elevation of the third eyelid, the lack of lip and ear tone on the right but the straight philtrum, and note that the clinical signs of peripheral vestibular system dysfunction are limited to the head tilt and abnormal nystagmus. This dog's balance is normal.
Anatomic Diagnosis: Right cranial nerves VII and VIII—vestibular nerve or its labyrinthine receptors
Differential Diagnosis: Right otitis media-interna, neoplasm involving the right temporal bone

OTITIS MEDIA-INTERNA

Otitis media-interna is the most common cause of this combination of cranial nerve dysfunctions.[3,44] However, your neurologic examination must show no postural reaction deficits, which, if present, would indicate a medullary lesion, possibly affecting these two cranial nerves as well. In small animals, the postganglionic sympathetic axons that innervate smooth muscle in the orbit course through or adjacent to the tympanic cavity, where they can be affected by the inflammation in middle-ear infections. Unknown is whether the dysfunction of the peripheral vestibular system requires inflammation within the inner ear or whether the alteration in pressure and temperature caused by the inflammation within the tympanic cavity is sufficient to cause these clinical signs. Otitis media is very common in small animals especially cats and young farm animals, which includes calves,

(Continued)

CASE EXAMPLE 12-2—cont'd

lambs, kids, crias, and pigs (Figs. 12-5 through 12-9). Extension of this infection into the cranial cavity is common when this ear infection is not treated vigorously, and the results of the extension can be lethal. Three anatomic routes for infection can be used to obtain access to the tympanic cavity: (1) from otitis externa, (2) from nasopharyngeal infections extending through the auditory tube, and (3) hematogenous from a bacteremia. Clinical signs can be acute or chronic in onset and progressive. The clinical signs of peripheral vestibular dysfunction are usually less severe than in dogs with the benign idiopathic disorder. The otitis can be bilateral but the neurologic signs unilateral. Otoscopic examination may show changes in the middle-ear cavity with the tympanic membrane ruptured or still intact. However, the otitis media is often undetected with this procedure, and imaging is required for the diagnosis. For years, we have relied on radiographs, but both computed tomographic (CT) and MR imaging are more reliable. CT images are better than MR images to show the degree of bone involvement (see Fig. 12-6). Ideally, treatment should be based on isolation of the infectious agent and the use of specific antibacterial or antifungal drugs to which the agent is most susceptible. Remember to avoid the aminoglycoside antibiotics that are ototoxic. Surgery may be required for chronic cases.

Neoplasms occasionally involve the tympanic and petrous portions of the temporal bone. They often arise from the tissues of the external ear canal and invade the temporal bone but primary bone neoplasms occur as well (Fig. 12-10). The anatomic diagnosis might well be identical to that in this dog. As the neoplasm expands medially, brainstem or cerebellar compression (or both) will result with corresponding clinical signs. Diagnosis is dependent on adequate imaging procedures. Squamous cell carcinoma is a common neoplasm that involves the ear of cats.

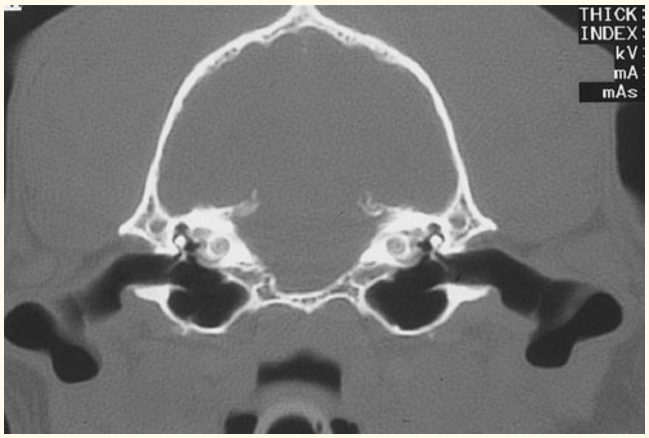

FIGURE 12-5 CT image of a normal dog's head at the level of the tympanic bullae.

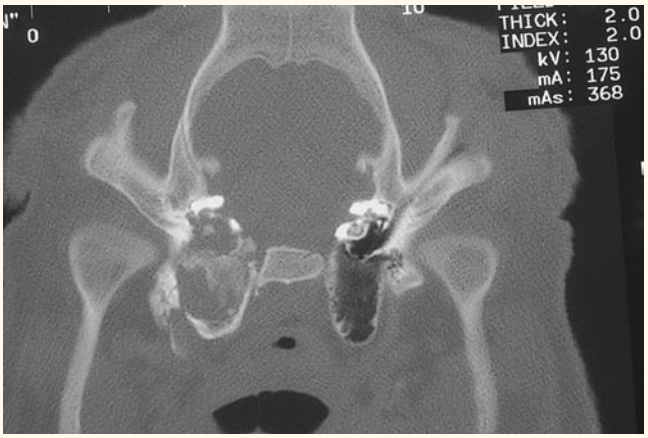

FIGURE 12-6 CT image of a young pig with left otitis media-interna. Note the distortion and destruction of the left tympanic and petrous portions of the temporal bone. This infection was associated with a brainstem abscess. Note the normal right pendular portion of the tympanic bulla, which contains many thin bony laminae. The tympanic cavity is free of these laminae just ventral to the petrous portion of the temporal bone.

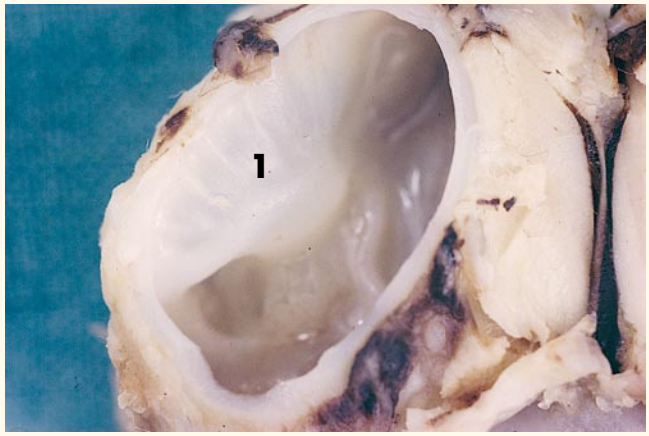

FIGURE 12-7 Normal tympanic bulla in a cat with the ventromedial portion of the tympanic cavity opened to expose the septum bullae (1).

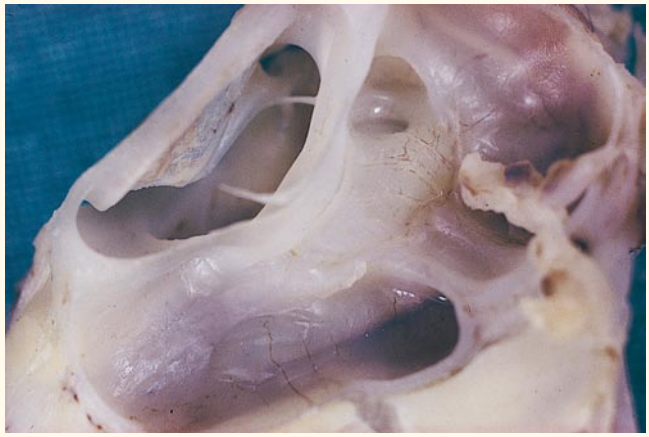

FIGURE 12-8 Same cat as in Fig. 12-7 with the septum bullae partially removed to open the dorsolateral portion of the tympanic cavity and expose the tympanum with the malleus embedded in it.

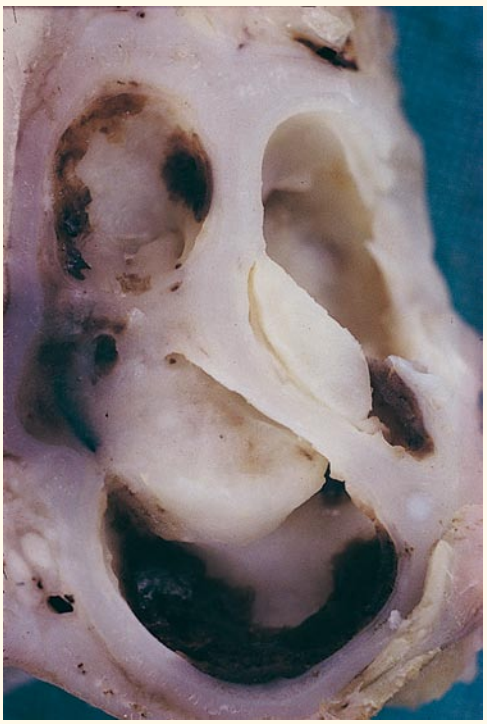

FIGURE 12-9 Same cat as in Figs. 12-7 and 12-8 with the opposite tympanic bulla and septum bullae opened to show suppurative exudate in both portions of the tympanic cavity (otitis media).

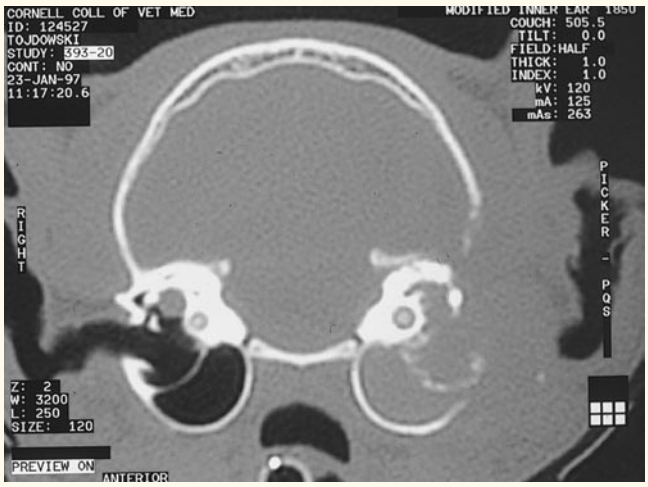

FIGURE 12-10 CT image of the head of an 8-year-old domestic shorthair at the level of the ears. Note the normal right tympanic bulla (left side of image). Also note the thin plate of bone—septum bullae—that partially divides the tympanic cavity into a small dorsolateral and larger ventromedial portion. The two portions communicate near the tympanum. This septum only forms a small ridge in dogs. Note the soft tissue density in the left tympanic bulla and its partial destruction along with destruction of portions of the rest of the temporal bone by a sarcoma.

CASE EXAMPLE 12-3

Signalment: 5.5-year-old female Chesapeake Bay retriever, Splash
Chief Complaint: Head tilt, facial deformity and depression
History: One year before this examination, the owner noticed that Splash had a slight right head tilt; the dog also tended to drool excessively from the right side of her mouth. One month before this examination, the owner noted that the right eye was sunken, and the head appeared to be deformed. For the 2 to 3 weeks before the examination, Splash was depressed and would occasionally stagger and fall.

Examination: See **Video 12-6**. Note the normal gait, and you should have appreciated that the hopping responses on the right side were consistently delayed and lacked the smooth quality seen with the left limbs. Paw replacement was normal. Note the absent right palpebral reflex but intact facial sensation, the elevated right ear with what we thought was increased tone in the right lips, and a very slight deviation of the philtrum to the right. Note the lack of temporal and masseter muscle mass on the right side. Splash resented having her mouth opened, and a mass lesion was palpated on the right side between the transverse process of the atlas and the caudal portion of the mandible. Not seen in the video was a persistent anisocoria with the right pupil always smaller than the left and an abnormal positional nystagmus when she was placed on her back. This nystagmus was vertical or directed to the right side.

Anatomic Diagnosis: Right pons or medulla (or both): right facial neurons, right vestibular system, right motor neurons of the trigeminal nerve, right UMN-GP systems in the pons or medulla (or both)

At the time of this examination, the right facial paralysis observed in this dog is associated with facial tetanus. Presumably the initial clinical signs of vestibular system dysfunction involved the peripheral components, but there is no way to prove this presumption. At the time of this examination, clinical signs of involvement of the UMN and GP systems were noted, most likely in the pons or medulla (or both), which might also affect the vestibular nuclei. The masticatory muscle atrophy implicates the mandibular nerve from the trigeminal nerve or motor nucleus of V in the pons. Otitis media-interna will not affect the trigeminal nerve or its ganglion where it passes through the canal for the trigeminal nerve in the rostral portion of the petrous part of the temporal bone. The thick portion of this bone that separates the tympanic cavity and this nerve prevents this occurrence. However, an erosive neoplasm in the temporal bone knows no boundaries. Presumably, this dog is deaf on her right side, but we cannot determine this loss of function in our physical neurologic examination.

Differential Diagnosis: Neoplasm—intramedullary or extramedullary, abscess—granuloma secondary to otitis media-interna, focal encephalitis—granulomatous meningoencephalitis

NEOPLASM

Based on the 1-year history of very slow progression of clinical signs and the palpation of a mass lesion in the area of the anatomic diagnosis, a neoplasm is the most likely clinical diagnosis. Radiographs determined that a large mass had obliterated most components

(Continued)

CASE EXAMPLE 12-3—cont'd

of the right temporal bone. Splash was euthanized, and necropsy diagnosed this extramedullary temporal bone neoplasm as a basal cell carcinoma (Figs. 12-11 through 12-14).

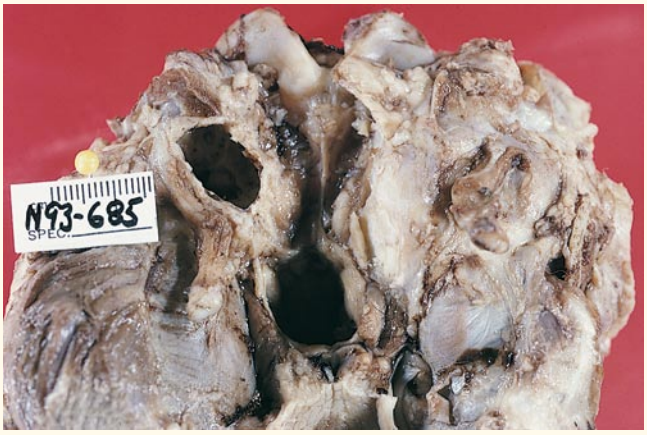

FIGURE 12-11 Ventral view of the head of the dog in Video 12-6 at necropsy with the lower jaw removed. The normal left tympanic bulla has been opened. The comparable right side of the specimen has been obscured and obliterated by the neoplasm.

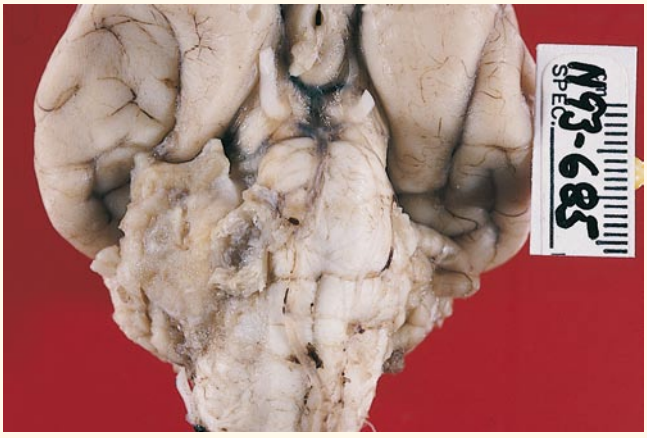

FIGURE 12-12 Ventral view of the preserved brain of the dog in this case example. Note the neoplasm compressing the right side of the caudal brainstem.

FIGURE 12-13 Transverse section of the brain in Fig. 12-12 at the level of the cerebellum and medulla, showing the extraparenchymal neoplasm at the right cerebellomedullary angle.

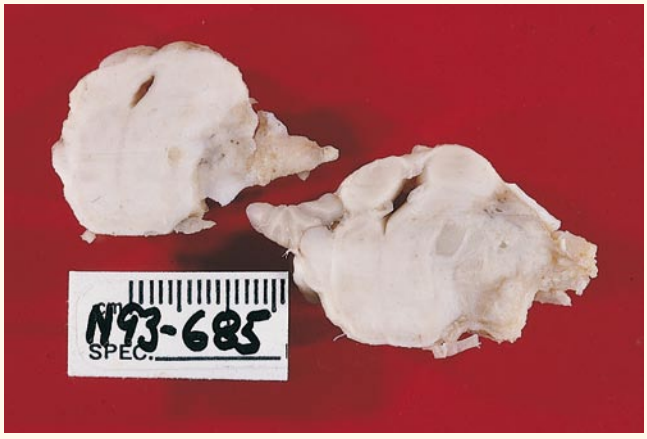

FIGURE 12-14 Transverse section of the brain in Fig. 12-12 at the level of the mesencephalon, showing the neoplasm in the meninges compressing the mesencephalon. This neoplasm is a basal cell carcinoma.

CASE EXAMPLE 12-4

Signalment: 6-year-old spayed female golden retriever, Courtney
Chief Complaint: Difficulty walking and frequent falling
History: Three days before examination, the owner first recognized clinical signs when Courtney fell down the stairs and had difficulty with her balance. The owner blamed the fall as the cause of an injury. However, Courtney developed a left head tilt, and her difficulty with walking progressively worsened. Be aware that neurologic signs associated with a fall are usually the cause of the fall and not the result of it.

Examination: See **Video 12-7**. Note the strong tendency to lean and circle to her left side and the right-side hypermetria with excessive limb flexion most evident in the thoracic limb. The abnormal positional nystagmus was mostly vertical but occasionally rotatory left or right.
Anatomic Diagnosis: Right cerebellum, pons, and medulla

The quality of the hypermetria represents a cerebellar dysfunction based on the excessive flexion of the limb on protraction. In the overreaching form of hypermetria that was described with cervical

spinal cord disorders, the thoracic limb is in extension when protracted. See **Video 12-8** described at the end of this case example. The slow hopping and hemiwalking with the right limbs supports a central nervous system (CNS) lesion involving the right UMN or GP systems (or both) in the caudal brainstem or the right side of the cerebellum. The head tilt and loss of balance are directed to the left, which suggests clinical signs of a paradoxical vestibular system disorder, unless multifocal lesions are present, such as right cerebellum and left vestibular nuclei. The clinical signs of a vestibular system disorder are profound. The quality of the gait abnormality, the deficit in postural reactions, and the abnormal nystagmus that changed direction with different head positions all support that the vestibular system involvement is in its central components. This finding indicates unequivocal central vestibular disease![46]

Differential Diagnosis: Neoplasm, inflammation, vascular compromise, malformation, toxicity, hypothyroidism

NEOPLASM

Based on the progressive nature of the clinical signs, neoplasia and focal inflammation are the two most common clinical disorders for consideration in this patient. Neoplasms in the caudal cranial fossa include intramedullary glioma, medulloblastoma (primitive neuroectodermal tumor), choroid plexus papilloma or carcinoma, ependymoma, and extraparenchymal meningioma.

GRANULOMATOUS MENINGOENCEPHALITIS

The most common focal encephalitis to occur in this area of the brain is granulomatous meningoencephalitis (GME).[6,21] The pathogenesis of this disorder is not well understood but is presently considered to be a form of lymphoproliferative disorder that may evolve into a lymphoma. An autoimmune disease has also been proposed. GME tends to be more common in young adult small- to medium-sized breeds, but any breed at any age can be affected. The angiocentric lesions predominate in the white matter and can be diffusely distributed through the brain and spinal cord, occur in multifocal sites, or be primarily located at one site where the perivascular and parenchymal proliferation of lymphoplasmacytic cells and macrophages (histiocytes) can be so extensive as to cause a mass lesion. Lesions in the cerebellum, pons, and medulla are common. A localized form is thought to occur in the optic nerves causing an optic neuritis. Optic neuritis is described in Chapter 14 on the visual system. CSF usually reflects the lesion with marked elevation of protein and nonsuppurative inflammatory cells. MR imaging is the preferred procedure to show these lesions, especially when they are focal. These lesions are hyperintense on T2-weighted and fluid-attenuated inversion-recovery (FLAIR) images. Contrast enhancement is variable. Immunosuppressive drugs such as prednisone or oral cyclosporine and lomustine may be effective at slowing or stopping the progression of the disease and alleviating some of the clinical signs. Focal lesions can be irradiated. Responses to these treatments vary.

Remember that this anatomic site is at risk for developing an abscess or more diffuse suppurative meningoencephalitis associated with extension of an infection from the middle and inner ear.

Vascular compromise causing ischemia or infarction are common in the cerebellum and are usually asymmetric, affecting part or all of one hemisphere and the vermis.[18,20,30] The clinical signs may be very similar to those seen in Courtney. See examples in Chapter 13 on the cerebellum. However, the clinical signs should be acute in onset and not progress over more than 24 hours as a rule. Malformation was included in the differential diagnosis because the caudal cranial fossa is a common site for epidermoid or dermoid cysts to occur.[28] These cysts are thought to be developmental in origin and result from an abnormality when the neural tube folds and closes in this area and separates from the overlying ectoderm. The epithelial lining of these cysts proliferates and secretes, causing the cyst to enlarge and, in time, produce clinical signs from its mass effect. Severe clinical signs of dysfunction in the components of the caudal cranial fossa occur with metronidazole toxicity, but these are usually symmetric and require a history of exposure to this drug.[14] Hypothyroidism has been associated in adult dogs with an acute onset of persistent or progressive clinical signs of a caudal cranial fossa lesion that included involvement of the central components of the vestibular system.[23] In this study, thyroid function evaluations were abnormal and all responded to treatment with levothyroxine. The pathogenesis of the disorder is unknown, although atherosclerosis was suggested in earlier studies.

MR imaging was performed on Courtney and revealed a mass lesion on the right side of the caudal cranial fossa primarily in the right cerebellar hemisphere and the vermis (see video). This finding was interpreted to be an intraparenchymal neoplasm, most likely a glioma. She was euthanized, and no necropsy was performed.

See **Video 12-8**. This video shows Arnie, a 4-year-old bull mastiff with a history of four to five generalized seizures over the previous 3 weeks and 3 days of a head tilt and abnormal gait. Note the right head tilt and drifting to his right side and the overreaching of the left thoracic limb with the limb in extension. This form of hypermetria contrasts with that observed in Courtney, Video 12-7. The prolonged protraction with the limb in extension is a clinical sign of a UMN or GP system disorder, or both. Not seen on the video were the slow hopping responses in the left limbs of Arnie and the abnormal positional nystagmus that changed directions in different positions of the head.

The anatomic diagnosis includes prosencephalon, left cerebellum, pons, and medulla. Seizures are caused by disorders that involve some portion of the prosencephalon. The left UMN-GP systems disorder can be anywhere from the pons through the first to fifth cervical spinal cord segments on the left side. The vestibular system signs are from a CNS lesion that is most likely in the left cerebellum, and these signs are paradoxical vestibular signs. Multifocal lesions are usually either inflammatory or neoplastic. The CSF was normal. MR imaging revealed a small hyperintense lesion in the left diencephalon and a large hyperintense lesion in the left cerebellar hemisphere and the vermis and the left dorsolateral medulla. See the video for the MR images of the cerebellar lesion. In these images, the axial sections alternate between the T2-weighted and proton-density images. The spinal cord was not imaged. Arnie's clinical signs progressed over the next 2 weeks, and he was euthanized. Necropsy diagnosed these areas of MR image hyperintensity as astrocytomas.

CASE EXAMPLE 12-5

Signalment: 9-year-old spayed female border collie, Mercy
Chief Complaint: Head tilt
History: Mercy was presented to Cornell 10 days after an acute onset of inability to stand, thrashing attempts to try to stand, and episodes of neck and thoracic limb extension. Over these 10 days, she improved remarkably but still had a mild head tilt.
Examination: See **Video 12-9**. Note the mild left head tilt, her tendency to drift to the right side, and the slow hopping responses in the right limbs when tested repeatedly. No abnormal nystagmus was noted.
Anatomic Diagnosis: The right side of the cerebellum, pons, and medulla. The head tilt was assumed to be a paradoxical vestibular sign.
Differential Diagnosis: Neoplasm, inflammation, vascular compromise, malformation, toxicity

ISCHEMIC ENCEPHALOPATHY

These diagnoses are the same as those listed for Courtney in Case Example 12-4. However, the acute nontraumatic onset and the steady improvement up to the time of this examination strongly indicated a vascular compromise with ischemic lesions, which were resolving. One week later, Mercy was examined by Eric Glass, who found no neurologic signs, and an MR imaging was normal at that time. These findings indicate a presumptive unilateral cerebellar vascular compromise with ischemia, which completely resolved.[18,20,30] The cause of the vascular compromise is unknown.

CASE EXAMPLE 12-6

Signalment: 6-year-old spayed female Papillon, Dolly
Chief Complaint: Unable to stand
History: Over a few days, Dolly had progressed from difficulty in walking, to difficulty in trying to stand, to tremors of her head.
Examination: See **Video 12-10**. Note the loss of balance with swaying of the body to either side, the difficulty in initiating limb movements, the tendency to assume an opisthotonic posture of the head and neck, the limb hypertonia, the resting vertical nystagmus, and her appearance of disorientation.
Anatomic Diagnosis: Cerebellum, pons, and medulla

These clinical signs are often loosely termed cerebellar-vestibular signs, with the latter a product of involvement of the central components of the vestibular system. They are usually accompanied by some degree of UMN and GP system dysfunction. Head and neck tremors occur with cerebellar disorders. The absolutely vertical nystagmus in combination with the other neurologic signs support a disorder of the central vestibular system components.

Differential Diagnosis: Neoplasm, inflammation, vascular compromise, malformation, toxicity

METRONIDAZOLE TOXICITY

These diagnoses are the same as those listed for Case Examples 12-4 and 12-5. The severity of these clinical signs, their symmetric nature, and the persistent resting abnormal nystagmus are strongly suggestive of metronidazole toxicity.[10,14,38] On questioning Dolly's owner about possible exposure to this drug, we were informed that Dolly had been receiving this drug for 1 month as a treatment for pancreatitis. Further inquiry determined that Dolly was receiving approximately twice the recommended dose of metronidazole. Be aware that dogs that receive recommended doses of this drug are also at risk for this toxicity. As a rule, however, the greatest risk for dogs to develop clinical signs of toxicity occurs when the drug is administered for long periods and especially at excessive doses.

CASE EXAMPLE 12-7

Signalment: 9-month-old female Labrador retriever, Roxy
Chief Complaint: Difficulty with standing and often falls
History: An abnormal gait was first observed at approximately 7 months of age. This phase slowly progressed to difficulty standing and falling to either side, which the owner described as a "drunken gait." Roxy also developed fine tremors of her entire body. The owner described that these clinical signs tended to wax and wane in severity during the day.
Examination: See **Video 12-11**. Note the similarity of these clinical signs to those in Case Example 12-6, Video 12-10, with the poor initiation of limb movements associated with sudden bursts of activity, the inability to coordinate to stand, the episodes of opisthotonus with thoracic limb rigidity, and the fine tremor of the entire body including the limbs. No abnormal nystagmus was noted, and the dog acted alert and responsive. Note the last portion of the video when the dog is urged to come out of her cage, which occurred approximately 1 hour after the first portion of the video during which the dog was resting in this cage. Note her ability to stand and walk here but with marked difficulty. Roxy was hospitalized the day before this examination, and she was observed to have a generalized seizure in her cage that lasted approximately 1 minute.
Anatomic Diagnosis: Diffuse CNS with a major component involving the cerebellum, pons, and medulla

The clinical signs observed on the video relate to dysfunction in the cerebellum, pons, and medulla similar to Dolly in Case Example 12-6. However, seizures are related to a disorder of some component of the prosencephalon, and the fine whole-body tremors require a diffuse disorder of myelin or axons in the entire CNS.

Differential Diagnosis: Degeneration, toxicity, inflammation

LEUKODYSTROPHY

The slow progression of symmetric clinical signs and the lack of any exposure to a known toxin make toxicity and inflammation less likely. Remember in cases such as this one to look at the breed and ask yourself if any recognized inherited degenerative disorder is described for this breed that causes similar clinical signs. When you search for this data in your textbooks or on the Internet, your answer will be *yes*. In 1975, Dr. Jack McGrath at the University of Pennsylvania described a fibrinoid encephalomyelopathy (Alexander disease) in two 8-month-old littermate Labrador retrievers with clinical signs of a diffuse CNS disorder.[33] This degeneration is a disorder of astrocytes. It is associated with a loss of myelin, especially in the cerebral white matter. Thus this disease is also known as *leukodystrophy*. The abnormal astrocytes are widely distributed in the CNS, but their perivascular density and the myelin loss in the cerebral white matter will appear as a diffuse bilaterally symmetric hyperintensity in T2-weighted and proton-density MR images. In 1985, Dr. Dennis O'Brien described a spongy degeneration of CNS white matter, a leukodystrophy, in Labrador retrievers.[37,52] The onset of clinical signs for the dogs in this report was 4 to 6 months of age. The lesion consists of a separation of the myelin lamellae, causing a dilation of the myelin sheath caused by the accumulation of fluid between lamellae, known as *myelin edema*. It is found throughout the CNS and is especially prominent where large bundles of white matter are found, such as the spinal cord, cerebellar medullary and folial white matter, internal capsule, centrum semiovale, and corona radiata. These lesions are hypointense on T1-weighted MR images and hyperintense on the T2-weighted images. An autosomal-recessive gene inheritance is presumed but is not yet proven. Roxy had a littermate that was euthanized at 4 months of age for generalized seizures, but no necropsy was performed. Roxy was euthanized, and a necropsy confirmed the diagnosis of a leukodystrophy similar to that described by O'Brien.

Cats

CASE EXAMPLE 12-8

Signalment: 3-year-old castrated male domestic shorthair, Reuben
Chief Complaint: Head tilt and loss of balance
History: One late July evening, Reuben's owner let him outdoors for the evening and found him in the morning on the back steps with a head tilt and difficulty walking. Reuben was brought to the hospital that day and videoed the next morning.
Examination: See **Video 12-12**. Note how alert this cat is. Note also his normal quick limb movements as he attempts to maintain his balance. He staggers to either side but more often to the left, which is the side of his head tilt and head turn. In the first portion of the video, when he looks left, note the brief head rotations. These movements correspond to the resting right nystagmus that is present. When you perform the hopping responses in cats, many of them will simply roll over and not respond at all. To prevent this result, hold the cat up and grasp the three limbs that you are not testing, and suddenly lower the cat to the ground with the limb to be hopped extended. As soon as the limb strikes the ground, move the cat laterally on it, and the normal cat will at least give you a few hops before rolling over. Note the elevation of the tail, which is typical of cats with severe balance loss.
Anatomic Diagnosis: Left peripheral vestibular system components
Differential Diagnosis: Benign idiopathic feline peripheral vestibular disease, otitis media-interna, ototoxicity

BENIGN IDIOPATHIC FELINE PERIPHERAL VESTIBULAR DISEASE

Benign idiopathic feline peripheral vestibular disease is the most presumptive clinical diagnosis based on the sudden onset of severe clinical signs of peripheral vestibular system dysfunction with no involvement of the facial nerve or postganglionic sympathetic nerves in the late summer in a young adult cat with access to the outdoors.[7,13] The cause of this disease is unknown. (See the discussion of the similar benign idiopathic canine disorder.) Because this disease in cats occurs at the same time of year as the acute-onset brain disease caused by the myiasis of the larva of a *Cuterebra* sp., some neurologists have hypothesized that this peripheral vestibular syndrome is caused by the migration of this larva in the middle and inner ear. No definitive proof has been found of this occurrence whatsoever. No *Cuterebra* sp. larva have been found in any part of the ear of a cat with or without these clinical signs, and the few necropsies that included study of the inner-ear structures have not found a recognizable lesion. Investigators have reported that this disease can occur in cats that have no access to the outdoors, but these reports are rare. The high incidence of this disorder from late July through September in outdoor cats implies some environmental factor (e.g., insect toxin, toxic spray, plant pollen) that may cause ototoxicity. This factor is unknown. The clinical signs are peracute in onset and typical for a severe dysfunction of the peripheral vestibular system. Although the clinical signs predominate to one side, a bilateral disturbance is suggested by the occasional wide head excursions to either side and the tendency of the cat to stagger in both directions. Fortunately, most of these cats will recover spontaneously. Their vestibular ataxia will be greatly improved by 7 to 10 days, and the head tilt usually resolves by 2 to 4 weeks. Occasionally, a residual head tilt persists. Even recovered cats may exhibit a slight head tilt and balance loss if they are significantly stressed. Without more knowledge of the cause of the pathogenesis of this disorder and the spontaneous recovery, treatment of these cats is unnecessary. However, the use of antibiotics is rational as a treatment for a possible otitis, which is the other most common cause of these clinical signs. Keep these cats in a protected environment while they recover. Rarely does this disorder recur in cats, which is unlike the canine disorder. Experimental surgical ablation of the inner ear of a cat will cause similar clinical signs, including recovery by cerebellomedullary compensation.[9] This disease represents just another of many reasons to keep cats indoors.

OTITIS MEDIA-INTERNA

Otitis media-interna is your other most significant concern for a disorder that would cause this anatomic diagnosis. The presence

(Continued)

CASE EXAMPLE 12-8—cont'd

of a facial paresis or Horner syndrome would be supportive of this diagnosis because these conditions never occur with the benign disorder just described. Usually the initial clinical signs of peripheral vestibular system dysfunction are not so severe with otitis, but an otoscopic examination should be performed on all of these cats. The most reliable way to diagnose otitis is with imaging, but when presented with a cat such as Reuben in this case example, we would delay imaging unless the patient's recovery was not satisfactory. Ototoxicity obviously requires a history of drug exposure.

See **Video 12-13**. This video shows a 4-year-old spayed female domestic shorthair with a sudden onset of the clinical signs observed on this video. You should appreciate that all of these clinical signs represent dysfunction in the peripheral components of the vestibular system. Not shown was the resting right rotatory nystagmus. Note that although the clinical signs are asymmetric with the left head tilt and leaning to the left, this cat has some indication of bilateral dysfunction with the tendency to stagger to either side and the uncontrolled head and neck movements in both directions. This presumptive diagnosis is benign idiopathic feline peripheral vestibular disease.

See **Video 12-14**. This video shows Socks, a 6-month-old castrated male domestic shorthair with a sudden onset of the abnormal gait and posture seen on this video. Your anatomic diagnosis should be right peripheral vestibular system components and left sympathetic innervation to the eye. This finding suggests a bilateral otitis media with the inner ear involved on the right side.

CASE EXAMPLE 12-9

Signalment: 2-year-old female domestic shorthair, Zaro
Chief Complaint: Abnormal head movements
History: Two months before this examination, Zaro was presented to a veterinarian for a sudden onset of a right head tilt and balance loss. These signs were diagnosed as a right peripheral vestibular system disorder. Evidence of right otitis externa was also found. During the next week, the clinical signs progressed to a bilateral loss of balance and what the referring veterinarian described as a "head bob." The head bob and a mild ataxia had persisted unchanged up to the time of this examination.
Examination: See **Video 12-15**. Note the wide head excursions with the inability to stop the head movements to either side. No abnormal nystagmus, no normal physiologic nystagmus, and no postrotatory nystagmus could be generated. This cat was also deaf.
Anatomic Diagnosis: Bilateral peripheral vestibular and cochlear components—cranial nerve VIII

The bilateral, wide, and uncontrolled head excursions are typical of bilateral peripheral vestibular disease. When the inner ear is affected by a disease process bilaterally, deafness can be recognized on your physical neurologic examination.
Differential Diagnosis: Otitis media-interna, ototoxicity

BILATERAL OTITIS MEDIA-INTERNA

Realistically, bilateral otitis involving the inner ear is the only clinical diagnosis we have ever seen as the cause of these clinical signs of acquired bilateral peripheral vestibular system dysfunction. The benign idiopathic disorder can cause bilateral clinical signs, but some asymmetry is most often seen. Radiographs of Zaro showed extensive bilateral changes diagnostic of otitis media. Despite antibiotic therapy and bilateral bulla osteotomy, Zaro's clinical signs remained unchanged.

See the following videos of other cats with bilateral otitis media-interna and clinical signs of bilateral peripheral vestibular nerve and cochlear nerve dysfunction.

Video 12-16. This video shows Fractal, a 12-year-old castrated male domestic shorthair that was anesthetized for surgical treatment of an aural hematoma. While still under anesthesia, both ears were flushed despite no indication of any otitis externa. Be aware that ear flushing procedures can cause complications and should be avoided unless absolutely necessary! On recovery from anesthesia, Fractal exhibited the clinical signs that you see on this video. Fractal did not startle even with rigorous banging of pans together behind his head as a source of a loud noise, and electrophysiologic testing (brainstem auditory evoked response [BAER]) showed no ability to stimulate a response in the cochlear nerves bilaterally. Ear flushing of any kind can result in what you have seen here, despite any indication of preexisting otitis externa. You cannot assess the tympanum for its barrier function, and small perforations may not be recognized.

Video 12-17. This video shows Magnum, an 8-year-old domestic shorthair with bilateral otitis media-interna.

Video 12-18. This video shows a 10-week-old female domestic shorthair with a 1-week history of losing her balance and what the owner described as "rolling eyes." Two days before this video was made, this kitten began to exhibit wide head excursions. Otitis media-interna was diagnosed in each ear. Treatment for otitis requires long-term oral antibiotics. Surgery is sometimes necessary, especially when the otitis is associated with polyp formation. Corticosteroids should definitely be avoided. We have seen numerous cases of otitis that have been treated with long-term corticosteroids that, secondary to immunosuppression, resulted in an abscess of the petrous portion of the temporal bone and eventual compression of the medulla and pons.

CONGENITAL PERIPHERAL VESTIBULAR SYSTEM DISEASE

Be aware that clinical signs of a peripheral vestibular system disorder are occasionally present at birth or are at least apparent as soon as the affected animal begins to move around and tries to stand and walk. These clinical signs are unilateral or bilateral and often affect both the vestibular nerve and the cochlear nerve or their labyrinthine receptors in the membranous labyrinth. Whether the vestibular system lesions are malformative or an early-onset abiotrophy is unknown. This lesion has been observed in many breeds of small animals with no proof of the presumed inheritance of the disorder. These breeds include the German shepherd,[45] Doberman pinscher, Akita, beagle, English cocker spaniel,[2] and Burmese and Siamese cats. Some of these affected animals improve or even recover in time, presumably from compensation by vestibular system components in the CNS. No microscopic lesions have been recognized in the inner ears of patients that have been studied, but mild lesions of degeneration such as an abiotrophy are difficult to recognize after the process of decalcification of the inner ear that is required to prepare tissue sections for study.

CASE EXAMPLE 12-10

Signalment: 12-year-old spayed female domestic shorthair, Pepi
Chief Complaint: Head tilt and severe balance loss
History: Six weeks before this examination, Pepi was examined for a head tilt and mild loss of balance. Otitis media-interna was diagnosed and treated with antibiotics. Despite 1 month of this therapy, her clinical signs worsened.
Examination: See **Video 12-19**. Study the severe clinical signs of vestibular system dysfunction and determine whether the involvement of this system is central or peripheral or both.
Anatomic Diagnosis: Cerebellum, pons, and medulla, sympathetic innervation to the head

You should have recognized the episodes of opisthotonus and extensor muscle rigidity in the limbs and trunk, the UMN paresis and GP ataxia in the limbs that was worse on the left side, the left facial paralysis, left facial hypalgesia, and the left sympathetic paresis. The last of these signs suggests that, in addition to the caudal cranial fossa brain lesion, a left middle-ear lesion is present or that there is one disorder affecting all of these structures. The latter diagnosis is suspected based on the palpable mass shown at the end of the video on the left side in the angle between the mandible and the transverse process of the atlas. Normally, you should be able to place your finger in a groove between these two structures as on the right side in this cat.
Differential Diagnosis: Neoplasm, inflammation-abscess

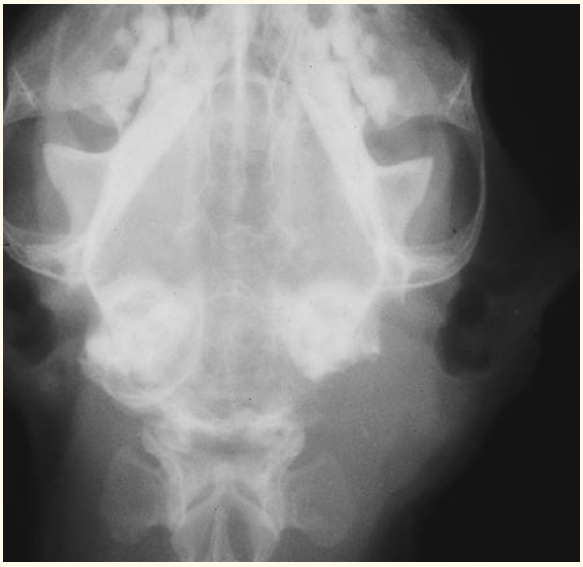

FIGURE 12-16 Dorsoventral radiograph of the head of the cat in Case Example 12-10, Video 12-19, showing the loss of a major portion of the left temporal bone (right side of image) and a soft tissue density in the right tympanic bulla.

NEOPLASM

Based on the assumption that the palpable mass near the area of the anatomic diagnosis is responsible for the clinical signs, a neoplasm or unusually large abscess or granuloma is the most likely clinical diagnosis. Radiographs suggested an aggressive neoplasm, with involvement of all portions of the left temporal bone that compressed the CNS components in the caudal cranial fossa on the left side (Figs. 12-15, 12-16). Pepi was euthanized, and necropsy confirmed this clinical diagnosis. The neoplasm was identified as a squamous cell carcinoma (Figs. 12-17, 12-18).

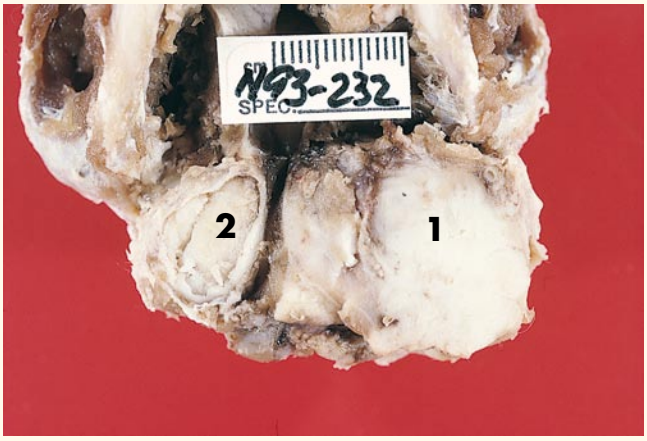

FIGURE 12-17 Ventral surface of the head of the cat in Video 12-19 at necropsy after removal of the lower jaw. Note the massive neoplasm obliterating the left temporal bone (1). Also note the exudate filling the right tympanic bulla (otitis media) (2).

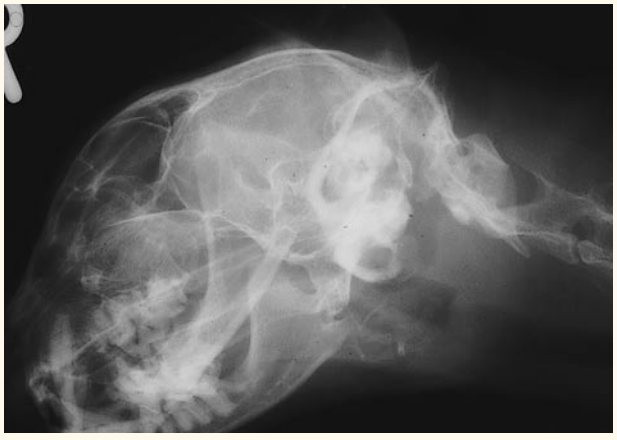

FIGURE 12-15 Lateral oblique radiograph of the head of the cat in Video 12-19. Note the loss of a major portion of the left temporal bone.

CUTEREBRA LARVAL MYIASIS

See **Video 12-20**. This video shows a 1-year old female domestic shorthair living on a farm in western New York State. Three days before this video was made, she rapidly lost the ability to stand and began to roll to the right side. These signs, as well as the right hemiplegia, can be seen on the video. She had a resting right or vertical nystagmus. Remember that persistent rolling is a clinical sign usually related to dysfunction of the central vestibular system components. The anatomic diagnosis is cerebellum, pons, and medulla. The most likely differential diagnosis for this 1-year-old cat would include three

(Continued)

CASE EXAMPLE 12-10—cont'd

FIGURE 12-18 Same specimen as in Fig. 12-17 to show the floor of the cranial cavity after removal of the brain. Note the neoplasm obliterating the left temporal bone and invading the caudal cranial fossa. The neoplasm was a squamous cell carcinoma.

FIGURE 12-19 Rostral surface of a transverse section of the preserved brain of the cat in Video 12-20 at the level of the cerebellum and medulla. Note the area of discoloration in the confluence of the cerebellar peduncles and right cerebellar medulla. This discoloration represents hemorrhage and necrosis caused by the migration of a *Cuterebra sp.* larva.

disorders: (1) Inflammation caused by the feline infectious peritonitis (FIP) virus or the protozoal agent *Toxoplasma gondii*. FIP encephalitis is the most common infection at this site. (2) Myiasis of a larva of the *Cuterebra* sp. of fly. (3) Abscess or suppurative meningoencephalitis secondary to otitis media-interna. CSF contained 89 mg/dl of protein (normal <20) and 289 white blood cells (WBCs)/mm^3 that were predominantly neutrophils. This finding supports an inflammation that might relate to any one of these three disorders. This cat was euthanized, and a necropsy diagnosed an extensive larval migration with the dead larva found in the vermis of the cerebellum. The larva was presumed to belong to a species of *Cuterebra* (Figs. 12-19, 12-20). *Cuterebra sp.* myiasis is described in Chapter 14.

FIGURE 12-20 Caudal surface of a transverse section of the preserved brain of the cat in Video 12-20 just caudal to the transverse section in Fig. 12-19. Note the discoloration of the right dorsolateral medulla and the cerebellar medulla caused by the migration of a *Cuterebra sp.* larva.

CASE EXAMPLE 12-11

Signalment: 8-month-old male Siamese
Chief Complaint: Unable to get up
History: Three months before this examination, this cat developed a gait abnormality in his pelvic limbs that slowly progressed to the thoracic limbs and involved some apparent loss of balance. For the previous few days, he has been unable to stand. During these 3 months, he was examined by the local veterinarian for numerous episodes of depression associated with a chronic fever.
Examination: See **Video 12-21**. Note the disparity in voluntary movements between the thoracic and pelvic limbs. Not shown was an abnormal vertical to horizontal left positional nystagmus.

Anatomic Diagnosis: Diffuse or multifocal including the cerebellum, pons, and medulla and the central portion of spinal cord segments C1 to C5

The history of balance loss and the persistent abnormal positional nystagmus indicates involvement of the vestibular system. The decerebellate posture (FIg. 12-21) indicates a caudal cranial fossa lesion. The tetraparesis and ataxia of all four limbs implicates dysfunction of the UMN and GP systems anywhere from the pons to the C5 spinal cord segment, with possible lesions caudal to this area as well. The more severe UMN paresis in the thoracic limbs indicates that if the lesion involves the C1-C5 spinal

cord segments, the lesions are more centrally located in these segments.

Differential Diagnosis: Encephalomyelitis—feline infectious peritonitis (FIP) virus, *T. gondii, Cryptococcus neoformans;* abscess or bacterial or fungal suppurative meningoencephalitis; *Cuterebra* larval myiasis; lymphosarcoma; neuronal storage disease

FELINE INFECTIOUS PERITONITIS VIRAL MENINGOENCEPHALITIS

An inflammatory disease is the most presumptive clinical diagnosis based on the episodes of fever. Infection with the corona virus that causes an exudative peritonitis in cats is termed *feline infectious peritonitis*. Many of these cats that have an exudative peritonitis also have a mild subclinical meningitis. A few cats develop an extensive chronic FIP viral meningoencephalomyelitis with profound neurologic signs and minimal peritonitis.[26,34,43] FIP viral meningoencephalomyelitis is by far the most common infectious disease of the CNS in cats, especially young cats. This abnormality is primarily a surface-oriented disease, which means that the leptomeninges on the external surface of the brain and spinal cord are affected, and the internal ependymal-lined ventricular system is also affected. The latter area includes the choroid plexuses and the central canal of the spinal cord. This disease is an immunopathologic disorder that involves an immune complex–induced vasculitis. The virus can be found in macrophages in the lesion. The degree of accumulation of inflammatory cells can be extensive enough to be seen on gross examination of the CNS, as well as on MR images. Although clinical signs can reflect involvement by this lesion at any level of the CNS, they often relate to the lesions in the area of the cerebellum, pons, and medulla, known as the *caudal cranial fossa*. One study reported pelvic limb paresis, abnormal nystagmus, and seizures as the most common clinical signs observed with this disease. Uveitis may also accompany the neurologic disorder. Clinical signs are slowly progressive and often include partial anorexia and a fever that are unresponsive to antibiotic therapy. The globulin fraction of serum protein is often elevated, and the CSF often is very abnormal, with protein levels even as high as 0.5 to 1.0 g/dl (normal <20 mg/dl) and hundreds of WBCs/mm^3 that vary from all mononuclear cells to a high percentage of neutrophils. Serum antibodies against this virus are usually, but not always, present in these cats. However, the antibodies are not specific for this virus but rather for the group of corona viruses.

This disease cannot be differentiated from toxoplasmosis or cryptococcosis based on the neurologic signs. The persistent fever is more typical of an FIP viral infection. As a rule, serum antibodies will be present in cats with toxoplasmosis, and an antigen test will detect cryptococcal organisms in the serum or CSF. These fungal organisms are usually evident in the cytologic examination of the CSF. Cats with an extension of infection from the middle and inner ear may produce evidence of this ear infection on your physical examination and should have recognizable temporal bone lesions on imaging studies. *Cuterebra* myiasis is less likely to cause such a slow progression of neurologic signs or the persistent fever. In addition, *Cuterebra* myiasis is seasonal. Lymphosarcoma most commonly causes an extradural focal compression of the spinal cord but is occasionally within the parenchyma and diffusely distributed through the CNS, primarily in the meninges and the perivascular spaces within the CNS. CSF changes would be expected to be mild and may include lymphocytes, lymphoblasts, or both. Many forms of neuronal storage diseases have been recognized in cats that cause slowly progressive diffuse neurologic signs of CNS dysfunction. Diffuse whole-body action–related repetitive myoclonus (tremor) is often present with storage diseases along with primarily prosencephalic signs of loss of vision, change in behavior, and seizures. Fevers do not typically occur in storage disorders.

In the cat in this case example, the CSF contained 498 mg/dl of protein and 1144 WBCs/mm^3 that were all lymphocytes or monocytes. These findings supported an FIP viral–induced inflammation. The cat was euthanized, and, at necropsy, a very extensive leptomeningitis, choroid plexitis, ependymitis, and associated encephalitis were observed that were characteristic for an infection with the FIP virus (Figs. 12-22 through 12-23).

THIAMIN DEFICIENCY ENCEPHALOPATHY

Be aware that an initial clinical sign of thiamin deficiency in small animals is usually vestibular ataxia.[15,40] However, this phase is usually

FIGURE 12-21 Cat in Video 12-21, exhibiting a decerebellate posture.

FIGURE 12-22 Transverse sections of the preserved brain of the cat in Fig. 12-21. Note the obliteration of the mesencephalic aqueduct on the left and the central canal of the C1 spinal cord segment on the right. In the center transverse section, note the thickening of the fourth ventricle caudal medullary velum, choroid plexus, and leptomeninges associated with the medulla just caudal to the confluence of the cerebellar peduncles. These areas show inflammatory lesions caused by the FIP virus.

(Continued)

CASE EXAMPLE 12-11—cont'd

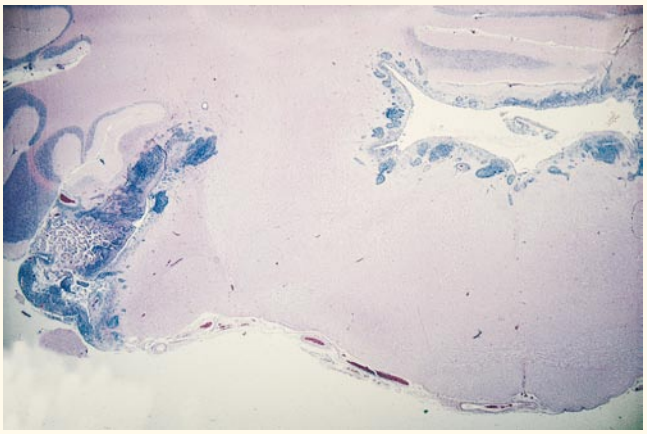

FIGURE 12-23 Microscopic section of the brain of the cat in Fig. 12-22 at the level of the confluence of the cerebellar peduncles. Note the discoloration associated with the choroid plexus on the left and associated with the fourth ventricle on the right. Infection with the FIP virus caused this choroid plexitis, ependymitis, and associated periventricular encephalitis.

rapidly followed by pupillary dilation and generalized seizures. This condition was more common when cats were fed a fish diet that contained thiaminase. Cooking the animal's food will destroy the thiamin. Also suspected is that prolonged anorexia may lead to a thiamin deficiency sufficient to cause clinical signs. The bilateral symmetric degenerative lesions in the vestibular nuclei, caudal colliculi, oculomotor nuclei, and the lateral geniculate nuclei may be recognized on MR images. The unique anatomy of these lesions was observed on MR images of a dog that led to the diagnosis of a thiamin deficiency of unknown cause.[19] Prompt treatment with thiamin intramuscularly in the early stages of this clinical disorder may lead to complete recovery from this metabolic encephalopathy rather quickly.

Horses

CASE EXAMPLE 12-12

Signalment: 4-year-old Thoroughbred-Trakener gelding
Chief Complaint: Right head deviation and "crooked" face
History: This horse was in training as a dressage horse for the U.S. Olympic team. For the past 3 weeks, the horse displayed a slight head deviation to the right and a tendency to drift to the right. For the previous 4 days, a deviation of the nose to the left was noted.
Examination: See **Video 12-22**. Note the method of blindfolding this horse and the exacerbation of the ataxia when this was performed.
Anatomic Diagnosis: Right peripheral vestibular system and facial nerve

You should have noted the normal strength and limb placement that this horse exhibits. This horse clearly knows where his limbs are located and has no postural reaction deficits.
Differential Diagnosis: Otitis media-interna, temporohyoid osteopathy, and temporal bone fracture

OTITIS MEDIA-INTERNA

These findings are the classical clinical signs of dysfunction of the vestibular portion of cranial nerve VIII and cranial nerve VII, which, in all species, most commonly relate to a middle- and inner-ear infection. We have not seen a neoplasm of the temporal bone in the horse or a neoplasm of these cranial nerves.

TEMPOROHYOID OSTEOPATHY

A unique bone disorder often accompanies this otitis in horses. This abnormality is a temporohyoid osteopathy, which involves an ankylosis of this joint associated with a proliferation of the long stylohyoid bone and probably the very small tympanohyoid by which it articulates with the petrous portion of the temporal bone. This circumstance results in a fusion of these bones at the level of the tympanic portion of the temporal bone.[5,16,47] This bony proliferation envelops the tympanic portion of the temporal bone but does not invade the tympanic cavity (see Fig. 6-41.) With this loss of mobility of the hyoid apparatus, a risk of fracture of the petrous portion of the temporal bone exists. The assumption is that the otitis precedes and induces the osteopathy, but no proof has been found. The few microscopic studies on the osteopathy have never shown any indication of an osteomyelitis. The cause of this bone lesion remains unknown and has not been observed in other species. The lesion is unrelated to any disease within the guttural pouch. The assumption is that the ankylosis is secondary to the infection, and the extensive enlargement of the stylohyoid bone is secondary to the immobility of this joint, which prevents normal remodeling of the bone. In some horses, the onset of clinical signs of vestibular nerve dysfunction and the facial paralysis are sudden and thought to be caused by the temporal bone fracture, especially in the few horses that exhibit a brief period of partial dysphagia from presumed involvement of cranial nerves IX and X at the jugular foramen. The latter development cannot be caused by the otitis. Whether otitis was present in these horses before the fracture is unknown. Occasionally, the bone lesion is bilateral, but the neurologic signs have always been unilateral. Radiographs will reveal the enlarged stylohyoid bone with fusion to the temporal bone, but this circumstance prevents evaluation of the middle-ear cavity. The ventrodorsal view is the most reliable view to observe this bone lesion but requires general anesthesia. Although CT imaging is the preferred way to diagnose this disorder and may reveal the fracture when it is present, general anesthesia is required. The enlargement of the stylohyoid bone, as well as the lack of movement

at the temporohyoid articulation, can be seen through the wall of the guttural pouch on endoscopic examination. See **Video 12-23** of an endoscopic examination of the guttural pouch of another adult horse that has a left-side stylohyoidosteopathy. The first portion of the video shows the left guttural pouch with the enlarged caudal portion of the stylohyoid bone and the lack of any movement at its articulation with the temporal bone. The last portion of the video shows the right guttural pouch with a normal stylohyoid bone. Note the movement of this bone at its articulation. You may suspect this abnormality during your physical examination by pressing dorsally on the basihyoid bone and assessing the range of motion of the hyoid apparatus, which depends on a mobile tympanohyoid articulation. You will feel resistance in horses with this bone lesion and fusion at this articulation. To prevent fracture related to this bone fusion, a portion of the affected stylohyoid bone is removed, or, more recently, the entire ceratohyoid bone has been removed. The latter surgery is easier to perform and has fewer complications.

The horse in this case example had endoscopic and radiographic evidence of the temporohyoid osteopathy. He was treated for many weeks with antibiotics, made a complete recovery, and was returned to training. Remember that this facial nerve lesion may interfere with tear production, as well as prevent eyelid closure, which places the patient at considerable risk for corneal ulceration, keratitis, or both. You must provide artificial tears for this patient. A temporary tarsorrhaphy may also be employed.

See **Video 12-24**. This video shows an 11-year-old Saddlebred gelding that, 3 days before hospitalization, suddenly experienced a severe loss of balance, with a left head tilt and a left ear droop, and with his nose deviated to the right side. He fell down and fought efforts to get him to stand for 3 days. The video was made on the third day shortly after he was helped to stand. He shows considerable limb trembling in the video, which we believe is related to his prolonged recumbency and muscle compression. Note how rapidly he moves his limbs to compensate for his balance loss. Your anatomic diagnosis should be left cranial nerve VII and the left vestibular portion of cranial nerve VIII. An enlarged stylohyoid bone was observed on endoscopic examination of the left guttural pouch. The assumption was that the sudden onset of these clinical signs was associated with a fracture of the petrous portion of the temporal bone. No CT scanning was available to confirm this diagnosis at the time this horse was studied. Although this horse improved on antibiotic therapy, 2 weeks later, he suddenly had a recurrence of the clinical signs and went down again. The assumption was that, without surgical interruption of the hyoid apparatus, another fracture had occurred. This horse was euthanized, and no necropsy was performed.

BENIGN IDIOPATHIC PERIPHERAL VESTIBULAR DISEASE

See **Video 12-25**. This video shows a 15-year-old Thoroughbred gelding with a peracute onset of balance loss with a right head tilt and a resting rotatory left abnormal nystagmus. The video was made approximately 24 hours after the onset of these clinical signs. Your anatomic diagnosis should be right vestibular portion of cranial nerve VIII. Your differential diagnosis should include otitis media-interna, temporohyoid osteopathy and temporal bone fracture, and benign idiopathic peripheral vestibular disorder. The last of these diagnoses is considered to be the most presumptive because of the acute onset of clinical signs and the absence of any facial nerve deficits. We are not aware of any published report of this benign disorder in the horse. Radiographs of the temporal and stylohyoid bones and guttural pouch endoscopy were all normal. This horse spontaneously completely recovered in approximately a 3-day period. Based on this examination and the rapid resolution of the clinical signs, we presumed that this episode was a possible example of benign idiopathic equine peripheral vestibular disease.

CASE EXAMPLE 12-13

Signalment: 15-year-old Standardbred mare
Chief Complaint: Abnormal gait
History: Three days before this examination, this mare suddenly acted unstable and exhibited a left head tilt. Her unsteady gait worsened over the 3 days.
Examination: See **Video 12-26**.
Anatomic Diagnosis: Cerebellum, pons, and medulla

If you compare the gait of this horse with that of the previously described three horses, you should recognize the significant loss of UMN and GP function in this horse that is not present in the others. This circumstance places the clinical signs of vestibular system dysfunction in this horse within the central components of the vestibular system. The right nasal hypalgesia is best explained by the lesion interrupting the spinal tract of the trigeminal nerve within the pons or rostral medulla.

Differential Diagnosis: Equine protozoal encephalitis; viral encephalomyelitis—rabies, West Nile, eastern equine; equine herpesvirus-1 vasculitis and encephalopathy; abscess; neoplasm

EQUINE PROTOZOAL ENCEPHALITIS

The most presumptive clinical diagnosis of a sudden onset and progression of clinical signs in this area of the brain is an infection with *Sarcocystis neurona*. This disorder is described in Chapter 11. The short period of observation makes rabies and eastern equine encephalomyelitis still strong contenders for this diagnosis, but the lack of any prosencephalic signs makes them less likely. The focal nature and the level of the anatomic diagnosis and the continual progression of the clinical signs make equine herpesvirus-1 infection less likely. The focal sign of facial hypalgesia in the absence of any contralateral prosencephalic signs makes any of these viral diseases unlikely. An abscess from extension of an otitis is unlikely with no initial clinical signs of otitis before the clinical signs of CNS involvement. *Streptococcus equi* abscesses are more common in foals and rare at this age. Focal neoplasms are uncommon in the CNS of horses.

The horse in this case example had serum antibodies for *S. neurona,* which supports exposure to this infectious agent. The CSF contained 51 mg/dl protein (normal <80) but 28 WBCs/mm^3 with 92% lymphocytes and 8% monocytes, which supports a nonsuppurative meningoencephalitis. Although caudal brainstem lesions caused by *S. neurona* have a fair prognosis when treated with antiprotozoal drugs, the owner of this horse elected for euthanasia. At necropsy, extensive necrosis and nonsuppurative inflammation were found in the pons and medulla associated with *S. neurona* organisms.

(Continued)

CASE EXAMPLE 12-13—cont'd

See Videos 12-27 through 12-30 for other examples of varying degree of dysfunction of the central components of the vestibular system with involvement of other systems in the medulla, pons, and cerebellum caused by a nonsuppurative encephalitis as a result of infection with *S. neurona*.

Video 12-27. This video shows a 5-year-old Standardbred gelding that, 10 days before this examination, was in training and unable to maintain his stride in the sulky and drifted to his right side. The gait disorder progressed, and 3 days before this examination the trainer noted a facial asymmetry and a tendency for the horse to circle to his right. Study this video. Note how much effort is needed make him circle to his left, and as soon as I (AD) let up on the lead shank, he veers off to his right side. Note the mild thoracic limb hypermetria with flexion of the joints, which suggests involvement of the cerebellum. Also note the left facial paralysis and atrophy of the left muscles of mastication. Your anatomic diagnosis should be cerebellum, pons, and medulla. The differential diagnosis is the same as that described for the horse in this case example. The lack of any prosencephalic signs after 10 days makes eastern equine encephalomyelitis unlikely. As a rule, rabies encephalomyelitis will cause recumbency in approximately 4 days and death by 7 to 10 days. Equine herpesvirus-1 infection causes an acute onset of clinical signs without progression after approximately 2 days. West Nile viral encephalomyelitis is still a candidate during the summer months when exposure to the carrier mosquitoes exists. However, protozoal encephalitis is still the most presumptive clinical diagnosis for this horse.

This horse was euthanized, and necropsy confirmed the diagnosis of protozoal encephalitis in the cerebellum and caudal brainstem (Figs. 12-24, 12-25).

Video 12-28. This video shows a 9-year-old Standardbred gelding that, for 4 weeks, exhibited slight ataxia when he came out of his stall. He continued racing until 10 days before this examination when he was removed from racing competition because of his progressive gait disorder. Study the video. Note the left head tilt, which indicates a dysfunction in some portion of the vestibular system. Also note that his gait clearly indicates dysfunction of the UMN and GP systems. The left facial paralysis can be caused by a lesion anywhere from the facial nucleus in the medulla to the stylomastoid foramen, where the facial nerve emerges from the facial canal and forms branches. Only a lesion in the pons and medulla can explain all of these clinical signs. This horse was treated for a presumptive *S. neurona* encephalitis and 1 month later was much improved but not sufficient to allow him to return to racing.

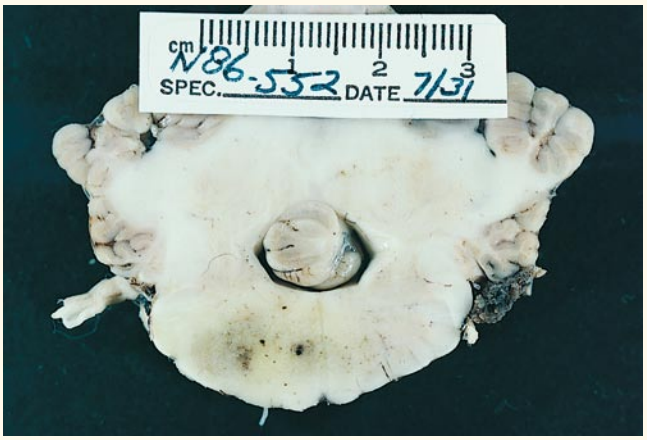

FIGURE 12-24 Caudal surface of a transverse section of the preserved brain of the horse in Video 12-27 at the level of the confluence of the cerebellar peduncles. Note the discoloration on the left side, which was caused by the inflammation and necrosis associated with infection by *S. neurona*.

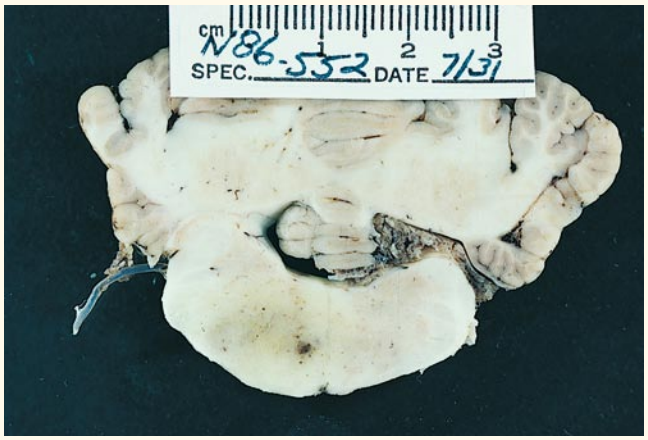

FIGURE 12-25 Caudal surface of a transverse section of the preserved brain of the horse in Video 12-27 just caudal to the transverse section in Fig. 12-24 showing the same lesion.

Video 12-29. This video shows a 7-year-old Thoroughbred stallion that, 10 days before this examination, stumbled on coming out of the starting gate. His gait abnormality worsened over the subsequent 10 days. Study the video. Note that the gait disorder represents a dysfunction of the UMN and GP systems that might be at any level between the pons and the C5 spinal cord segment. The severe atrophy of the right muscles of mastication (note the prominence of the right ramus of the mandible and facial crest) indicates that at least part of this lesion is in the pons where the motor nucleus of V is located. The only recognized cause of unilateral atrophy of the muscles of mastication in the horse at this time is an infection with *S. neurona* with loss of these GSE neuronal cell bodies and replacement by astrocytes. No obvious clinical signs of vestibular system dysfunction are noted in this horse. This horse was treated for several weeks with antiprotozoal drugs and recovered his normal gait. This recovery is on the video when snow is seen in the background. Note the absence of recovery of the muscles of mastication because that lesion is permanent.

Video 12-30. This video shows a 10-year-old Appaloosa mare that developed a right head tilt and leaned to the right one day after foaling. Her gait disorder progressed over the next 3 days before this examination. Study the video, and note her mild head tilt and tendency to lean and drift to her right side. However, note the marked clinical signs of dysfunction in the UMN and GP systems that cause her to scuff her hooves and stumble in either direction. She was euthanized, and necropsy confirmed the diagnosis of protozoal encephalitis in the caudal brainstem.

Ruminants

CASE EXAMPLE 12-14

Signalment: 1-month-old female Holstein
Chief Complaint: Head tilt
History: For the previous few days, this calf has exhibited a mild head tilt and occasionally stumbled.
Examination: See **Video 12-31**. The examiner is indicating loss of tone in the left ear, eyelids, and lips. The left palpebral reflex was decreased, but nociception from the nasal septum was normal.
Anatomic Diagnosis: Left cranial nerve VII and the vestibular portion of cranial nerve VIII
Differential Diagnosis: Otitis median-interna is the only realistic disease to consider in a calf with these clinical signs,[29] which is common in all young farm animals.[39] Similar to dogs and cats, imaging studies will help confirm this diagnosis, with CT being the most reliable. See Video 6-5 for an example of this disorder in another calf and a CT scan of the lesion. These patients should be treated rigorously with antibiotics to prevent extension of the suppurative inflammation into the cranial cavity. These patients with otitis media-interna may exhibit only clinical signs of facial nerve paralysis or only clinical signs of peripheral vestibular system dysfunction.

OTITIS MEDIA-INTERNA IN A CALF

See **Video 12-32**. This video shows two calves from the same farm. The smaller one is 2 months of age, and the larger one is 4 months of age. Both calves have shown clinical signs for approximately 10 days. The smaller calf is alert, responsive, and walks well, but you should recognize a head tilt and ear droop and make the anatomic diagnosis of a right facial (VII) and vestibular nerve (VIII) dysfunction. You should make a presumptive clinical diagnosis of a right otitis media-interna for this calf. This presumption was supported by radiographs that revealed this otitis.

OTITIS WITH INTRACRANIAL ABSCESS IN A CALF

The older calf is depressed and needs assistance to stand and holds its neck in an abnormal extended position. She has a right head tilt, drifts right, and has a left ear droop and no palpebral reflex on the left side but normal eye retraction when the eyelids are stimulated. Your anatomic diagnosis for this larger calf should be pons and medulla because of the depression, difficulty standing, and the neck extension. The left facial paralysis may be caused by the medullary lesion or an otitis media on this side. You should make a presumptive clinical diagnosis of an abscess or suppurative meningoencephalitis at this level that is an extension of an otitis media-interna that may be bilateral. CSF should reflect this suppurative inflammation. This calf was euthanized, and necropsy showed bilateral suppurative otitis media-interna and an abscess and meningitis on the left side of the pons and medulla.

CASE EXAMPLE 12-15

Signalment: 2-year-old female Hereford-Holstein cross
Chief Complaint: Depression and head tilt
History: This cow became depressed and developed a right head tilt approximately 10 days before this examination. She became more depressed and, on occasion, continually walked in circles.
Examination: See **Video 12-33**. Note that this cow's sensorium borders on obtundation. Note also the right head tilt, the paresis of the right facial muscles, muscles of mastication, and tongue muscles.
Anatomic Diagnosis: Pons and medulla—possibly diencephalon. The obtundation suggests the possibility of more than just a caudal brainstem disorder, and the dysfunction of the ascending reticular activating system may be at the level of the diencephalon.
Differential Diagnosis: Listeriosis, rabies, abscess, suppurative meningitis, thrombotic meningoencephalitis

The most common caudal brainstem disorder of adult cattle in the northeast is listeriosis.

LISTERIOSIS IN A COW

Listeriosis is caused by the bacterium, *Listeria monocytogenes*.[8,41] Most affected cattle are over 1 year of age and exhibit various combinations of clinical signs of cranial nerve dysfunction. These signs include facial paralysis, tongue paresis, dysphagia, jaw paresis, and dysfunction of the central components of the vestibular system, along with clinical signs of UMN and GP system dysfunction and loss of their normal sensorium. Some patients continually circle. This circling appears more as a propulsive circling than circling caused by a loss of balance with a vestibular system dysfunction. However, this circumstance is poorly correlated with specific lesion location. Prosencephalic lesions are uncommon with listeriosis yet are the most common cause of propulsive movements. The propulsive circling may possibly occur in these ruminants with listeriosis from involvement of the substantia nigra in the mesencephalon. The prominent caudal brainstem location of this disease reflects the likely route of entrance to the brain for this bacterium. The bacterium enters the body through abrasions and lacerations of the oral mucosa and gains access to the dendritic zones of general somatic afferent (GSA) neurons in the branches of the trigeminal nerve. The bacterium travels retrograde over these axons through the trigeminal ganglion and into the pons, where the fifth cranial nerve attaches to the brainstem. Inflammation occurs in these nerve branches and in the caudal brainstem. Small foci of necrosis filled with neutrophils are scattered primarily through the pons and medulla. Adjacent to these necrotic foci is a nonsuppurative inflammation that includes the meninges. The CSF usually reflects the nonsuppurative component of the inflammation. Rigorous treatment with penicillin will usually improve or resolve the clinical signs in cattle that are still standing. The prognosis is less favorable in small ruminants. Recumbent animals have a poor prognosis regardless of the species. Be aware that this bacterium can affect humans; thus you should, at least, wear protective gloves for this examination and administration of therapy. This organism thrives in poorly prepared silage (pH greater than 5.5), and removal of this as a feed source may prevent further affected animals on the same farm. We have never seen blindness in cattle with listeriosis or cattle with the anatomic diagnosis of a spinal

(Continued)

CASE EXAMPLE 12-15—cont'd

cord location of listeriosis. The latter circumstance may be the result of the lack of lesions in the spinal cord or the masking of these UMN and GP system lesions by the pontomedullary lesions that affect the same systems. See Video 11-33 in Case Example 11-10. This is a lamb with profound spinal cord lesions caused by listeriosis.

Rabies is an unlikely clinical diagnosis because it generally causes recumbency in a few days and death by 7 to 10 days. An abscess or suppurative meningitis (or both) secondary to otitis media-interna is more common in calves and is usually preceded by clinical signs of facial paralysis or peripheral vestibular system dysfunction. Thrombotic meningoencephalitis is caused by the bacterium *Histophilus somni* (*Hemophilus somnus*). This abnormality is a severe suppurative vasculitis and associated parenchymal necrosis that usually causes a sudden onset of profound brainstem signs or just acute death. Thrombotic meningoencephalitis is an unlikely cause of the more mild brainstem signs with cranial nerve deficits, as seen in the cow in this case example. Lesions may also occur in the prosencephalon and spinal cord. This disease is more common in feedlot cattle in the Midwest than dairy cattle in the northeast.

The CSF in the cow in this case example had 79 mg/dl protein (normal <40) and 31 WBCs/cmm^3, all of which were mononuclear cells. Listeriosis was the presumptive clinical diagnosis. This cow was euthanized, and listeriosis was confirmed at necropsy.

CASE EXAMPLE 12-16

Signalment: 9-month-old male Saanen goat
Chief Complaint: Head tilt and abnormal gait
History: Five weeks before this examination, this buck was purchased from a goat herd in Washington State and shipped by air to upstate New York. For the past 3 to 4 weeks, this buck has progressively had more difficulty walking. Recently, he has fallen, with his head extended over his neck and his eyes twitching.
Examination: See **Video 12-34**. Note the right head tilt and abnormal vertical positional nystagmus, the left spastic hemiparesis and ataxia, and the episode of rolling induced by head and neck extension.
Anatomic Diagnosis: Cerebellum, pons, and medulla

The left spastic hemiparesis and ataxia result from UMN and GP system dysfunction on the left side of the pons and medulla. The history suggesting opisthotonus may be an indication of a rostral cerebellar, pons, or midbrain lesion. The right head tilt, abnormal nystagmus, and the rolling episode to the right indicate a paradoxical involvement of the central components of the vestibular system from a lesion in the left cerebellar peduncles or a lesion in the right vestibular nuclei.
Differential Diagnosis: Listeriosis, caprine arthritis encephalitis (CAE) viral encephalitis, *Parelaphostrongylus tenuis* myiasis, abscess, neoplasm

Listeriosis, CAE, and *P. tenuis* myiasis are all common diseases of goats in the Northeast, which can occur at this anatomic site. This goat came from a CAE-free herd in the state of Washington and had no serum antibodies for this viral agent. White tail deer are not indigenous to the state of Washington, and this goat had been in New York State for only 1 week before clinical signs were observed. This time period is too short for this goat to ingest an infected mollusk or the stage-3 larva of *P. tenuis* and develop neurologic signs. Experimentally, the earliest that clinical signs were observed after feeding large quantities of stage-3 larvae to sheep and goats was 11 days. The history reveals no sign of otitis media-interna with neurologic signs to suspect an intracranial extension of that suppurative lesion. In addition, no history of any illness was found to cause a bacteremia that might result in a brain abscess. Neoplasia is rare in goats, especially at this age. Medulloblastoma (primitive neuroectodermal tumor) occurs in the cerebellum of young calves. Listeriosis was considered to be the presumptive clinical diagnosis. The CSF contained 35 mg/dl of protein (normal <40) and 15 WBCs/mm^3, with 67% monocytes and 33% lymphocytes. This buck was treated with antibiotics for 10 days but showed no improvement. He was euthanized, and necropsy showed a large well-encapsulated abscess centered in the left cerebellar peduncles and left cerebellar medulla (Fig. 12-26).[22] No source of this focal infection was found. This lesion would have been evident on CT scan or MR imaging.

See **Video 12-35**. This video shows a 4-year-old castrated male Pygmy goat that was found one afternoon with a right head tilt and circling to his left. He was worse the next day when the examination seen in the video was made. Note his severe disorientation, his right head tilt, and a tendency to drift right. Also note that his gait shows only a vestibular ataxia, and note the difficulty with holding this goat stable while trying to evaluate the hopping responses. We concluded that the hopping responses in his right limbs were mildly slow. Note his abnormal resting nystagmus. Not shown was the shift in the direction of the nystagmus with changes in the position of his head. The anatomic diagnosis is right cerebellum, pons, and medulla. The differential diagnosis is the same as that in this case example. This animal is a New York State goat, where the white tail deer are plentiful. CAE is unlikely at this age. Listeriosis and myiasis with the larva of *P. tenuis* are the most presumptive clinical diagnoses for this goat. Listeriosis is the more common cause of these brainstem signs. The CSF contained 170 mg/dl protein (normal <40) and 312 WBCs/mm^3, with 52% neutrophils, 17% lymphocytes, 31% macrophages, and no eosinophils. This goat was euthanized and a necropsy diagnosed a necrotizing meningoencephalitis associated with *L. monocytogenes* organisms.

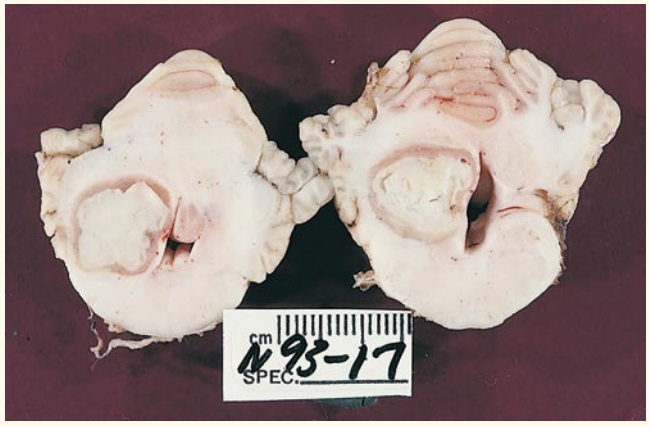

FIGURE 12-26 Caudal surface of a transverse section of the preserved brain of the goat in Video 12-34 at the level of the confluence of the cerebellar peduncles, showing an abscess centered in the left cerebellar peduncles.

Congenital Nystagmus

Congenital pendular resting nystagmus occurs in humans as an inherited abnormality or secondary to congenital lesions in the visual system of the infant, especially the retina, including ocular albinism. The nystagmus is usually pendular, meaning that the eye movements are equal in velocity in both directions and it is very rapid. This nystagmus is benign and does not interfere with vision, given that the brain usually compensates for this presumably at the level of the cerebral cortex.

A congenital rapid pendular nystagmus, which usually resolves spontaneously in a few weeks, occasionally occurs in one or more of a litter of puppies. The cause is unknown.

In the 1970s I (AD) studied a severe congenital nystagmus in an adult female Belgian shepherd (Groenendael) and in three of her six offspring from one litter. In the United States, these dogs are called Belgian sheepdogs. This extreme nystagmus was pendular, which varied in rate but was usually quite rapid. No obvious visual deficiency was noted, and ocular examination was normal. Occasionally, a dog briefly held its head to one side as it was about to jump down from a table level. No ataxia was evident. The head would occasionally oscillate with the nystagmus. Necropsy of the three littermates revealed a complete lack of any optic chiasm (Figs. 12-27 through 12-29). The optic nerve fibers continued into the ipsilateral optic tract uninterrupted and without any indication of decussation. Two of these dogs were 4 years of age at the time of necropsy, and their nystagmus had not changed. On the presumption that this malformation was an inherited disorder, and at the request of a neuroscientist interested in what determines the crossing of axons at the optic chiasm, the owner repeated the mating that produced these three affected dogs, resulting in more achiasmatic puppies with a pendular nystagmus and numerous publications.[24,48] These studies established that the retina is relatively normal in these dogs, and the effect of the autosomal-recessive inherited mutation is most likely exerted outside the retina.

In cattle, a congenital rapid fine pendular nystagmus is observed in many breeds and usually persists for the life of these animals. It does not appear to interfere with vision. As a rule, the farmer is unaware of the nystagmus until a veterinarian observes it on an examination of the animal or when restraining an animal for routine blood testing. These cattle have normal extraocular muscle function and no indication of any vestibular system dysfunction. We are not aware of any structural abnormality in the visual system of these cattle, and they have no indication of any albinism. It is sporadic in occurrence, but a high incidence was seen in one Guernsey herd. The inheritance of this nystagmus is unknown. An

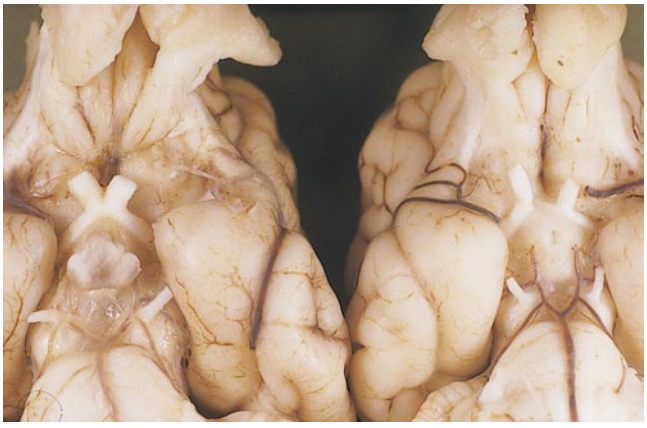

FIGURE 12-27 Ventral surface of the preserved brain of a normal dog on the left and a young adult achiasmatic Belgian shepherd on the right. Note the complete absence of the optic chiasm. This dog exhibited a constant congenital pendular nystagmus.

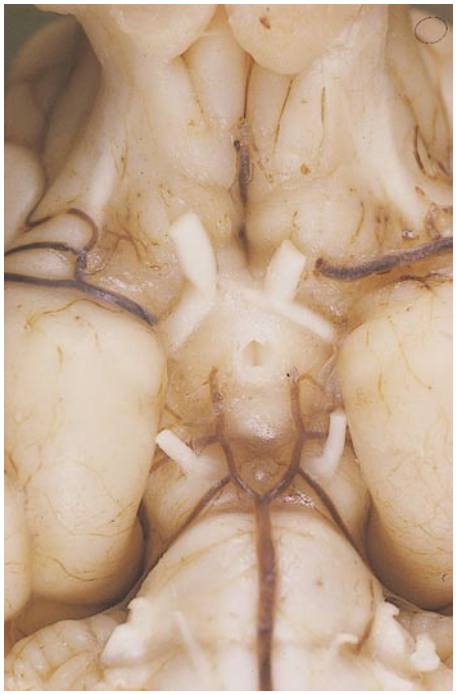

FIGURE 12-28 Ventral surface of the brain of the Belgian shepherd in Fig. 12-27 with congenital nystagmus and a failure of the optic chiasm to develop.

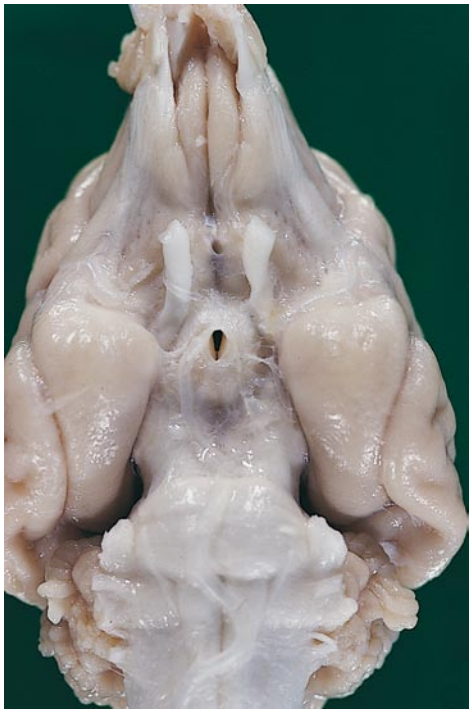

FIGURE 12-29 Ventral surface of the brain of an achiasmatic littermate of the Belgian shepherd in Fig. 12-28.

examination of 2932 cattle seen in 1 month by the ambulatory clinic at Cornell University revealed 15 animals with this pendular nystagmus.[31] See **Video 12-36**. This adult cow has congenital pendular nystagmus, also termed *ocular tremors*.

Congenital rapid fine pendular nystagmus is most often observed in cats with a varying degree of ocular albinism. An abnormality in the retinogeniculate projections and the neuronal organization of the lateral geniculate nucleus have been observed in the Siamese cat and the white Persian tiger. More retinal ganglion neurons project their axons contralaterally in Siamese cats than the normally pigmented feline breeds. No obvious impairment of vision is noted. Many of these cats also have a mild strabismus. This congenital pendular nystagmus also occurs in some cats and cattle with the Chédiak-Higashi syndrome in which pigmentation and melanin granules are abnormal.[12]

Congenital pendular nystagmus may be a result of abnormal sensory input to the system that controls the eye movements related to vision. Some aberration of the architecture of the visual pathway may be the common factor in these patients. The albino cat exhibits excessive contralateral projection of optic nerve axons, and the Belgian shepherds shows complete lack of any contralateral projection.

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