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Comparative Anatomy of the Horse, Ox, and Dog: The Brain and Associated Vessels*

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ABSTRACT: Veterinary practitioners have limited access to information about cranial nerve distribution, intracranial circulation, and brain neuroanatomy in the horse and ox. Branching of the cranial nerves varies to some degree in these species, but the exit points from the skull are very dissimilar. The arterial supply and venous drainage of the brain are decidedly different in the horse and ox. This article reviews the intracranial anatomy of the horse and ox, with reference to the dog. The motor cortex of the horse is widely distributed compared with that of the dog, and the corticospinal tract of all ungulates is poorly developed.

Neurologic problems in horses and oxen are of significant clinical, public health, and economic importance. Although many of the diseases that lead to neurologic dysfunction in these species are well described, information regarding clinical neuroanatomy is not readily available. This article covers four major topics: cranial neuroanatomy, nerves and vessels associated with the guttural pouch, brain vasculature, and gross and projection anatomy of the telencephalon and brainstem.

CRANIAL NEUROANATOMY

Like all reptiles, birds, and other mammals, the horse, ox, and dog have 12 pairs of cranial

nerves. These nerves can contain various types of projections, including special visceral (taste, smell) and special somatic (vision, hearing) afferents, general visceral and general somatic afferents, general somatic efferents (motor fibers to somatic musculature), general visceral efferents (autonomic nervous system projections), and special visceral efferents (fibers innervating muscles phylogenetically related to pharyngeal arches; these projections are now included in the general somatic efferent group).¹ Although the location and function of nuclei are generally similar between species, named nerve exit points from the skull and cutaneous zones vary (Figures 1 and 2).

The **olfactory nerve** arises from the telencephalon and contains only special visceral

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*A companion article on anatomy of the vertebral column and peripheral nerves appeared in the September/October 2007 issue.

^aDr. Levine has received research funding from Scott & White Health Center in Temple, Texas, and is a consulting veterinarian at Capital Area Veterinary Specialists in Round Rock, Texas.

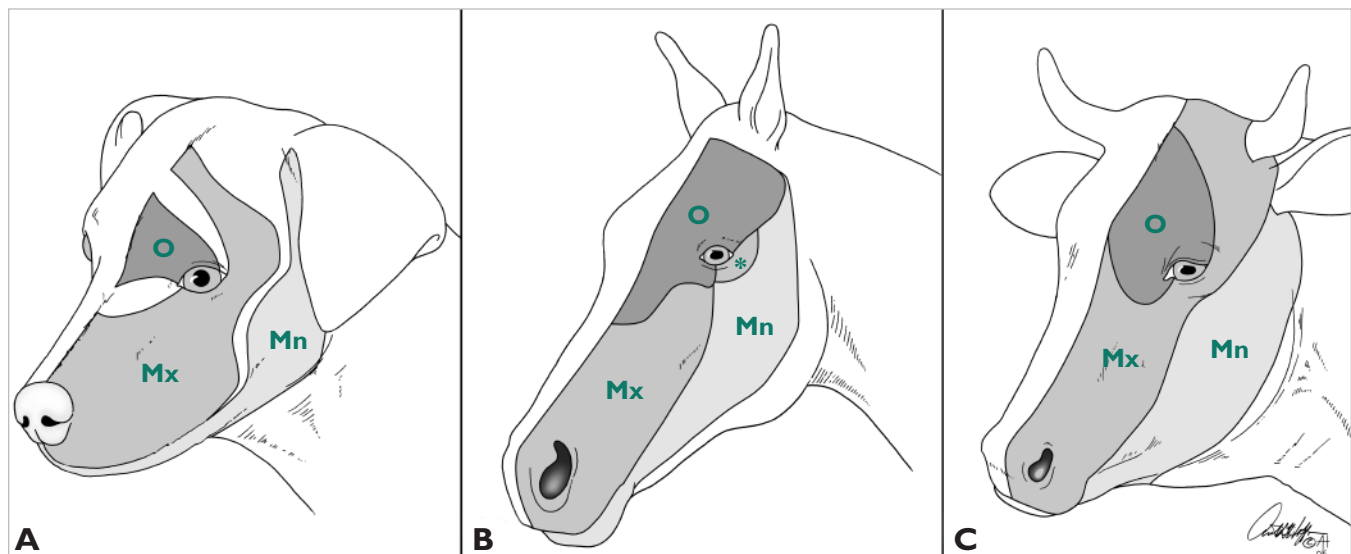


Figure 1. Schematic illustration of the autonomous and cutaneous distribution of nerves pertaining to the head of the (A) dog, (B) horse, and (C) ox. O = ophthalmic nerve; Mx = maxillary nerve (* = also within the maxillary distribution of the horse); Mn = mandibular nerve.

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afferent fibers.¹ All species have primary afferent cell bodies located in the olfactory epithelium of the nasal mucosa. Projections from these cell bodies, which replicate throughout life, enter the skull via the numerous foramina of the cribriform plate and terminate at the olfactory bulb.¹⁻³ The dog, horse, and ox also have terminal nerves arising from the nasal septum that course into the olfactory bulb along with a vomeronasal nerve arising from the vomeronasal organ.^{3,4} Neurons within the olfactory bulb project through the lateral and medial olfactory tracts, which ultimately send fibers to the medial forebrain bundle, amygdala, septal nuclei, and habenular nuclei.^{3,5,6}

Significant attention has been paid to the visual system in all species. Horses and cattle have laterally positioned eyes that afford them an almost spherical field of view.⁷ Estimated binocular overlap in the horse is 55° to 65°, with a mean maximum unocular field of 190° to 195°. Visual acuity is low, except in the ventral retina.⁹ Compared with horses, dogs have a smaller unocular field and greater binocular overlap, presumably because they evolved as a predator species.⁷

The basic neuroanatomy of the retina is similar in all mammals. Photoreceptors send projections to the inner nuclear layer, which in turn interacts with retinal ganglion cells.¹ The retinal ganglion cells and their projections enter the skull as the **optic nerve** via the optic canal.¹ Most sources indicate that 85% to 88% of fibers

from the optic nerves cross (decussate) at the optic chiasm in the horse and ox.^{1,8,10,11} The optic nerves of the horse are especially susceptible to shearing injury after head trauma, which may lead to prechiasmatal blindness.^{12,13} In the dog, approximately 75% of the optic nerve fibers decussate.^{1,7,14} Projection fibers from the retinal ganglion cells, after decussating at the optic chiasm, course caudally as the optic tract to the lateral geniculate nucleus, which sends fibers through the optic radiations to the occipital lobe for visual processing.^{1,2} The ganglion cells also project to the pretectal nuclei for modulation of parasympathetic tone to the iris and to the rostral colliculi for the startle response.^{1,2}

The **oculomotor nerve** contains two fiber types: general somatic efferent fibers, which innervate the levator palpebrae superioris, medial rectus, dorsal rectus, ventral rectus, and ventral oblique muscles; and general visceral efferent (parasympathetic) fibers, which supply the iris.^{1,5,6} In the dog, after traversing the caudal and middle cranial fossa on the ophthalmic nerve, sympathetic postganglionic projections also associate with the oculomotor nerve in the retrobulbar area; the anatomy of this pathway is believed to be similar in the ox and horse.^{1,5,6} In the horse, the oculomotor nerve courses with the cavernous sinus and exits the skull by way of the orbital fissure; the same is true for the dog.^{1,5,6,15} The ox has an oculomotor nerve that runs within the cavernous sinus for a short distance and then exits the calvaria via the

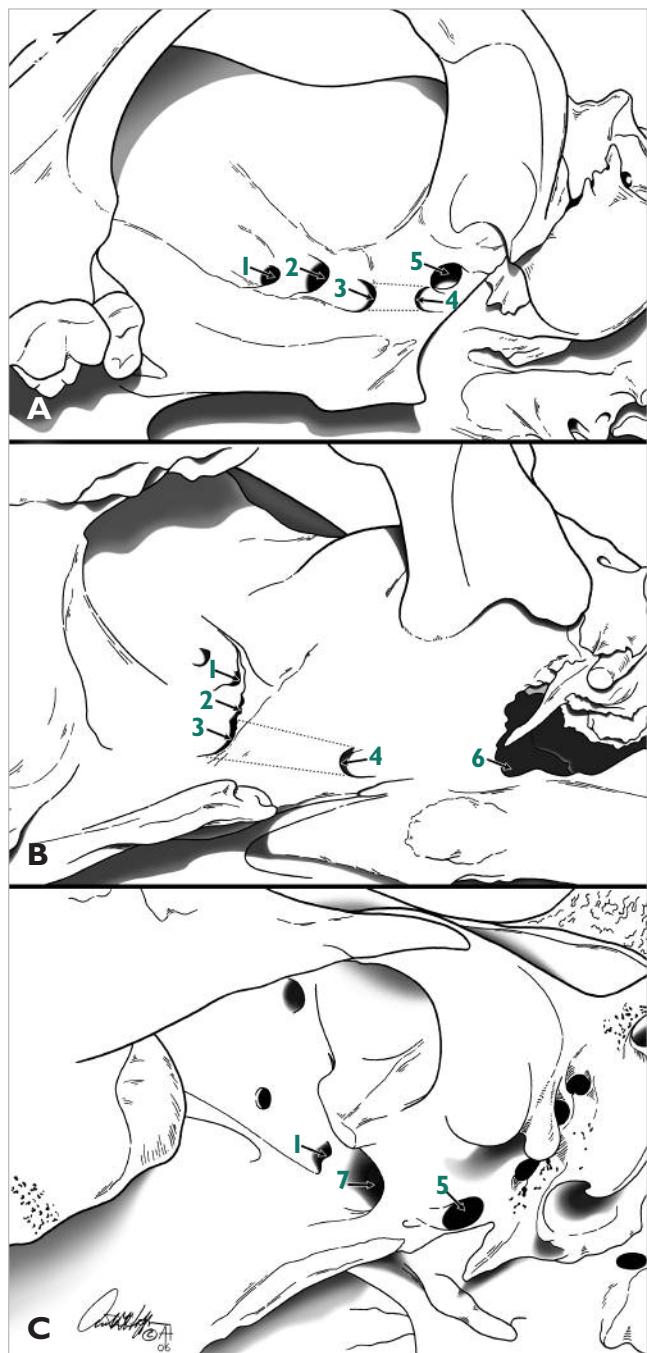


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Figure 2. Schematic illustration of the ventrolateral skull of the (A) dog, (B) horse, and (C) ox, showing various foramina. 1 = optic canal; 2 = orbital fissure; 3 = rostral alar foramen; 4 = caudal alar foramen; 5 = oval foramen; 6 = foramen lacerum (exit point of mandibular nerve in horse); 7 = foramen orbitorotundum.

foramen orbitorotundum.⁵ The foramen orbitorotundum represents fusion of the orbital fissure and foramen rotundum (round foramen) found in other species.^{5,16}

The **trochlear nerve** originates from the dorsal mid-brain and decussates within the rostral medullary velum to distribute its general somatic efferent fibers to the contralateral dorsal oblique muscle in the three species discussed.^{1,2} In the horse, the nerve may exit the calvaria by the orbital fissure or by a separate trochlear foramen.^{5,15} In the ox, the trochlear nerve exits via the foramen orbitorotundum and may be affected during lead toxicity or polioencephalomalacia, resulting in dorsomedial strabismus.⁵

The **trigeminal nerve** has three divisions: the ophthalmic, maxillary, and mandibular nerves. General somatic afferent fibers distribute through all three divisions to the head and cranial vault; the mandibular division also contains general somatic efferents that innervate muscles of mastication. The trigeminal ganglion contains the primary afferent cell bodies. In the horse, the ganglion is located dorsal to the foramen lacerum; in the ox, it sits dorsal to the foramen ovale; and in the dog, it is contained within the trigeminal canal of the petrous temporal bone.^{5,6} The cutaneous distribution of these afferents is well described in the dog and horse. More limited information is available in the ox. The trigeminal motor nucleus is located within the pons, and the afferent nucleus of the trigeminal nerve, which receives primary afferent projections, is positioned lateral to the motor nucleus as a column running through the mesencephalon, metencephalon, and myelencephalon and within the cranial cervical spinal cord.¹⁷

The **ophthalmic nerve** of the horse and dog passes laterally along the cavernous sinus and exits via the orbital fissure.^{5,6} In the ox, the nerve exits through the foramen orbitorotundum. The lacrimal branch in all species contains associated postganglionic parasympathetic fibers from the pterygopalatine ganglion that distribute to the lacrimal gland. The lacrimal nerve also contains general somatic afferents that provide sensation to the lateral superior eyelid in the ox and horse; in the dog, this nerve does not innervate facial skin.^{6,18} In the horse, the frontal branch of the ophthalmic nerve exits the medial aspect of the orbit via the supraorbital foramen, becoming the supraorbital nerve, and innervates the upper eyelid and forehead.¹⁹ Dogs and oxen lack a supraorbital foramen; in these species, the nerve exits medially through the periorbita.^{5,6} The **infratrochlear nerve** innervates the medial aspect of the eyelids, the third eyelid, and the frontal sinus in all three species.^{5,6} Long ciliary nerves, which carry postganglionic parasympathetic fibers from the oculomotor nerve to

the iris, also provide sensory innervation to the globe in all species.^{1,5,6,19} The **cornual nerve**, which is only present in the ox, originates as a branch of the zygomaticotemporal nerve and supplies sensation to the horn.^{5,17}

The **maxillary nerve** courses medially along the cavernous sinus and exits the calvaria via the foramen rotundum in the dog and the horse.^{5,17} It then enters the alar canal. Oxen lack an alar canal; therefore, the foramen orbitorotundum acts as the egress point for the maxillary nerve in this species.^{5,17} The branches of the maxillary nerve, which include the infraorbital and zygomaticofacial nerves, supply sensation to the lower eyelid, superior arcade of teeth, upper lip, nasal planum, and dorsal face in all species.

In the horse, the **mandibular nerve** exits the calvaria by way of the foramen lacerum; in the ox and dog, egress is through the foramen ovale.^{1,5,6,19} The major branches have similar distributions in all species and include the auriculotemporal, buccal, lingual, mylohyoid, and inferior alveolar nerves. The auriculotemporal nerve

supply the inner surfaces of the pinnae; general visceral efferent (parasympathetic) fibers that go to select salivary glands, the lacrimal gland, and the nasal gland; and special visceral afferent fibers that are responsible for taste in the rostral two-thirds of the tongue.^{1,5,6,19,21} In all species, the facial nerve exits the calvaria via the internal acoustic meatus; courses through the facial canal, where the autonomic and taste fibers split from the main trunk; and emerges caudomedial to the bulla from the stylomastoid foramen.^{1,5,6,19,21} Major branches in the horse, ox, and dog include the auriculopalpebral, buccal (dorsal and ventral), and cervical branches.

The **vestibulocochlear nerve** contains special somatic afferent fibers that project from the vestibular apparatus and cochlea. The nerve exits the calvaria via the internal acoustic meatus.^{5,17} Limited information is available on the physiology of the vestibular and auditory systems of the horse and ox. Both species seem to have lower thresholds for high-frequency sound compared with low-frequency sound, with normal latency of auditory

The ox has a foramen orbitorotundum that represents a combination of the orbital fissure and round foramen found in other species. This structure conveys the oculomotor, trochlear, ophthalmic, maxillary, and abducent nerves.

carries sensory input from the medial ear, temporal area, and, in the horse, portions of the guttural pouch.^{5,19,20} The lingual nerve conveys general somatic afferent fibers from the tongue. It also carries special somatic afferent fibers that have cell bodies located in the geniculate ganglion of the facial nerve and that convey taste information.²¹ Preganglionic parasympathetic fibers from the facial nerve, destined to innervate the mandibular and sublingual salivary glands, also course with the lingual nerve.²² The mandibular nerve gives rise to the inferior alveolar nerve and mental nerves, which innervate the inferior arcade of teeth and the skin over the rostral mandible, respectively.^{5,17}

The **abducent nerve** exits the skull through the orbital fissure of the dog and horse and via the foramen orbitorotundum of the ox.^{5,17} It contains general somatic efferent fibers that innervate the lateral rectus and retractor bulbi muscles in all three species.

The **facial nerve** contains general somatic efferent fibers that innervate muscles of facial expression and the caudal digastricus; general somatic afferent fibers that

evoked potentials only determined in the horse.^{23–25} Morphometry of the vestibular apparatus and cochlea in mammals exhibits few structural differences between species.²⁶

The **glossopharyngeal nerve** carries general somatic efferent fibers to the skeletal muscles of the pharynx, receives sensory projections from the pharynx, conveys information regarding taste from the caudal one-third of the tongue, receives general visceral afferents from the carotid sinus, and projects parasympathetic fibers to the parotid salivary gland. In the horse, ox, and dog, the nerve exits the calvaria via the jugular foramen. After exiting the jugular foramen, it reaches extracranial structures by coursing through the tympanoccipital fissure.⁶ The vagus and accessory nerves have the same exit points as the glossopharyngeal nerve in each species.

The **vagus, accessory, and hypoglossal nerves** are very similar in the horse, dog, and ox. The vagus nerve contains general visceral efferent parasympathetic fibers that innervate the heart and gastrointestinal system, general somatic efferent fibers (pharynx, larynx), general

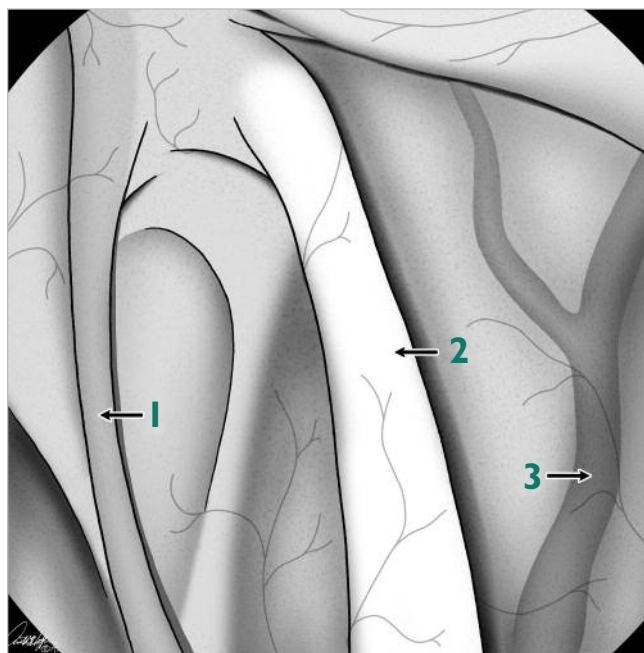


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Figure 3. Schematic illustration of the caudal aspect of the guttural pouch of the horse. 1 = mucosal fold containing the internal carotid artery, glossopharyngeal nerve, vagus nerve, accessory nerve, hypoglossal nerve, cranial cervical ganglion, and cervical sympathetic trunk; 2 = stylohyoid bone (dividing pouch into lateral and medial compartments); 3 = external carotid artery (dividing into maxillary and superficial temporal arteries).

somatic afferent fibers (nonosseous external acoustic canal), general visceral afferent fibers (gastrointestinal system, lungs), and special visceral afferent fibers to convey taste from the epiglottis.⁶ The accessory nerve has only general somatic efferent fibers and has brain and spinal cord motor nuclei. It supplies, in part, the sternocephalicus, omotransversarius, and brachiocephalicus muscles in all species discussed here.²⁷ It is the sole supply to the trapezius muscle.^{5,6,16} The hypoglossal nerve contains only general somatic efferent fibers that supply motor function to the intrinsic and extrinsic muscles of the tongue.

THE GUTTURAL POUCH

Guttural pouch mycosis is the third most common upper respiratory condition of the horse and the only disease of the guttural pouch that consistently causes neurologic signs.²⁸ Given the high incidence of guttural pouch disease, a thorough understanding of the associated vessels and cranial nerves is important.

The guttural pouch is a ventral diverticulum of the auditory tube found only in horses (Figure 3). It is

bounded by the sphenoid and occipital bones and atlas dorsally, the pharynx and esophagus ventrally, and the pterygoids, parotid salivary gland, and mandibular salivary gland laterally.^{5,29} The internal carotid artery, glossopharyngeal nerve, vagus nerve, accessory nerve, hypoglossal nerve, cranial cervical ganglion, cervical sympathetic trunk, and postganglionic sympathetic fibers to the head are found in a mucosal fold in the caudal portion of the medial compartment.^{5,19,29,30} The facial nerve has limited contact with the guttural pouch and runs dorsocaudally along the lateral compartment.^{5,19,30} The external carotid artery courses ventral to the medial pouch; as the maxillary artery, it is closely associated with the lateral compartment wall.^{5,29} The mandibular nerve has limited contact with the dorsal wall of the lateral portion.^{27,30}

Guttural pouch mycosis usually results in paresis of cranial nerves IX through XII and erosion of the internal carotid artery as infection extends into the caudodorsal portion of the medial compartment.^{28,31} Horner's syndrome, vestibular disease, and facial paresis are less common sequelae.²⁸ Rarely, the infection can spread along cranial nerves or embolize to the brain.³²

BRAIN VASCULATURE

Knowledge of the routes of venous and arterial blood flow to the brain is important for understanding disease pathophysiology and appropriate therapeutic intervention. Cerebrovascular accidents (strokes), septic emboli, and pituitary abscesses all result from lesions within blood vessels. Dissemination of neoplasia and infection also depends on vascular anatomy.

Cerebrovascular accidents not resulting from infection are rarely reported in large animals.³³ This may be due to lack of adequate recognition and limited imaging capabilities. In other species, animals with stroke present with acute-onset, lateralized central nervous system signs that may resolve with time.³⁴⁻³⁷ Understanding the particular vascular distributions in horses and oxen allows better neurologic examination, interpretation of neurologic signs, and recognition of cerebrovascular lesions on advanced imaging studies.

Septic emboli are probably the most common cause of central nervous system vasculopathy in oxen and represent a subclassification of cerebrovascular accident.^{38,39} Emboli may arise from localized infection or disseminated disease. The caudally directed basilar artery flow of the ox may lead to patterns of embolization in this species that are altered compared with those of the dog and

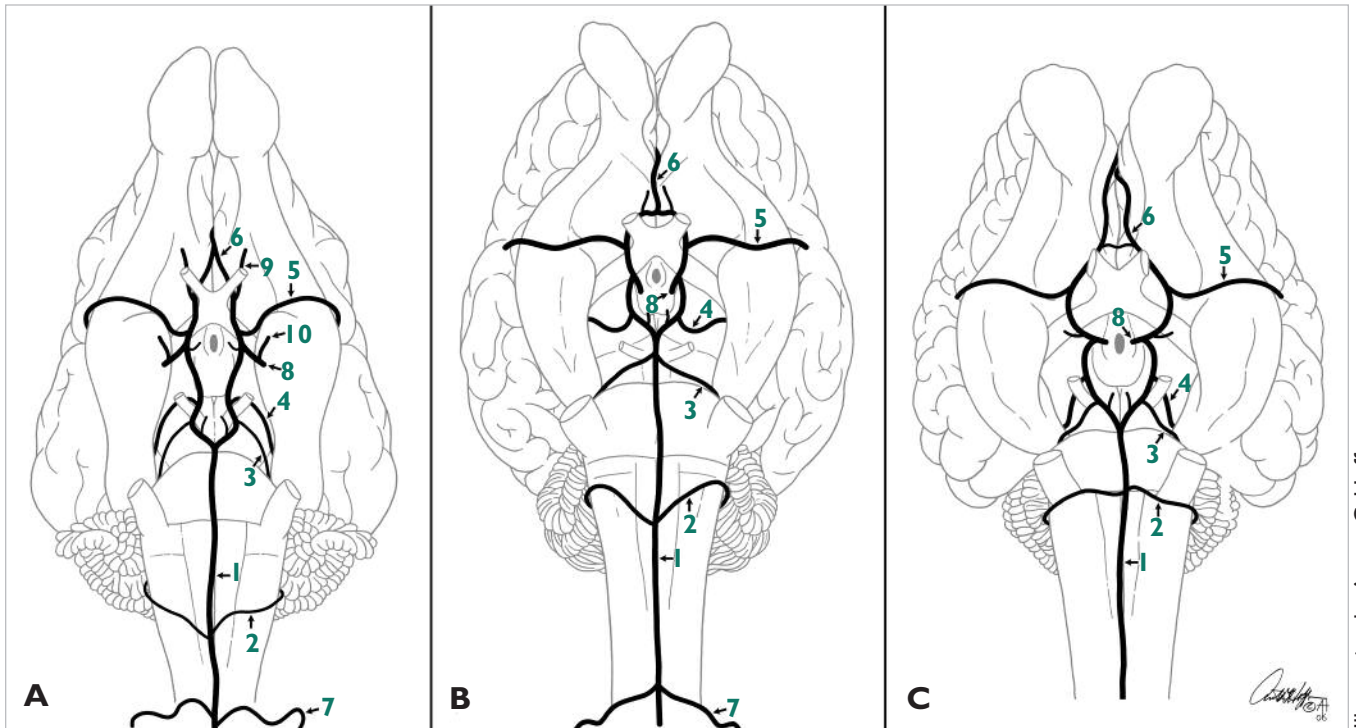


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Figure 4. Schematic illustration of the arterial vessels associated with the ventral aspect of the brain of the (A) dog, (B) horse, and (C) ox. 1 = basilar artery; 2 = caudal cerebellar artery; 3 = rostral cerebellar artery; 4 = caudal cerebral artery; 5 = middle cerebral artery; 6 = rostral cerebral artery; 7 = vertebral artery; 8 = internal carotid artery (artery of the rete in the ox); 9 = internal ophthalmic artery; 10 = anastomotic artery from external ophthalmic artery and rete mirabile.

horse. Blood flow is also important in generating pituitary abscesses. Oxen may be more frequently affected than other species due to their complex rete mirabile (discussed below).⁴⁰

Intracranial surgery, intracranial pressure monitoring, radiotherapy, and vessel-targeted chemotherapy are in their infancy in veterinary medicine.^{41–44} Variations such as the bifurcated sagittal sinus of the horse, lack of true confluence of sinuses in the horse, and rete mirabile of the ox need to be considered before surgical and other therapeutic approaches and procedures are more completely developed.^{45–49}

Arteries

The internal carotid, basilar, and maxillary arteries are three potential sources of blood for the mammalian arterial circle (Figure 4). The ventral spinal artery and the vertebral arteries contribute to the basilar artery; however, in the dog, the occipital anastomoses of the vertebral supply to the basilar artery are small.⁶ In horses, the vertebral arteries receive occipital arterial supply,^{45,46} and only the internal carotid and basilar

arteries significantly contribute to the arterial circle. The internal carotid artery is particularly large, distributing blood to all but the most caudal portions of the cerebrum.^{2,45} The maxillary artery contributes significantly to the arterial circle via a rete mirabile in the dog (33% of the blood flow) and the ox; it is not involved in circulation of blood to the brain in the horse, but it does supply the meninges.^{6,45–47,50}

In the ox, the arterial circle receives blood from the internal carotid, maxillary, occipital, and vertebral arteries^{5,45}; therefore, the cerebrum receives a mixture of blood from all sources.² Although the basilar artery is attached to the arterial circle and receives some of the occipital artery supply, its flow is directed caudally rather than rostrally, as in the horse and dog.^{2,45} The ox, like most other ruminants, loses the proximal two-thirds of its internal carotid by 18 months of age.² The distal internal carotid remains, receiving branches from the rete mirabile as it courses within the cavernous sinus to the arterial circle.²

The rete mirabile is a complex network of vessels that feeds the arterial circle in dogs and oxen. In the ox, this

network has interconnected rostral and caudal divisions that are supplied by maxillary and occipital (condylar) or vertebral artery branches, respectively.^{2,5,45} The rostral rete mirabile may directly supply the hypophysis and optic chiasm.⁵ The rete mirabile of the dog is small and connects to the internal carotid artery and the external ophthalmic artery (a branch of the maxillary artery).^{6,46,50}

Five pairs of arteries directly supply the brain in all species: the rostral cerebral, middle cerebral, caudal cerebral, rostral cerebellar, and caudal cerebellar.² In the horse, ox, and dog, these paired vessels, with the exception of the caudal cerebellar artery, which usually originates from the basilar artery, arise from the arterial circle.^{2,5,45} In the dog, the rostral cerebellar artery may arise from the basilar or caudal cerebral artery.^{34,35,51}

The distribution patterns of the five major branches from the arterial circle are similar between the dog, horse, and ox. The rostral cerebral artery courses dorsally in the longitudinal fissure to supply the rostromedial portions of the cerebrum.^{5,6,52} The middle cerebral artery distributes to the rostrolateral cerebrum, basal ganglia, and internal capsule.^{5,6} The caudal cerebral artery takes a

In general, the dorsal system begins at the convergence of several dorsal cerebral veins in the area of the crista galli of the cribriform plate in the rostral fossa.^{2,27,48} The dorsal sagittal sinus arises from this convergence and passes caudally along the dorsal midline, lying directly against the skull bones and encased in the dorsum of the falx cerebri, to the dorsum of the osseous tentorium. Along its course, it receives cerebral veins, meningeal veins, and diploic veins from the skull.^{2,6,27,48} The dorsal sagittal sinus of the horse, unlike that of the ox or dog, is partially divided by a septum or fibrous bands and bifurcates rostral to the osseous tentorium.^{27,48,54} Embryologically, in this species, the vessel originates from two separate venous channels.⁵⁴

In all species, just before the dorsal sagittal sinus reaches the osseous tentorium, it receives a single straight sinus that drains the medial cortex, the corpus callosum, the basal ganglia, and part of the diencephalon.^{6,48} The transverse sinuses run ventrally and diverge from the midline as they extend from the osseous tentorium to the retroarticular foramen, where they exit to join the extracranial venous system.^{6,48}

The horse lacks a discrete foramen ovale. Instead, this opening is part of a larger bony void known as the foramen lacerum, through which the mandibular nerve exits.

dorsomedial course through the longitudinal fissure and supplies the caudomedial portions of the cerebrum.^{5,6} The cerebellar arteries have variable distributions to the cerebellum and cerebellar peduncles, with the rostral artery typically supplying the rostral cerebellar hemispheres and vermis.^{34,53}

Venous Sinuses

Venous sinuses are vascular channels that drain the brain, meninges, and surrounding bone as well as participate in cerebrospinal fluid resorption; they are arranged into two systems.^{2,48} The dorsal system lies within the dura mater of the vault and drains the cortex of the cerebrum, the cortex of the cerebellum, the deeper telencephalon, part of the diencephalon, and the tectum of the midbrain.^{2,17,48} A ventral (basilar) system lies on the floor of the vault and drains the bulk of the brainstem.^{2,17,48} These two systems are minimally interconnected, but each has a number of communications with the extracranial venous system.^{2,17,48} Details of each system vary between species, but the similarities far outweigh the differences.

Along their course, the transverse sinuses receive the dorsal petrosal sinuses, which mainly drain the rhinencephalon.^{6,48} The transverse sinuses also receive veins from the caudal part of the cerebrum, the dorsum of the midbrain, and the meninges. In most animals, the transverse sinuses are bridged across the midline and connected to the dorsal sagittal sinus by the confluences of sinus within, or dorsal to, the base of the osseous tentorium.^{6,17,48} The confluence of sinuses in the horse (also called the *communicating sinus* in this species) connects both transverse sinuses without directly joining to the dorsal sagittal sinus.^{6,17,48} In some species, the transverse sinuses branch before exiting the retroarticular foramen, and these branches exit the skull in several places, eventually reaching the peripheral venous system.^{6,17,48}

The ventral sinus system contains the cavernous sinuses, basilar sinus, and ventral petrosal sinus and is especially plexiform in cattle.^{2,6,16,48} The cavernous sinuses lie on either side of the pituitary on the floor of the cranial vault, and cranial and caudal intercavernous sinuses join

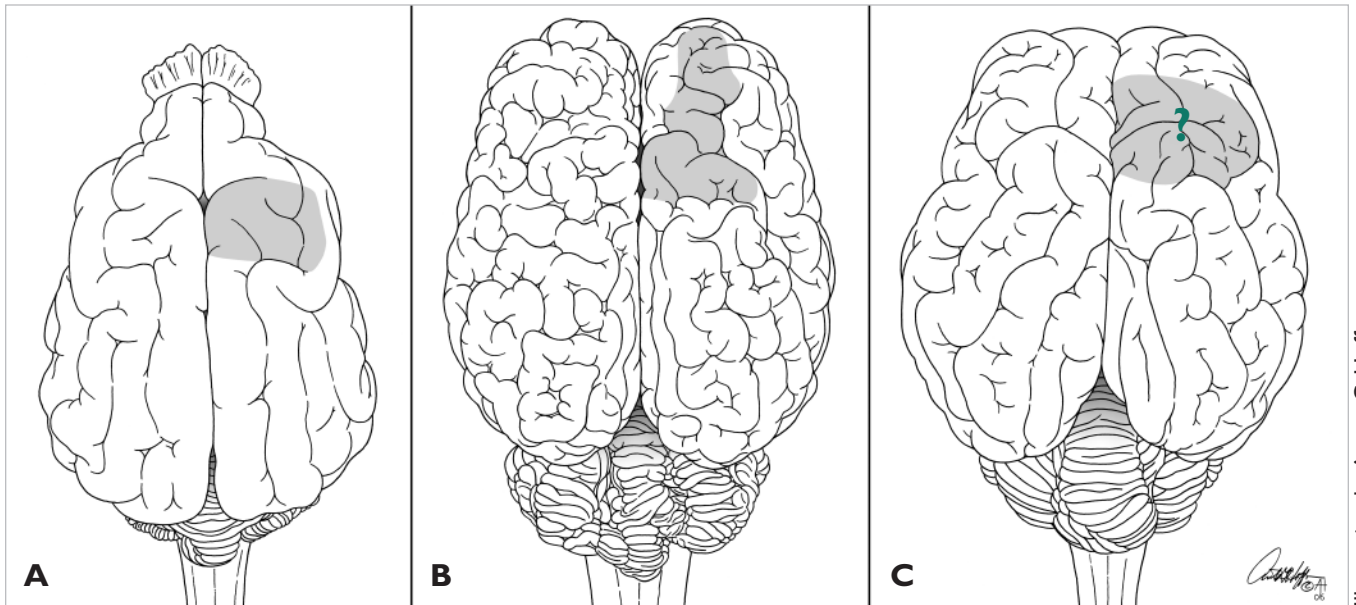


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Figure 5. Schematic illustration of the dorsal aspect of the (A) dog, (B) horse, and (C) ox brain depicting the motor cortex (shaded areas). The question mark overlying the motor cortex of the ox indicates that this illustration is speculative.

them across the midline just rostral and caudal to the pituitary. This circle of sinuses around the pituitary has emissary connections through the orbital fissure, the optic foramen, and the oval foramen to various peripheral veins.^{2,6,48} The internal carotid artery in the horse and dog and the rete mirabile in the ox lie within this circular sinus system.^{6,27} Caudally, the cavernous system communicates with the basilar sinus (very prominent in cattle), which lies on the floor of the occipital bone, and the ventral petrosal sinus, which lies within the dura mater in the caudal part of the cranial vault.^{2,6,48} The ventral petrosal sinus exits the foramen lacerum or jugular foramen to become continuous with the internal jugular vein.^{2,6,16,48}

THE TELEENCEPHALON AND BRAINSTEM

Differences in motor cortex locations and upper motor neuron tract anatomy may lead to variations in neurologic signs between species. As with brain vasculature, comparative knowledge of structure may aid in developing recommendations regarding surgical approach or radiotherapy. While radiography has traditionally been used to visualize the calvaria, advanced imaging techniques such as computed tomography and magnetic resonance imaging are now available for use in equine medicine and will allow better understanding of intracranial diseases.^{55,56} Recently, three surgical approaches

allowing access to the rostral and dorsolateral cerebral cortex of the equine brain have been described.⁴⁹ Suboccipital craniectomy was complicated by the presence of the nuchal ligament, transverse and temporal sinuses, and cranial cervical musculature.

Although the telencephalon varies more among species than other elements of the brain, its architecture is still well conserved. The telencephalon is larger and of greater transverse diameter in the horse than in the ox.⁵ The horse and ox have significantly more gyri and sulci than the dog, but the cruciate sulcus in each species is poorly developed.^{5,57} The internal structure of the telencephalon is relatively similar in all three species. The only gross differences of note are that the horse has an exceptionally small tail of the caudate nucleus and the ox and horse have relatively large amygdalas.⁵⁷

The motor cortex has been well defined in dogs and horses (Figure 5). Most sources indicate that the dog has motor and premotor areas located in gyri caudal and lateral to the cruciate sulcus.⁵⁸ The motor cortex of the horse is distributed over the dorsal rostral half of the telencephalon and can be accessed by rostrotentorial craniectomy.^{49,59} The neck and shoulder musculature has the largest motor cortex distribution.⁵⁹

The upper motor neuron systems are series of nuclei located in the telencephalon and brainstem that project

through the spinal cord to modulate alpha and gamma motor neuron activity. Two systems of upper motor neurons exist: pyramidal and extrapyramidal. Although the anatomy of these tracts has been well defined in humans, dogs, and cats, little work has been done in horses and oxen.

The corticospinal tract is the lone pyramidal projection to the spinal cord. Its nuclei are located in the motor cortex, and the axons project directly to spinal cord interneurons by way of the internal capsule, crus cerebri, and pyramids (where decussation occurs).^{1,2} It is believed to facilitate activity of flexor alpha motor neurons by way of the interneurons.^{1,2} The tract is best developed in primates and carnivores and is important in fine motor control of the distal limbs.^{1,2,60} Hooved animals have particularly poorly developed corticospinal tracts that end in the cervical spinal cord, although some sources indicate a caudal continuation through the dorsal funiculus.^{1,2,19,61} While almost the whole tract decussates in the pyramids of carnivores, only 50% of fibers decussate in ungulates.^{19,62} Only minimal paresis is seen with loss of this tract in dogs, and presumably even smaller effects would be seen in the ungulates.⁶³

The cell bodies of the rubrospinal tract are located at the level of the rostral colliculus within the red nucleus of the mesencephalon. The projection fibers decussate almost immediately and activate flexor motor neurons. The rubrospinal tract is important in semiskilled movements and is believed to be essential in gait initiation in domestic animals.^{2,64} The tract is most prominent in horses and less developed in dogs.⁶⁰

The cell bodies of the vestibulospinal tract are located in the lateral vestibular nucleus within the medulla. This tract, via interneurons, activates ipsilateral extensors, inhibits ipsilateral flexors, and inhibits contralateral extensors.^{1,2,65-67} Few differences among species are presumed to exist in this primitive system.⁶⁰

Some upper motor neurons in the medulla and pons project to the spinal cord via the reticulospinal tract. Differences of opinion exist as to whether this is a bilateral system or one that is predominantly ipsilateral.^{1,2} The pontine reticulospinal tract facilitates extensor activity, whereas the medullary system inhibits extensors.^{1,68} Little information is available on how the reticulospinal tracts differ anatomically and functionally in ungulates.

The tectospinal tract is important in the startle reflex, relaying auditory and visual information to the contralateral spinal cord.^{1,2} Given that ungulates have dis-

proportionately large rostral colliculi, this tract is presumed to be well developed in these animals.^{2,60}

CONCLUSION

The anatomy of the intracranial portions of the central nervous system is generally well conserved between species. Most observed differences are in supporting structures, such as the vasculature and calvaria. Understanding these differences, however, may prove important when considering surgical approaches to the central nervous system or the pathophysiology of specific diseases.

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ARTICLE #2 CE TEST

This article qualifies for 2 contact hours of continuing education credit from the Auburn University College of Veterinary Medicine. **Subscribers may take individual CE tests or sign up for our annual CE program.** Those who wish to apply this credit to fulfill state relicensure requirements should consult their respective state authorities regarding the applicability of this program. CE subscribers can take CE tests online and get real-time scores at CompendiumEquine.com.

1. **In the horse, the mandibular nerve exits the calvaria by way of the**
 - a. foramen orbitorotundum.
 - b. foramen lacerum.
 - c. foramen ovale.
 - d. foramen rotundum.
2. **Which statement is true with regard to the visual system in the dog, horse, and ox?**
 - a. More fibers decussate at the chiasm in the dog than in the horse or ox.
 - b. The binocular visual field of the horse is larger than that of the dog.
 - c. Visual acuity in the horse is low, except in the ventral retina.
 - d. Projection fibers from the retina ganglion cells course to the medial geniculate nucleus.
3. **The _____ is not associated with the medial compartment of the guttural pouch of the horse.**
 - a. vagus nerve
 - b. accessory nerve
 - c. internal carotid artery
 - d. mandibular nerve
4. **The rete mirabile**
 - a. is supplied by the maxillary artery in the ox.
 - b. is supplied by the basilar artery in the ox.
 - c. delivers approximately 33% of the arterial blood to the brain in the ox.
 - d. receives vertebral artery branches in the dog.
5. **Which statement is true regarding the arterial supply to the brain?**
 - a. The middle cerebral artery supplies the craniomedial cerebrum.
 - b. The caudal cerebral artery supplies portions of the brainstem.
 - c. The rostral cerebellar artery usually supplies the rostral cerebellar hemispheres and vermis.
 - d. The distribution pattern of the major branches of the arterial circle varies considerably between species.
6. **Which statement concerning the dorsal sagittal sinus is true?**
 - a. In the dog, it is bifurcated and does not connect to the confluence of sinuses directly.
 - b. It originates rostrally from a convergence of several dorsal cerebral veins in the region of the crista galli.
 - c. It passes caudally in a paramedian fashion, lying subdurally.
 - d. It only is connected to the transverse sinus in the dog.
7. **The ventral system of sinuses does not contain the**
 - a. cavernous sinuses.
 - b. basilar sinus.
 - c. transverse sinus.
 - d. ventral petrosal sinus.
8. **Which statement is false regarding the motor cortex of the horse and dog?**
 - a. The motor cortex of the horse is distributed over a larger region of the brain (dorsal rostral telencephalon).
 - b. The motor cortex of the dog is closely associated with the cruciate sulcus.
 - c. The hoof is the area of largest representation in the equine motor cortex.
 - d. The neck and shoulder are the areas of largest representation in the equine motor cortex.
9. **The corticospinal tract**
 - a. is essential to gait initiation in domestic animals.
 - b. is well developed in ungulates.
 - c. completely decussates in ungulates.
 - d. facilitates activity of flexor alpha motor neurons and is best developed in primates and carnivores.
10. **The rubrospinal tract**
 - a. is believed to be the most important upper motor neuron projection involved in gait initiation in domestic animals.
 - b. is important in fine movement coordination.
 - c. is not present in ungulates.
 - d. has cell bodies located within the telencephalon.