CANINE INTRACRANIAL VENOUS SYSTEM: A REVIEW

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ABSTRACT

The intracranial venous system (ICVS) represents in mammals a complex three-dimensional structure, which provides not only for adequate brain perfusion, but has also a significant impact on: cerebrospinal fluid (CSF) resorption, maintaining of the intracranial pressure (ICP), and brain thermoregulation. An intimate understanding of the anatomy and physiology of ICVS is fundamental for neurological diagnostics, selection of therapeutic options, and success of neurosurgical procedures in human and veterinary medicine. Since the intracranial interventions in dogs are recently performed more frequently than twenty or thirty years ago, the authors decided to review and report on the basic knowledge regarding the complex topic of morphology and function of the canine ICVS. The research strategy involved an NCBI/NLM, PubMed/MEDLINE, and Clarivate Analytics Web of Science search from January 1, 1960, to December 31, 2021, using the terms “canine dural venous sinuses” and “intracranial venous system in dogs” in the English language literature; also references from selected papers were scanned and relevant articles included.

Key words: dog; function; intracranial venous system; morphology

INTRODUCTION

The fact that the central nervous system in humans, apes, and other mammals receives: a prominent part of the cardiac output, demonstrates the key role which the cerebral blood circulation plays in maintaining adequate perfusion of the brain, and copes with its high metabolic demands is very important [16, 43]. The intracranial vasculature consists of arterial and venous parts. The intracranial venous system (ICVS) is composed of: the dural venous sinuses (DVSs), dorsal cerebral veins (DCVs), ventral cerebral veins (VCVs), cerebellar veins (CBVs), meningeal veins (MVs), emissary veins (EVs), and diploic
veins (DVs). In comparison with the arterial compartment, the venous one contains about 70—80% of the circulatory volume inside the skull [12, 16, 34, 43, 49]. Detailed knowledge of: the morphology, composition, and function of DVSs, their tributaries, important connecting veins, and potential occurrence of their anomalies is essential for neurological diagnostics, assessment of therapeutic options, and the success of neurosurgical interventions in both, human as well as in veterinary health care practice [1, 3, 7, 12, 15, 26, 32, 39, 49]. Since traumatic events as well as different pathological processes involving the skull, meninges, brain, vertebral column, and spinal cord in humans, also occur in big mammals, the structure and function of their ICVSs are similar; the porcine, canine, ovine, and feline models are often used in experimental and clinical neuroscience for translational research [10, 13, 14, 22, 24, 26, 28, 30, 34, 35, 37, 47, 51, 53—56, 58, 59]. Besides, there are owners willing to pay considerable sums of money for the treatment of their pets, the intracranial procedures in cats and dogs are performed more and more frequently during the last decades [18, 22, 31, 40, 46, 50, 52, 53]. One of the significant hazards of craniotomy and brain surgery is an injury of important venous structures. It may cause profuse bleeding, air embolism, thrombosis, development of brain oedema and/or venous haemorrhagic infarction, i.e., serious complications potentially leading to a permanent neurological deficit, even fatality [2, 48, 62]. The above-mentioned reasons inspired the authors to concentrate on the complex subject of the canine intracranial venous system.

**MATERIALS AND METHODS**

English language literature published between January 1, 1960, and December 31, 2021, was searched in the PubMed/MEDLINE, and Clarivate Analytics Web of Science databases using specific strings of terms, for example: “canine dural venous sinuses”, “intracranial venous system in dogs”, “cerebral venous system in domestic mammals”; also references from selected papers were scanned and relevant articles included. The titles and abstracts were screened by two independent reviewers (I.L., M.G.) and selected publications were critically evaluated and assessed for their quality and relevance. The literature search yielded 362 articles of which 63 met the inclusion criteria given by the 62-year time interval, by the above-mentioned string of terms, and by the preference of the sources that underwent the peer-review process. Papers published in almanacs, eventually in collections of abstracts were excluded. Any disagreements between reviewers were resolved by the consensus of all authors involved.

**Venous drainage of the canine skull and intracranial structures**

The venous blood from the canine cerebrum, cerebellum, meninges, and skull bones is collected by DCVs, VCVs, CbVs, EVs, DVs, and MVs to DVSs which transport it into the systemic circulation via paired maxillary, internal jugular, and vertebral veins, as well as via the internal vertebral venous plexus [3—5, 12, 34, 39, 49]. The vascular structures (besides DVSs), are valveless, thin-walled vessels lacking *tunica media* and *tunica adventitia* [12, 49]. By contrast, the walls of DVSs (*sinus durae matris*) in mammals are thicker, but the structure and quality of individual sinus walls may significantly differ, which is particularly important for neurosurgeons [7, 8].

**The dural venous sinuses**

The DVSs are usually situated between the periosteal and meningeal layers of the *dura mater*; in dogs, they also can run inside the canals within the cancellous layer of skull bones (*diploë*). The walls of DVSs are composed of connective tissue, that consists of collagen and elastin fibres with fibrocytes, sometimes also myocytes, i.e., plain muscle cells. The inner surface of the DVSs is covered by a smooth layer of endothelial cells [1, 17, 20, 45]. Inside DSS and TrSs in humans and in some animals (sheep) occur *chordae Willisii* [7, 26]. Besides the draining function, the dorsal sagittal sinus (DSS) also participates in the resorption of *liquor cerebrospinalis* (cerebrospinal fluid—CSF), which is accomplished via villi of arachnoid granulations situated inside the DSS and TrSs [21, 26, 31, 38, 58]. Since the intracranial veins have no valves, they are able to develop alternative channels, e.g. in the case of their obstruction [42, 43, 49]. Generally, there are two main systems providing for venous outflow from the canine cerebrum—a dorsal and ventral one [12, 15, 19, 23, 39].

The dorsal system of dural venous sinuses is composed of the DSS (*sinus sagittalis dorsalis* in Latin), the straight sinus (SS—*sinus rectus*), and usually paired (right and
left) transverse sinuses (TrSs—sinus transversus dexter et sinistre). The TrSs are usually paired, but one may be dominant, the other recessive, even absent [12, 13, 49].

The DSS begins at the cribiform plate of the ethmoid bone by the confluence of the right and left nasal veins draining the venous blood from the nasal septum, its mucous membranes, the olfactory bulbs, and adjacent meninges, and external ethmoid veins draining the right/left ophthalmic plexus [12, 14, 26]. The DSS runs caudally within the dorsal margin of the falx cerebri ventral to the sagittal suture between the parietal bones and the interparietal process of the occipital bone. Before the DSS enters the occipital bone through a special foramen (foramen sinus sagittalis dorsalis) and subsequently terminates by merging with transverse sinuses (TrSs) in the confluence of sinuses (CoSs) inside the diploë of the occipital bone (os occipitale), it is usually joined by StS. The venous blood from the cortex of frontoparietal lobes of cerebral hemispheres is drained by three to five irregularly located pairs of DCVs (venae cerebri dorsales) entering the rostral segment of the DSS. The venous blood from the cortex of occipital lobes of cerebral hemispheres is usually drained by two pairs of DCVs entering the caudal segment of the DSS [4, 12, 39, 49]. The DCVs (also termed the bridging veins) traverse the subdural space, i.e., the gap between the cerebral cortex and the dura mater, which they penetrate and enter the DVSs. The walls of the bridging veins are composed of connective tissue with circumferentially arranged collagen fibres, but they lack the outer reinforcement by arachnoid trabeculae [20]. This feature explains why their subdural portion is more fragile and prone to laceration, which usually results in the development of subdural hematoma [16, 20, 30, 32].

The venous blood from the dorsal cerebellar cortex is drained by several dorsal cerebellar veins (DCbVs—venae cerebelleares dorsales) into the right or left TrS. The venous blood from the ventral parts of the cerebellar hemispheres is collected by tiny ventral cerebellar veins (VCbVs—venae cerebelleares ventrales), also draining into the TrSs [4, 39, 49].

The venous blood from the white matter of the cerebral hemispheres, the caudate nucleus (nucleus caudatus), the diencephalon (the small parts of the brain located on either side of the 3rd ventricle, composed of the thalamus, hypothalamus, epithalamus, and subthalamus), the choroid plexus (plexus chorioideus) of the 3rd ventricle, and the mesencephalic tectum (tecum mesencephali, i.e., the dorsal part of the midbrain, is drained by the right or left thalamostriate vein (TsV—vena thalamostriata) to the paired, i.e., right or left internal cerebral vein (ICV—vena cerebri interna) [6, 19]. The right and left ICVs merge, affiliate the unpaired vein of the corpus callosum (VCC—vena corporis callosum), and drain the venous blood into the unpaired great cerebral vein (GCV—vena cerebri magna).

The GCV joins the unpaired straight sinus (StS—sinus rectus), which enters the DSS, the principal constituent of the confluence of the sinuses (CoSs—confluens sinus). However, the StS also can enter the occipital bone via an accessory foramen and merge separately with the CoSs [3, 12, 13, 15, 19, 39, 41].

The ventral system of dural venous sinuses is composed of the right and left cavernous sinus (CS—sinus cavernosus dexter et sinistre) interconnected by the rostral and caudal intercavernous sinus (IcS—sinus intercavernosus rostralis et caudalis), right and left temporal sinus (TS—sinus temporalis dexter et sinistre), and right and left dorsal petrosal sinus (DPS—sinus petrosus dorsalis dexter et sinistre), right and left ventral petrosal sinus (VPS—sinus petrosus ventralis dexter et sinistre), and right and left sigmoid sinus (SS—sinus sigmoideus dexter et sinistre), as well as right and left basilar sinus (BS—sinus basilaris dexter et sinistre) interconnected usually by an interbasilar sinus (IBS—sinus interbasilaris), located at the rostral rim of the great foramen of the occipital bone (foramen magnum ossis occipitalis). Exceptionally there are two (rostral and dorsal) interbasilar sinuses. The right/left BS is connected with the cranial segment of the ipsilateral ventral vertebral vein (vena vertebralis) by the emissary veins of the hypoglossal canal, i.e., vena emissaria canalis hypoglossi [1, 3, 12, 13, 15, 39, 41].

The venous blood from the cortex of the temporal lobes is drained by VCVs (vena cerebri ventralis dextra and sinistra) into the right or left DSS, which joins the right or left TS. TSs pass through the right or left temporal meatus (meatus temporalis) to the retroauricular foramen (foramen retroauriculare). Here the TSs become emissary veins of the foramen (vena emissaria foraminis retroauricularis dextrae et sinistre) draining into the right or left maxillary vein (MaV—vena maxillaris dextra et sinistra) [3, 5, 12, 14, 21, 41].

The venous blood from the ventral parts of the midbrain and the pons is drained into the right or left SS; the
venous blood from the dorsal medulla and choroid plexus of the 4th ventricle (ventriculus quartus) also is drained into the SSs. The SSs after merging with the VPSs continue as the right or left BS caudally, draining venous blood into the ventral internal vertebral venous plexus. The venous blood from the ventral medulla is drained via the tiny medullary veins directly into the BSs, which merge with the ventral internal vertebral venous plexus [3, 6, 12, 49].

The cavernous sinus (CaS—sinus cavernosus) is the paired venous sinus, actually trabecular dural venous structure, located parallel to either side of the hypophyseal fossa (fossa hypophyseos) on the floor of the cranium, which contains the pituitary gland. The CaS extends from the orbital fissure (fissura orbitalis) to the apex of the pyramid of the temporal bone (pyramis ossis temporalis), where it joins the right or the left VPS. The VPSs, passing through the right or left intraosseous petrooccipital canal (canalis petrooccipitalis), connect the caudal parts of the right or left CaS with the ipsilateral SSs. Each SS then fork to the internal jugular vein (IJV) rostrally, and to the vertebral vein (VV) caudally [3, 12, 31, 49]. Diagrams of the canine intracranial venous system—see Fig. 1 and Fig. 2.

**The emissary veins**

The EVs are valveless, thin-walled vascular structures connecting the extracranial venous system (e.g. the cutaneous or subcutaneous veins) with dural venous sinuses [12, 49]. Under normal physiologic conditions, deoxygenated blood is drained through EVs from extracranial to intracranial space. However, the direction of blood flow may be reversed, which helps to decrease the elevated intracranial pressure (ICP), caused by different pathological conditions, such as brain oedema, cerebral congestion, and dural venous obstruction. This way EVs (analogous to the nasal veins, the rostral tributaries of the DSS) participate in cerebral thermoregulation by protecting the brain against a rise in intracranial temperature [49]. However, the EVs also may help spread the extracranial infections into the ICVS and the brain [34]. The specific EVs get their names according to the foramina or the canals they pass through [12, 19, 44, 49].

The main emissary veins are:

a) The right/left mastoid emissary veins (MsEmVs) originate from the distal parts of TrSs or from the SSs, penetrate the occipital bone, emerge on the surface of the right or left mastoid process, and anastomose with the...

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**Fig. 1. The diagram of the canine intracranial venous system, dorsal view**

1—veins from the nasal cavity; 2—dorsal sagittal sinuses; 3—dorsal cerebral veins; 4—transverse sinuses; 5—occipital emissary veins; 6—temporal sinuses; 7—dorsal petrosal sinuses; 8—ventral cerebral veins; 9—sigmoid sinuses; 10—basilar sinuses; 11—ventral petrosal sinuses

**Fig. 2. The diagram of the canine intracranial venous system, lateral view**

1—vein from the nasal cavity; 2—dorsal sagittal sinus; 3—frontoparietal diploic veins; 4—transverse sinus; 5—occipital emissary vein; 6—vein of corpus callosum; 7—internal cerebral vein; 8—great cerebral vein; 9—straight sinus; 10—temporal sinus; 11—dorsal petrosal sinus; 12—ventral cerebral vein; 13—sinus cavernous; 14—ventral petrosal sinus; 15—sigmoid sinus; 16—basilar sinus
occipital or the dorsal auricular veins, the tributaries of the external jugular veins. The MsEmVs may be absent uni-, even bilaterally, but may also be multiple [12, 19, 23, 44, 49].

b) There are three sets of the condylar emissary veins (CoEmVs). The ventral CoEmVs connect the right/ left internal jugular vein with the system of the internal vertebral venous plexuses. The lateral CoEmVs and the dorsal CoEmVs connect the right/left internal jugular vein with the system of the external vertebral venous plexuses [12, 19, 23, 49].

c) The right/left emissary vein of the retroauricular foramen (EmVRaF) originate in the right or left TS, leave the skull through the ipsilateral retroauricular foramen and join the right or left maxillary vein caudal to the temporomandibular joints [12, 19, 23, 44, 49].

d) The right/left emissary vein of the round foramen (EmVRdF) originate in the CaS, pass through the right or left round foramen together with the maxillary branch of the trigeminal nerve, continue through the alar canal (where it joins the ophthalmic plexus) until it caudally joins the maxillary vein and veins of the pterygoid plexus. The above-mentioned extracranial veins and EmVRdF can again act as potential passages for transmitting the infection to ICVs [12, 19, 49, 61].
e) The right/left emissary carotid canal venous plexus (EmCarCanVP) passes via the carotid canal together with the right/left internal carotid artery. The EmCarCanVPs connect the CaS with the right/left internal jugular veins [12, 19, 49].

f) The right/left emissary vein of the foramen lacerum (EmVLaF) originates in the place where join the CaS with the VPS traverse the right/left foramen lacerum and enters the ipsilateral maxillary vein [12, 19, 23, 44, 49].

g) The right/left emissary carotid canal venous plexus (EmCarCanVP) passes via the carotid canal together with the right/left internal carotid artery. The EmCarCanVPs connect the CaS with the right/left internal jugular veins [12, 19, 49].

h) The right/left emissary vein of the hypoglossal canal (EmVHgC) connects the ipsilateral BSs with the internal jugular veins (IJVs), or the cranial parts of the vertebral veins (VVs) [12, 19, 49, 61].
i) There are two emissary veins connecting the ophthalmic plexus with the extracranial venous system. The first one is the right/left external ethmoidal vein (eEmV) which passes together with the ipsilateral ethmoidal artery through the ethmoidal foramen and enters the right/left ventral ophthalmic vein. The second one is the right/left frontal diploic vein passing through the right/left supraorbital foramen which connects the venous plexus located inside the diploë of the frontal bone with the ipsilateral dorsal ophthalmic veins [12, 19, 44, 49].

The diploic veins

DVs are considered an integral component of the intracranial venous system [3, 19, 39]. They are formed by thin-walled, valveless vessels which collect venous blood from the skull bones and transport it to the DVSs [49]. There are three groups of diploic veins draining specific areas of the canine skull:

a) The frontal diploic veins (FDVs—venae diploicae frontales) drain venous blood from the cancellous layer of the frontal bone via extracranial anastomoses into the right or left angular vein of the eye, eventually via intracranial anastomoses into the rostral DCVs, or directly to the rostral segment of DSS [12, 23, 31].
b) The parietal diploic veins (PDVs—venae diploicae perietales) begin in the cancellous layer of the central area of the parietal bones, Anastomose with the occipital diploic system and via intracranial anastomoses drain the venous blood into the DSS, or DCVs [12, 23, 34].
c) The occipital diploic veins (ODVs—venae diploicae occipitales) begin in the cancellous layer of the occipital bone, Anastomose with parietal diploic venous system and via intracranial anastomoses drain venous blood into the right, left, or both TrS. Frequently there are several ODVs located bilaterally [12, 23, 34].

The meningeal veins

Other significant components of the ICVS are meningeal veins [19, 49]. There are usually two groups of bilaterally located, thin-walled and valveless vessels, that collect venous blood from the dura mater—the rostral and middle meningeal veins:

a) The rostral meningeal veins (RMVs) are tiny vessels that begin in the meninges covering the frontal lobes of the cerebral hemispheres. They perforate the inner layers of the frontal bone and drain the collected venous
blood into the frontal diploic veins in the region of the cribiform plate, i.e. lamina cribrosa [12, 39].

b) The middle meningeal veins (MMVs) pass together with the middle meningeal arteries (MMAs) in the dura mater overlying the lateral surface of the cerebral hemispheres. The impression of the MMA (sulcus arteriae meningeae mediae) is visible on the internal surface of the parietal and temporal bone [44]. The middle meningeal artery enters the cranium via its foramen (foramen arteriae meningeae mediae); the MMVs join the right or left CAS. Into the oval foramen, the MMVs issue the right or left emissary veins (vena emissaria foraminis ovalis) connecting the cavernous sinus with the ipsilateral maxillary vein [12, 19, 39].

**Drainage of the intracranial venous blood to the systemic circulation**

The SSs (also named the connecting sinuses) collect the deoxygenated blood from the dorsal intracranial vascular network via the TrSs, from the ventral intracranial vascular network via the DPSs and VPSs [19, 39]. The SSs, therefore, are the principal components of the intracranial draining system returning the venous blood from the brain and the skull via the maxillary, internal jugular, external jugular, and vertebral veins, eventually internal vertebral venous plexuses to cranial or caudal vena cava (vena cava cranialis/vena cava caudalis), to the right atrium (atrium dextrum cordis), and systemic circulation [12, 49]. This task is accomplished via several specific routes. The right maxillary vein drains to the cranial vena cava via the right external jugular vein and the right brachiocephalic trunk. The left maxillary vein drains venous blood to the cranial vena cava via the left external jugular vein. The internal jugular veins are direct tributaries of the cranial vena cava, terminating in the right atrium [12, 19, 49]. The left VVs drain via the hemiazygos vein to the azygos vein, and the right VVs drain directly to the azygos vein, the tributary of the cranial vena cava. The longitudinal internal vertebral venous sinus drains the deoxygenated blood from the spinal canal via segmentally arranged intervertebral veins, passing through the intervertebral foraamina together with the spinal nerves. In the neck, the intervertebral veins drain into the right/left VVs, while in the thoracic cavity, the right intervertebral veins drain directly into the azygos vein; the left intervertebral veins, into the hemiazygos vein, and then to the azygos vein. In the cranial part of the abdomen the intervertebral veins drain via the azygos vein into the cranial vena cava; and in the caudal part of the abdomen into the caudal vena cava [12, 19, 49]. The valveless craniospinal venous system freely anastomoses with the thoracic, abdominal, sacral, as well as pelvic veins, and venous plexuses, thus providing a route for intraspinal or intracranial propagation of cancer cells or bacterial emboli and spread neoplastic or septic metastases [11, 25]. The prolonged or chronic increase of intraabdominal pressure or compression of the caudal vena cava (e.g. by gravidity, intraabdominal tumour, ascites) may also participate in the development of idiopathic intracranial hypertension [57].

The variations in size and shape of the cranium in different breeds of Canis lupus familiaris (e.g. in brachycephalic, mesocephalic, or dolicocephalic dogs) principally influence neither the elementary morphology nor function of the ICVS [14, 15].

**Physiology of intracranial venous circulation**

According to the Monro-Kellie hypothesis, the sum of brain volume plus CSF volume, plus cerebral blood volume in an intact skull remains constant [43, 60]. Therefore, any increase in one of these parameters causes a reduction in one or both of the remaining two. However, circulating arterial blood volume is not reduced, as the venous pressure is much lower and the volume of venous blood in the ICVS considerably exceeds the volume of blood inside the cerebral arteries [43]. The pulsatile arterial blood flow generates the synchronous pulsations of the brain and this phenomenon positively influences the intracranial venous blood flow. Generally, the intracranial pressure (ICP) provides for the stability of the diameter of thin-walled cerebral veins. The continuous blood flow in these vessels is maintained by the residual intracapillary pressure (vis a tergo), by the transmission of brain pulsations (vis a latere), and supported by the progressively decreasing (in an upright position negative) pressure in the intracranial venous sinuses (vis a fronte) [16, 43].

The veins in the superficial layers of the neck collapse when the surrounding pressure exceeds the venous pressure. However, veins inside the vertebral canal do not collapse. When a dog is in the sitting position, the venous pressure in the neck is usually less than atmospheric pressure. In this situation, the superficial neck veins collapse, but deeply located ones do not. Therefore, the venous blood from the head of mammals is drained via the
collapsible as well as noncollapsible channels. The blood flow in the collapsed vessels is governed by the Starling resistor principle, in the non-collapsed vessels by Poiseuille’s law [27, 29, 33, 36, 60]. Both mechanisms help to maintain steady brain perfusion as well as the stability of intracranial pressure (ICP). Several experiments in dogs have shown that CSF pressure is higher than the pressure within the DSS and that an acute elevation of CSF pressure is not followed by increased pressure in the sinus. These data imply that there is a pressure gradient encouraging the transport of CSF to the sinus. It also demonstrates that the ICVS is able to compensate for the acute changes in CSF pressure by acting as a low-pressure runoff for the subarachnoid veins [47]. Poiseuille’s law defines the velocity of the steady movement of a liquid flowing through a narrow tube (e.g. blood vessel). The value of this quality is directly proportional to the pressure gradient of the liquid between both ends of the tube and to the fourth power of its radius and is inversely proportional to the viscosity of the tube and its length [36]. The Starling resistor maintains constant flow through collapsible tubes (e.g. cortical draining veins) located in the subarachnoid space surrounded by CSF, subject to the influence of the fluctuating pressure in the rigid skull, as well as prevents siphoning of venous blood from the ICVS to the systemic circulation, and over drainage of CSF from the cranial to the spinal compartment [33, 60]. The Starling resistor is a site of compression (a so-called choke point) at the junction between the bridging vein and the DSS when the pressure in the DSS drops and becomes negative during the upright positioning of a man or an animal. In this situation, the higher CSF pressure compresses the downstream connection to the DSS and prevents venous over drainage [27, 33]. Concurrently, the pressure in the cerebral veins proximal to the choke point is maintained at a higher level than CSF pressure due to the created back force. Thus the Starling resistor helps to maintain pressure hierarchy among the liquid compartments in the cerebrum, i.e. the arterial inflow pressure is higher than the cerebral venous pressure, it is higher than the subarachnoid CSF pressure, and this is still higher than the dorsal sagittal sinus pressure [27, 60]. By contrast, this mechanism creates a pressure gradient that supports CSF drainage into the DSS via capillaries in arachnoidal villi [12, 27, 38, 60]. In the upright position of the body, the internal jugular veins collapse due to the influence of surrounding atmospheric pressure, but the rigid vertebral column seems to prevent epidural veins to collapse, and the negative epidural pressure may promote drainage of the venous blood from the skull via the noncollapsible vertebral venous plexuses [9, 27, 33, 43]. The place where the craniospinal axis gets atmospheric (the zero point) is usually at the level of the foramen magnum [33]. The intracranial and spinal CSF compartments freely intercommunicate through the foramen magnum. Under physiologic conditions, the CSF pressure is approximately 10—12 cm H₂O in the dog in a horizontal position. In the upright (e.g. in sitting) position of a dog, is the CSF pressure at the level of foramen magnum about 5 mm H₂O, but at the caudal end of the spinal canal, it can reach 30—40 cm H₂O, due to the hydrostatic pressure of CSF [27, 43]. The dura mater in the skull adheres to the inner surface of the cranium. By contrast, there is the epidural space between the spinal dural sac (saccus dura matris spinalis) and the vertebral canal, filled with compressible fatty tissue and venous epidural plexuses, and its capacity in dogs varies between 100 and 300 ccm. This reservoir helps to absorb the CSF (and intracranial) pressure fluctuations [43]. Even during expiration is the intrathoracic (intrapleural) pressure subatmospheric, i.e. about 5 cm H₂O. An inspiration usually causes the further decrease of the intrathoracic pressure (to approximately 8 cm H₂O). This negative pressure helps to keep dilated the intrathoracic veins and supports the return of deoxygenated blood from the head to the right atrium [43, 63].

In most quadrupeds, including dogs, the longitudinal axis of the skull and the centreline of the vertebral canal, as well as centre lines of major veins in the atlantooccipital region meet at an obtuse angle [44]. When the animal is placed in a non-physiological supine position (e.g. for abdominal surgery or imaging procedure), its head is reclined. Accordingly, jugular and vertebral veins become stretched and/or kinked, which significantly reduces cerebral venous outflow. This may cause venous congestion and a concomitant increase of the intracranial pressure, potentially damaging the brain [27, 33].

CONCLUSIONS

The canine cerebral venous system is composed of DVs, as well as DCVs, EVs, DVs. DVs are located between a periosteal and meningeal layer of the dura mater,
eventually inside the diploic canals of cranial bones. The intracranial veins are thin-walled, valveless vessels, DVSs are noncollapsible channels. The ICVS is divided into the dorsal and ventral systems. The dorsal system consists of the DSS, StS, TrSs, and their tributaries, i.e. GCV, dorsal and ventral CbVs, DVs, and EVs. The ventral system consists of the CsS, ICsS, DVPs, VPSs, TSs, SSs, BS, IBS with their tributaries, i.e. VCVs and MVs. The ICVS drains the venous blood to the systemic circulation via MaVs, IJVs, EJVs, and vertebral venous plexuses. The steady brain perfusion as well as CSF resorption, and stability of ICP in the rigid canine skull are maintained by the Starling resister mechanism, the Poiseuille’s law, and the Monro-Kellie doctrine. The presented paper reports on basic knowledge regarded the complicated topic of ICVS. Further studies dealing with the canine ICVS variations as well as with the canine dural sinus wall microstructure are planned.

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Conflict of Interest

The authors declare no conflict of interest.

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