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Domestic cat's internal carotid artery in ontogenesis

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Abstract: The aim of the study was to trace the presence of the internal carotid artery in the system of cerebral arteries of the domestic cat and to determine the role of this artery in supplying blood to the brain in ontogenesis. The available publications provide ambiguous or even contradictory information. The authors of some studies claim that there is no extracranial segment in the domestic cat's internal carotid artery. Other authors reported the internal carotid artery in the arterial pattern of the encephalon base. The study was conducted on sixty-one domestic cats: fifteen foetuses, sixteen juvenile cats, and thirty adult cats were analysed. The internal carotid artery – a vessel with a relatively large lumen – was fully preserved in all the foetuses and most of the juvenile animals. This artery was not complete with regard to the adults and some juvenile individuals, because it had lost the extracranial segment as a result of the obliteration process. A precise description of this area is not only of biological, but also of clinical, significance. The knowledge of the anatomical structure of cerebral vessels is particularly important to correctly interpret images obtained during diagnostic tests and to conduct surgical procedures correctly.

Keywords: anatomy; brain arteries; brain supply; morphology

The available publications provide ambiguous or even contradictory information on the internal carotid artery in the arterial system of a cat's head. The authors of some studies state that there is no extracranial segment in the domestic cat's internal carotid artery (Kamijyo and Garcia 1975; Bugge 1978; Klein 1980; Simoens et al. 1987; Frackowiak 2003; Frackowiak and Godynicki 2003; Kier et al. 2019). Some authors (Nickiel and Schwarz 1963; McClure et al. 1973; Nickel et al. 1996) did, however, find an extracranial segment of the internal carotid artery in cats. The authors of some studies analysed very few specimens, for example, Kamijyo and Garcia (1975) analysed seven adults, while Simoens et al. (1987) analysed a total of five cats. These facts inspired our research in an attempt to verify this ambiguous information.

A precise description of this area is not only of biological, but also of clinical, significance. The knowledge of the anatomical structure of cerebral vessels is particularly important to correctly interpret images obtained in diagnostic tests, both by computed tomography (CT) and magnetic resonance imaging (MRI).

Unlike classic X-ray images, CTs and MRIs give images with good tissue contrast in places with high-complexity tissue structures such as the central nervous system (CNS), chest, and abdominal cavity (Caine et al. 2019). Information about arterial vessels is particularly important during brain surgery as it enables the precise location and ligation of the vessels supplying blood to the brain (Ijiri et al. 2014).

The aim of the study was to trace the presence of the internal carotid artery in the cerebral arterial system of the domestic cat and to determine the role of this artery in supplying blood to the brain in ontogenesis.

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MATERIAL AND METHODS

The study was conducted on sixty-one domestic cats of both sexes (thirty-nine females and twenty-two males) divided into three groups: fifteen foetuses with a crown-rump length of 84–126 mm, sixteen juvenile cats aged 4–8 weeks, and thirty adult cats. The cadavers were delivered from veterinary clinics. These animals had been euthanised [using xylazine (intramuscular; i.m.), ketamine (i.m.), and pentobarbital (intravenous; i.v.)] for medical reasons other than circulatory or neurological disorders.

Forty-two randomly selected cadavers were processed by injecting a COLOREX® (Śnieżka, Warszawa, Poland) stained solution of the chemo-setting acrylic material Duracryl® Plus (SpofaDental, Jičín, Czech Republic) into both the common carotid arteries. After a short time (15–20 min) necessary for setting, the specimens were enzymatically macerated with Persil® powder (Henkel, Düsseldorf, Germany) diluted in water at 42 °C for about a month. This procedure resulted in corrosion castings of the vessels on a bone scaffold (without the animal's tissues, except the bones). The second method, applied to nineteen specimens, consisted of passing the liquid-stained latex LBS 3060 into both common carotid arteries, leaving it to set in a 5% formalin solution for 2 weeks, then preparing the blood vessels manually using surgical instruments during dissection, in order to view them within the tissue.

No ethics committee approvals were required to conduct the experiments on the cadavers. An ethical commission approval is only needed to use live animals. The transport and collection of the cadavers were carried out in accordance with the standard operating procedure: SOP-17-CW-03.

The names of the anatomical structures were standardised according to Nomina Anatomica Veterinaria (International Committee on Veterinary Gross Anatomical Nomenclature 2017).

RESULTS

The analysis of the course of the internal carotid artery in the cat cadavers revealed an intracranial segment located in the cranial cavity and an extracranial segment located outside the skull. The intracranial segment finally branched into the rostral cerebral artery and the caudal communicating artery, i.e., the main components of the cerebral arterial circle. The extracranial segment of the internal carotid artery was a branch of the final division of the common carotid artery.

The common carotid artery was divided into the external carotid artery and internal carotid artery bilaterally in all the foetuses and in twelve out of the sixteen juvenile animals. The external carotid artery continued as the main arterial vessel in the head. The internal carotid artery supplies blood to the encephalon and is first directed dorsally, entering the jugular foramen without passing through it, and forming an arc of about 180°. It is shaped like an inverted letter U (Figure 1). In its further course, it is directed towards the cranial cavity, in which it enters through the carotid artery canal. The vessel has a relatively large lumen throughout its course.

The internal carotid artery in all the adult cat specimens and four juveniles was incomplete by virtue of the extracranial segment being missing. All the adult cats had the carotid sinus at the point where the obliterated extracranial segment of the internal carotid artery diverged from the common carotid artery. The carotid sinus is a very short section of the extracranial part of the internal carotid artery and it was not found in the foetuses or juvenile cats. The occipital artery branched from the carotid sinus; however, in the foetuses and juvenile animals, it branched directly from the common carotid artery, bilaterally in nineteen cats and unilater-

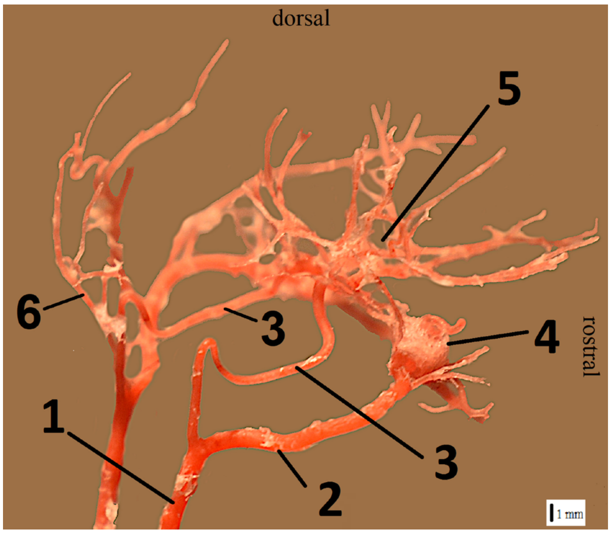

Figure 1. Corrosion cast of the common carotid artery and its branches in a cat foetus. The internal carotid artery is fully functional

1 – common carotid artery; 2 – external carotid artery; 3 – internal carotid artery; 4 – rete mirabile of the maxillary artery; 5 – arterial circle of the brain; 6 – occipital artery

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ally in three. In five foetuses and the juvenile cats, the occipital artery branched bilaterally from the external carotid artery, and unilaterally in three. The ascending pharyngeal artery is a branch of the occipital artery running along the lateral surface of the bulla tympanica and dividing into two branches in the middle of its course. One of these, located medially, was directed towards the pharyngeal wall, and the branch with a lateral course was directed towards the carotid artery canal. The lateral branch of the ascending pharyngeal artery was connected with the internal carotid artery in the carotid artery canal in ten foetal specimens. A similar connection of the arteries was found in the specimens of eleven juvenile cats (Figure 2). No connection, of these arteries, was observed in the remaining specimens from these groups. There was also no extracranial segment of the internal carotid artery found in the specimens of five juvenile animals.

No extracranial segment of the internal carotid artery was observed in any specimen from the group of thirty adult animals, with only the intracranial segment of this vessel apparent. The connection of the lateral branch of the ascending pharyngeal artery with the intracranial segment of the internal carotid artery was observed in nineteen specimens. There was a unilateral connection of these arteries in three specimens. These arteries did not connect in the remaining eight specimens because the final fragment of the ascending pharyngeal artery lost its lumen and did not reach the intracranial segment of the internal carotid artery. Regardless of the presence or absence of this connection between these vessels, the ascending pharyngeal artery was always a vessel with a very small lumen.

There was a permanent connection between the intracranial segment of the internal carotid artery

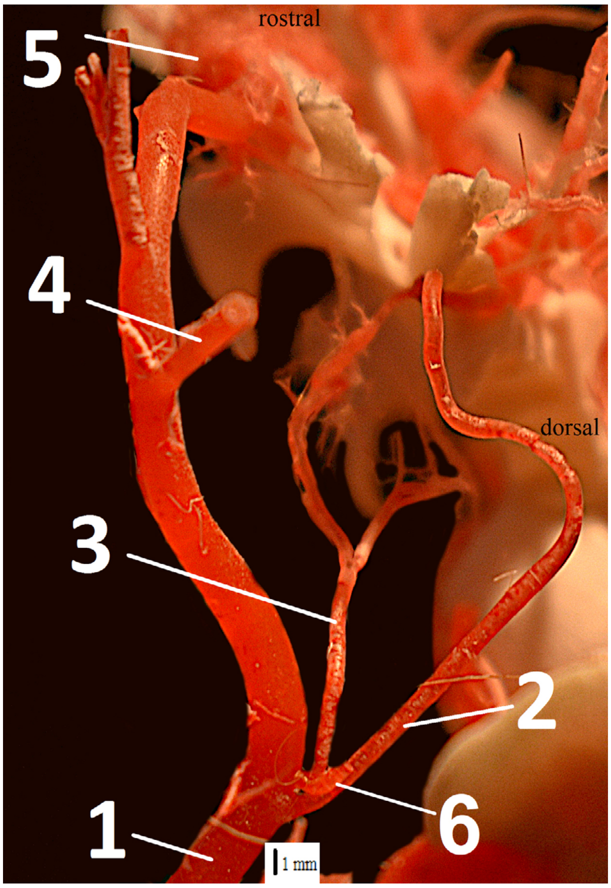

Figure 2. Corrosion cast of the common carotid artery and its branches in a juvenile cat. The ascending pharyngeal artery is a branch of the occipital artery. The lateral branch of the ascending pharyngeal artery is connected to the internal carotid artery

1 – common carotid artery; 2 – internal carotid artery; 3 – ascending pharyngeal artery; 4 – caudal auricular artery; 5 – rete mirabile of the maxillary artery; 6 – beginning of the occipital artery (the remainder of the occipital artery has been removed to allow better visibility of the internal carotid artery)

Table 1. Summary of the blood vessels in the analysed cats

Name of vessel	From	In whom it occurs
The internal carotid artery (extracranial and intracranial segments)	the common carotid artery	in all the foetuses and in 12 out of the 16 juvenile cats
The occipital artery	the carotid sinus	in the adult cats
The occipital artery	the common carotid artery	in the foetuses and juvenile cats: 19 bilaterally, 3 unilaterally
The occipital artery	the external carotid artery	in the foetuses and juvenile cats: 5 bilaterally, 3 unilaterally
Lateral branch of the ascending pharyngeal artery	the occipital artery	bilaterally in 10 foetuses, 11 juvenile cats, 19 adult cats, unilaterally in 3 adult cats
Rami retis	the maxillary artery	in all the cats

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and the rami retis passing through the orbital fissure in all the cat specimens of all age groups. The branches emerged from the rete mirabile of the maxillary artery.

It is also possible that the ascending pharyngeal artery provides blood flow to the intracranial segment of the internal carotid artery (Table 1).

In the adult specimens, the lumen of the intracranial segment of the internal carotid artery was larger from the connection with the rami retis to the site of the final division into the vessels of the arterial circle of the brain. However, the caudal fragment of this artery was characterised by a very small lumen, which was comparable to the cross-section of the ascending pharyngeal artery with which it connects.

DISCUSSION

Our study showed that the internal carotid artery in the studied domestic cats underwent fundamental changes at different periods of ontogenesis. In the foetuses and the majority of the juvenile cats, it was fully developed (contained extracranial and intracranial segments) and connected to the common carotid artery with the arterial circle of the brain. However, the initial segment, i.e., the extracranial segment of the internal carotid artery, became obliterated in the older and adult animals. The only trace of its earlier presence was the carotid sinus – the bulb remaining on the common carotid artery. As a result of the obliteration of the extracranial segment of the internal carotid artery, the connection of the common carotid artery with the arterial circle of the brain was broken. In the foetuses and juvenile cats, the blood supply to the brain came from two sources: the complete internal carotid artery and the maxillary artery. Blood was distributed from the maxillary artery to the arterial circle of the brain through the vessels of the rete mirabile of the maxillary artery. The rami retis passed through the orbital fissure and anastomosed with the intracranial segment of the internal carotid artery. Some researchers did not find the extracranial segment of the internal carotid artery (Kamijyo and Garcia 1975; Bugge 1978; Klein 1980; Simoens et al. 1987; Frackowiak 2003; Frackowiak and Godynicki 2003; Kier et al. 2019). The results of their studies, in line with ours, found it only in adult cats as well as in some juvenile individuals. The authors of the following studies stated that they observed the extracranial segment of the internal carotid artery in their cat specimens (Nickiel and Schwarz 1963; McClure et al. 1973; Nickel et al. 1996).

The specific arterial pattern of the domestic cat's encephalon base was confirmed by the phylogenesis of the species from the Felidae family. Obliterations of the extracranial segment of the internal carotid artery and the participation of the rete mirabile of the maxillary artery in the distribution of blood to the encephalon were demonstrated in the African lion (Hsieh and Takemura 1994; Frackowiak and Godynicki 2003), serval, Eurasian lynx, Bengal cat, jungle cat, puma, leopard, jaguar, and tiger (Frackowiak and Godynicki 2003). Apart from those, such an arterial pattern of the encephalon base was also observed in other representatives of the Carnivora order, e.g., the large Indian civet of the Viverridae family (Frackowiak 2003) and the hyena of the Hyaenidae family (Bugge 1978).

Interestingly, the extracranial segment of the internal carotid artery is not obliterated in the representatives of other families and species of the Carnivora order. During the entire ontogenesis, it is a source of blood for the brain, as was demonstrated in studies on the dog, fox, raccoon, and representatives of the Phocidae, Mustelidae, Ursidae, and Procyonidae families (Nickiel and Schwarz 1963; Frackowiak 2003; Skoczylas et al. 2016). As the internal carotid artery in the dog and other canines (Caniformia) is active throughout their lifetime (Nickiel and Schwarz 1963), the arterial patterns of the encephalon base are fundamentally different in Feliformia. In the available literature, speculation can be found on the advisability of a loss of the internal carotid artery in some animal species. According to Zedenov (1937), the obliteration of a ruminants' extracranial segment of the internal carotid artery takes place to eliminate factors emitting interference with low-frequency sounds. This process consists of the displacement of the tympanic part of the temporal bone.

The internal carotid artery is also the main source of blood in animals belonging to various other taxa, e.g., the domestic horse and donkey (Nickiel and Schwarz 1963; Aly et al. 1981) as well as the European rabbit and European hare (Brudnicki et al. 2012; Brudnicki et al. 2015). The connection of the arterial circle of the brain with the internal carotid artery was found in some rodents (Rodentia), e.g., the Cairo spiny mouse, muskrat, brown rat, and North

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American porcupine (Bugge 1978; Frackowiak 2003; Szczurkowski et al. 2007; Esteves et al. 2013). The obliteration of the extracranial segment of the internal carotid artery, which was demonstrated in our study and described in other representatives of the Felidae family, was also observed in animals of other orders. The phenomenon of the obliteration of the extracranial segment of the internal carotid artery or the presence of a vessel with a very narrow lumen, without significance to the supply of blood to the brain, was found in some animals of the Rodentia order, such as the African crested porcupine, guinea pig, common degu, long-tailed chinchilla, and red squirrel (Ocal and Ozer 1992; Aydin et al. 2005; Aydin 2008; Brudnicki et al. 2014; Kuchinka 2017), and in ruminants (Wible 1986).

Our study showed that the weak ascending pharyngeal artery in the cat may connect the common carotid artery with the intracranial segment of the internal carotid artery. There were similar descriptions of the domestic cat's lateral branch of the ascending pharyngeal artery in other publications (Kamijyo and Garcia 1975; Klein 1980; Kier et al. 2019).

In conclusion, it can be stated, that:

1. The internal carotid artery is fully preserved in the foetuses only and, in most cases, juvenile cats up to about 8 weeks of age.
2. After the obliteration of the extracranial segment of the cat's internal carotid artery, the arterial circle of the brain connects with the common carotid artery only through the thin (weak) ascending pharyngeal artery.
3. After the obliteration of the extracranial segment of the cat's internal carotid artery, the maxillary artery becomes the main source of blood for the encephalon.

Conflict of interest

The authors declare no conflict of interest.

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