

Morphological examination of the domestic cat's cervicothoracic ganglion in ontogenesis

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Summary

The cervicothoracic ganglion belongs to the sympathetic part of the autonomic nervous system. It is responsible for transmitting signals from the central nervous system to the organs of the thorax. Its most important function is to transmit impulses modulating heart activity. We present the results of an anatomical study that was conducted on 33 domestic cats from three age groups. The results allow us to determine which changes occur in the morphology of the cervicothoracic ganglion during the development of the domestic cat and those that occur already in adult life. The variability of this structure manifests itself in the shape, location and size of the bilateral ganglia. There is also a difference in the course of the cardiac branches and of the bilateral ganglia. In adult cats, the predominant location of the ganglion was the first intercostal space. In contrast, in young cats and fetuses, the ganglia were more distributed between the first and second intercostal spaces. Additionally, the younger the cat, the more often the ganglia occurred under the second rib. The ganglia in domestic cats show some similarities with other species, but retain species-specific features such as the direction of propagation of the subclavian loop fibres.

Keywords: anatomy, cervicothoracic ganglion, cat, ontogenesis

The cervicothoracic ganglion (*ganglion cervicothoracicum*) aka the stellate ganglion (*ganglion stellatum*) is an element of the autonomic nervous system which derives from its sympathetic division. The stellate ganglion is located in the thoracic cranial aperture region. It is a structure which can be found on both sides of the body. It is located in the first intercostal space between the seventh cervical and first thoracic vertebrae and caudally from the transverse process of the seventh cervical vertebra. The ganglion is located on the longus colli muscle of the neck above the trachea, at the height of the subclavian artery. The cervicothoracic ganglion is formed by fusion of the caudal cervical ganglion with one or more of the first thoracic ganglia. The numerous nerve fibres extending from it account for its second name, i.e. the stellate ganglion. A series of branches diverge from the stellate ganglion to the structures filling the thoracic cavity. In consequence, the ganglion is responsible for the neurological control of the structures which it contacts. The subclavian loop (*ansa subclavia*) is a specific branch of the cervicothoracic ganglion because it connects this ganglion with the middle cervical ganglion (10). The spinal nerve, which

innervates the meninges of the spinal cord, diverges from the ganglion body and is directed towards the cranium in the spinal canal. The cervicothoracic ganglion also contributes to the formation of the cardiac plexus in the aortic arch region (15).

The aim of the study was to examine the anatomy of the domestic cat's (*Felis catus*) stellate ganglion and its variability depending on the animal's age, body side and sex.

Material and methods

The study was conducted on 18 adult, 6 juvenile (the sternum length of less than 13 cm) and 9 fetuses of the domestic cat (17 males and 16 females). The animals for the study were acquired from veterinary clinics. They had been euthanised for other than neurological reasons. The corpses were stored in a 10% formaldehyde solution. The examination was based on macroscopic preparation. The thorax was opened by making a longitudinal incision along the sternum. The lungs were removed and the ganglion site was cleaned of the connective tissue. A 2% acetic acid solution was used to visualise the stellate ganglia. The length and width were measured with a calliper with an accuracy of 0.5 mm.

Results and discussion

The cervicothoracic ganglion in the domestic cat arises from the fusion of the caudal cervical ganglion with two or three thoracic ganglia. In 56.0% of cases, the cervicothoracic ganglion was composed of three ganglia. On the right side, a ganglion composed of three ganglia was more common (63.6%), while on the left side, a ganglion composed of four ganglia was more common (51.5%). In males, a ganglion made of three ganglia was more common (67.7%), while in the female, a ganglion made of four ganglia was more common (56.3%). The left-sided ganglion in the male was composed of three ganglia in 64.7% of cases and the right-sided ganglion in 70.6% of cases was composed of three ganglia. The left-sided ganglia of females consisted of three ganglia in 31.3% of cases and the right-sided ganglia in 56.3% of cases consisted of three ganglia.

The analysis of the location of the cervicothoracic ganglion in the adult cats gave the following results. There were 27 cases (12 on the left and 15 on the right; 75.0% of all cases) of the ganglion located in the first intercostal space. The location of the ganglion under the second rib was much less frequent, i.e. 6 cases (4 on the left and 2 on the right; 16.6% of all cases). The location of the ganglion in the second intercostal space was observed in 8.4% of the cases. In the group of juvenile cats the ganglion was found in the first intercostal space in 41.6% of the cases. In comparison with the adult cats, the stellate ganglion was much more often located under the second rib, i.e. 33.4% of the cases. The percentage of ganglia located in the first intercostal space was slightly higher in the foetuses, i.e. 44.4% – 8 cases. The cervicothoracic ganglion located in the second intercostal space was often found in the foetuses (22.2%). In the adults it was possible to differentiate the position of the ganglion in the first intercostal space. The ganglia classified as subcostal were completely covered by the second rib. The ganglia located in the first intercostal space tended to vary in their closeness to the ribs or central location in the intercostal space. There were 15 cases (41.6%) of centrally located ganglia (6 on the left, 9 on the right). The ganglia located closer to the cranial edge of the second rib or a small part of the ganglion under the second rib accounted for 27.7% of all cases (4 on the left and 6 on the right). There were two ganglia located closer to the caudal edge of the first rib (on the right for the male and on the left for the female). The most frequent configuration in adult cats were the ganglia located bilaterally centrally in the first intercostal space (27.7%).

The cervicothoracic ganglion in the adult cats was most commonly shaped like an irregular star (30.5%) or it was round (30.5%). There were 11 cases of an irregular star-shaped ganglion (7 on the left and 4 on the right), 11 cases of a round ganglion (5 on the left and 6 on the right), and 7 cases of a triangular ganglion (3 on the left and 4 on the right). The irregular

star-shaped ganglion was the most common on the left side (38.8%), whereas the round ganglion was the most common on the right side (33.3%). The irregular star-shaped ganglion was the most common in the females (56.3%). The round ganglion was the most common in the males (35.0%). It is noteworthy that the foetuses and juveniles had comet-shaped ganglia – the body of this ganglion tapered towards the sympathetic trunk. The comet-shaped ganglion was found in 50.0% of the male and 62.5% of the female foetuses and in 50.0% of the male and 37.5% of the female juvenile cats. This shape was dominant in these age groups.

The length and width of the cervicothoracic ganglion in the adult domestic cats varied proportionally to the length of the sternum – the longer the sternum was, the larger the ganglion was. On average the ganglion in the adult cats was 4.75 mm long and 3.81 mm wide. The longest ganglion was dissected from a male cat on the left side (6.5 mm). The longest ganglion in a female cat was 6 mm long and it was located on the left and right sides of the animal. The widest ganglion in a male cat (5.5 mm) was located on the right side. The widest ganglion in a female cat (4.5 mm) was also located on the right side of the animal's body. The shortest ganglion in an adult cat was 3 mm. It was found on the right side of a male cat's body. The narrowest ganglion (2 mm) was dissected from the right side of a male cat's body.

The cervicothoracic ganglion branches into the subclavian loop, whose caudal branch goes towards the sternum, curls under the subclavian artery and goes to the middle cervical ganglion (Fig. 1). The cranial

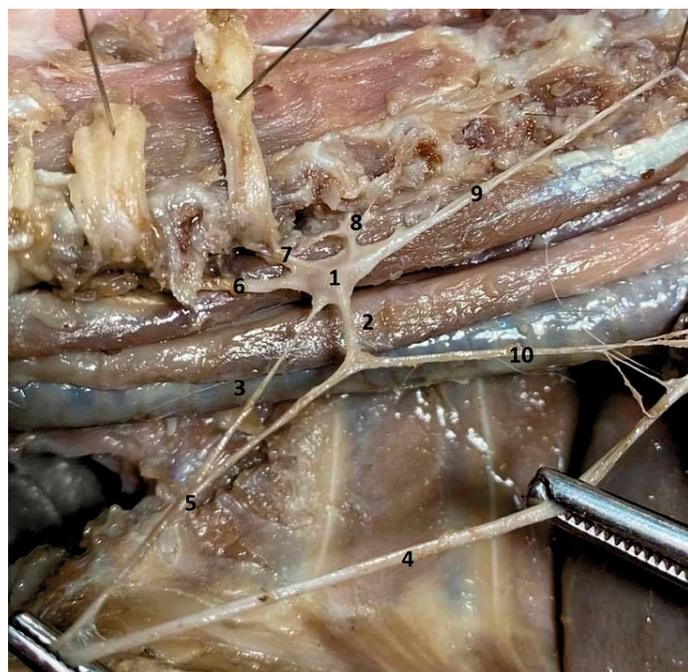


Fig. 1. Left cervicothoracic ganglion in adult cat. Cervicothoracic ganglion on the left side in adult domestic cat

Explanations: 1 – stellate ganglion, 2 – subclavian loop (caudal branch), 3 – subclavian loop (cranial branch), 4 – vagus nerve, 5 – middle cervical ganglion, 6 – vertebral nerve, 7 – ramus communicans Th1, 8 – ramus communicans Th2, 9 – sympathetic trunk, 10 – cardiac branch

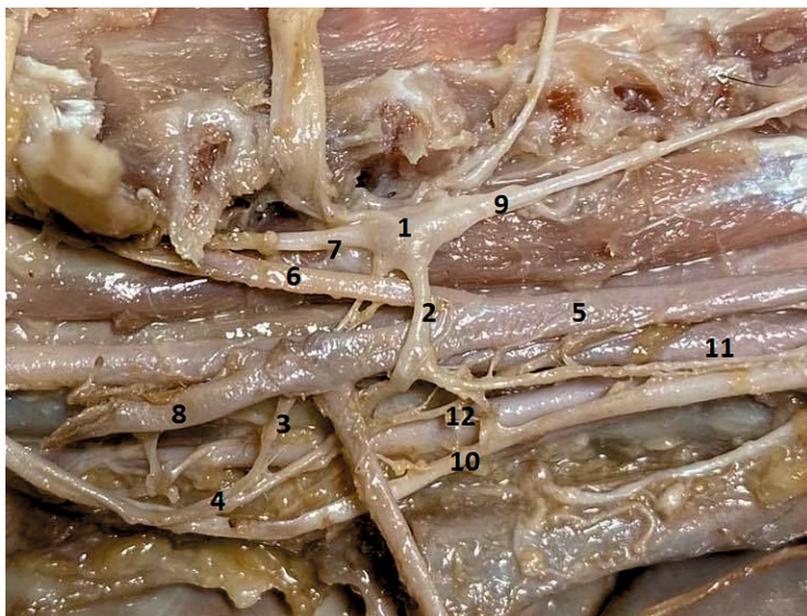


Fig. 2. Left cervicothoracic ganglion with thoracic blood vessels in adult cat. Cervicothoracic ganglion with arterial vessels on the left side in domestic cat

Explanations: 1 – stellate ganglion, 2 – subclavian loop (caudal branch), 3 – subclavian loop (cranial branch), 4 – middle cervical ganglion, 5 – subclavian artery, 6 – vertebral artery, 7 – vertebral nerve, 8 – axillary sinistral artery, 9 – sympathetic trunk, 10 – vagus nerve, 11 – cardiac branch, 12 – connecting branch with vagus nerve

branch diverges from the cranial side of the ganglion, runs towards the larynx and joins the caudal branch of the loop just before the middle cervical ganglion. The subclavian loop also forms part of the subclavian plexus (*plexus subclavius*), which encircles the subclavian artery (Fig. 2). Another branch is the vertebral nerve, which is formed in the cranial part of the ganglion. It runs along the vertebral artery in the transverse process canal, where the vertebral plexus (*plexus vertebralis*) is formed around the artery. It has branches in the canal, which connect it to the cervical nerves. The ganglion has branches connecting it to the vagus nerve. They are formed cranially, extending from the caudal branch of the subclavian loop and running along with it in the connective tissue sheath. The branch connecting it to the phrenic nerve diverges from it in the region where the caudal branch of the subclavian loop begins. The ganglion also connects to the recurrent laryngeal nerve. The visceral branches are also important. They lead the cardiac nerve fibres, which form the cardiac plexus together with the cervical cardiac nerves of the other ganglia. They may extend from the caudal side of the ganglion body separately or together with the caudal branch of the subclavian loop on the ventral side of the stellate ganglion. Other visceral branches are branches to the pulmonary plexus. There are also vascular branches, which reach individual blood vessels in the thoracic cavity. The cervicothoracic ganglion also supplies sympathetic fibres to the brachial plexus. Fibres are exchanged between the ventral branch of the first thoracic nerve and the fibres leading to the cervi-

cothoracic ganglion in the groove of the first rib. The communicating branch is attached to the ganglion between the vertebral nerve and the communicating branch to the first thoracic nerve. Thanks to communicating branches the cervicothoracic ganglion maintains contact with the spinal cord.

The asymmetry of the domestic cat's bilateral cervicothoracic ganglia is manifested by their location and the course of the fibre. The asymmetric position of the bilateral ganglia is also determined by the cat's age. The asymmetric position of the bilateral ganglia was found in 38% of the adult cats analysed in our study. In 57.1% of the asymmetric bilateral ganglia while the left ganglion was positioned under the rib, whereas the right one was in the first intercostal space. The other bilateral ganglia consisted of one ganglion located in the second intercostal space and the other in the first space. 66.6% of the juvenile cats and 77.7% of the foetuses had asymmetric ganglia. There are also anatomical reasons for the asymmetry of the ganglia. Both stellate ganglia form the cardiac plexus. Therefore, the cardiac branches diverging from the left ganglion are shorter and weaker than the cardiac branches

diverging from the right ganglion. Branches run from the left ganglion along with the subclavian loop and reach the heart together with the vagus nerve. The path of the fibres is straight, as they run in the caudal direction, slightly deviating to the left from the longitudinal axis of the body (Fig. 2). The course of the cardiac branches of the right ganglion is much more interesting. These fibres must move from the right to the left side to reach the heart. They diverge from the ganglion body along with the caudal branch of the subclavian loop. They pass under the trachea in the caudoventral direction towards the aortic arch. This pattern was observed in all the individuals analysed in our study.

The authors of earlier studies on the anatomy of the cervicothoracic ganglion indicated differences between bilateral ganglia. These differences were found in the connections between the ganglia the stellate ganglion was composed of, the shape, and the location of the ganglion body. Our study also showed significant differences between the bilateral ganglia. The European cat's cervicothoracic ganglion is composed of the caudal cervical ganglion as well as the first, second, and third thoracic ganglia. There may be different configurations of these ganglia. Kłęczowska-Nawrot et al. (7) conducted a study on 20 Persian kittens delivered after 58 days of gestation and made similar observations to ours. The kittens differed in the number of ganglia making the cervicothoracic ganglion. Of all the foetuses under study four had bilateral ganglia composed of the Gcca, GTh1, and GTh2. Evans and de Lahunt (4) observed similar differences in their study on dogs.

The researchers found that the dog's cervicothoracic ganglion may be composed of the caudal cervical ganglion as well as the first, second, or third thoracic ganglia. According to Nickel et al. (15), the dog's cervicothoracic ganglion is mainly composed of the Gcca, GTh1, and GTh2, which may be connected to the third and fourth thoracic ganglia. According to Marcer et al. (12) the human cervicothoracic ganglion is formed as a result of connection of the inferior cervical ganglion (equivalent to the Gcca in animals) with the first or first and second thoracic ganglia. Interestingly, Abumandour and El-Defrawy (1) observed that the fourth thoracic ganglion did not participate in the formation of the horse's cervicothoracic ganglion. Klećkowska et al. (5) conducted a study on nine-week-old pig foetuses and observed that the cervicothoracic ganglia were composed of the Gcca, GTh1, and GTh2. According to Kabak et al. (8), the roe deer's cervicothoracic ganglion is formed in a similar manner. It is formed by the caudal cervical ganglion made of C8 as well as the first and second thoracic ganglia. Although the cat and dog are carnivores and are closer to each other in terms of the evolutionary development, the location of the cats' cervicothoracic ganglion is similar to the location of the ganglion in small ruminants and roe deer. The cervicothoracic ganglion in these species is located in the first intercostal space. On the other hand, the location of the dog's stellate ganglion is similar to the location of the ganglion in the horse. According to König et al. (11) it is most often located under the first rib or, like in the horse, at the height of the 5/6 cervical vertebrae. The pig's cervicothoracic ganglion is located similarly, i.e. at the height of the cranial edge of the first rib or at the height of the seventh cervical vertebra. This corresponds to the position of the human cervicothoracic ganglion, i.e. at the cervical vertebrae level or between the seventh and eighth cervical vertebrae. Pinto et al. (17) conducted a study on tamarins, which are classified as primates, and found the cervicothoracic ganglion under the second rib. The shape of the ganglion depends on the species. The dog's cervicothoracic ganglion is usually oval or oblong, or less commonly, it is spindle-shaped (6). On the other hand, the cat's cervicothoracic ganglion is usually shaped like an irregular star and it is similar to the shape of the roe deer's cervicothoracic ganglion. The triangular shape of the cervicothoracic ganglion is characteristic of the pig. The dog differs considerably from the cat in the location of the cranial branch of the subclavian loop due to the position of the middle cervical ganglion, which the subclavian loop must reach. The dog's middle cervical ganglion is located at the height of the cervicothoracic ganglion (14). For this reason, the dog's cranial branch of the subclavian loop diverges from the ventral side, whereas the domestic cat's cranial loop begins on the cranial side of the body of the cervicothoracic ganglion, because middle cervical ganglion is located cranially and ventrally to the stellate ganglion. The cat's middle cervical ganglion is poorly marked and

can be identified only with histological methods (18). The shape of the cranial branch of the subclavian loop in the domestic cat is similar to the shape in the goat and sheep (9). However, their branches are shorter and in small ruminants the middle cervical ganglion itself is larger in relation to the cervicothoracic ganglion than in domestic cats. The cardiac branches in domestic cats and dogs extend from the caudal side of the ganglion body or along with the caudal branch of the loop in the connective tissue sheath (6). The cardiac branches in horses, goats and sheep originate in the caudal-middle corner of the ganglion. In addition, similarly to our observations of the considerable variation in the course of bilateral cardiac nerves extending from the ganglion body, such variations were also described by McKibben and Getty (13) in a study on cattle and by Ellison and Williams (3) in a study on humans. The spinal nerve diverges and runs similarly in all of the aforementioned mammals. It connects to cervical nerves 6 or 7 in the dog's spinal canal and then forms the vertebral plexus. In domestic cats, it connects to cervical nerves 2-7 and forms the vertebral plexus around the vertebral artery (3). In humans the vertebral plexus is transformed into the vertebral ganglion and is similarly located at the site of the vertebral plexus in other mammals. The communicating branches to the phrenic nerve, not listed in the *Nomina Anatomica Veterinaria* (16), were found as 1-2 fine branchlets in the dog. On the other hand, this connection has the form of 1-5 branchlets in the domestic cat. Numerous connections with the structures of the thoracic cavity are responsible for the physiological functions of the cervicothoracic ganglion. The cervicothoracic ganglion is an element of the sympathetic system and is responsible for mobilisation of the body in its broad sense. It is located in the front part of the body, so it has the greatest influence on the organs and structures of the thoracic cavity. It receives signals from the thalamocortical pathway and transmits them to the cardiac plexus through sympathetic fibres, which are called cardioacceleratory fibres (10). Lajos Anqyan (2) conducted a study on the domestic cat's basal ganglia and observed that the stimulation of the dorsal nucleus of thalamus increased the animal's blood pressure. The cervicothoracic ganglion acts as an intermediary in the transmission of nerve impulses from the higher centres of the nervous system. The modulation of the flow of nerve impulses through the stellate ganglion affected the cardiac function. Modulation of nerve impulse flow through the stellate ganglia affects heart function, as noted in a study on 30 dogs suffering from ventricular arrhythmia after acute myocardial infarction (19). Before they noticed that higher activity of the stellate ganglion increased the occurrence of ventricular arrhythmias in the dogs. The study showed that the stimulation of the spinal cord in the region of the stellate ganglion could prevent ventricular arrhythmias after acute myocardial infarction. Thus, the reduced transmission of impulses between the central nervous

system and the cervicothoracic ganglion significantly influenced the results. The knowledge of the structure of connections between the cervicothoracic ganglion and the thoracic cavity structures enables assessment of the influence of stimulation or damage to the ganglion on the function of correlated organs.

The cervicothoracic ganglion varies depending on the animal's age, sex, and body side. The asymmetry of bilateral ganglia is manifested by the shape, location, and components of the ganglion as well as the branches extending from it. The shape of the ganglion depends on the largest number of factors, i.e. the animal's body side, sex, and age. The variability in the location of the ganglion decreases as the age of the domestic cat increases. The bilateral ganglia were more often asymmetrically located in the foetuses than in the adult cats. The asymmetry of the branches does not depend on the animal's age or sex, but on the body side. It is influenced by the anatomical position of the cardiac plexus, to which fibres extend from both ganglia.

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