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MORPHOMETRIC ANALYSIS OF THE CILIARY GANGLION IN THE DOMESTIC TURKEY (*MELEAGRIS GALLOPAVO F. DOMESTICA*) AND DOMESTIC DUCK (*ANAS PLATYRHYNCHOS F. DOMESTICA*)

MAŁGORZATA RADZIMIRSKA

Department of Nature Conservation, Institute of Biology,
Jan Kochanowski University, 25-406 Kielce, Poland
malgorzata.radzimirska@ujk.edu.pl

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Abstract

The research was performed on 16 one-year-old domestic turkeys of Beltsville race and 16 domestic ducks of the Pekinese race, of both sexes. Standard histological technique was used and morphometric analysis was performed using histological samples. Ciliary ganglion morphometric analysis revealed the presence of two cell populations of ganglionic neurocytes: choroid and ciliary cells, clearly differing in diameter. Ciliary cells were predominant in turkeys, whereas choroid cells in ducks. The statistical analysis showed that the diameter and surface area of ganglionic neurocytes, the diameter and cross sectional area through the ciliary ganglion, as well as, the number of ganglionic cells on the cross-section through the ganglion were significantly larger ($P<0.001$) in turkeys than in ducks. The difference in the number of choroid and ciliary cells in domestic turkey and domestic duck is probably connected with eye accommodation, which seems to be greater in turkeys.

Key words: domestic turkey, domestic duck, ciliary ganglion, morphometric analysis.

Cephalic parasympathetic ganglia in birds, as one of the main elements of the autonomic nervous system, constitute the subject of research for many scientists. The ciliary ganglion is the most frequently analysed parasympathetic ganglion in birds. Its anatomic structure has been described for over 60 species from over a dozen families (1, 6, 12, 16, 18-20, 22). So far, no morphometric analysis of this ganglion in any of the species has been done although it has been known for a long time that two cell populations: ciliary and choroids, can be distinguished in it.

Therefore, an investigation has been taken in order to perform a comparative morphometric analysis of the ciliary ganglion of the domestic turkey (*Meleagris gallopavo f. domestica*) and domestic duck (*Anas platyrhynchos f. domestica*). This study is important for both cognitive and comparative anatomy reasons as turkey belongs to the order of *Galliformes* and the family of *Phasianidae,* whereas the duck represents the order *Anseriformes* and the family of *Anatidae*. These species differ in many morphological features and the lifestyle. The *Galliformes,* being ground-feeding birds, live on the ground, whereas the *Anseriformes* representatives are water birds, hence they are perfect swimmers and divers.

The obtained results will be of cognitive and practical value, particularly in diagnostics of the organ of vision and the structures, which innervate this organ in the animals. They can be used by clinicists and other biological disciplines representatives in the future. Numerous researches presented histopathological changes in the ciliary ganglion caused by glaucoma, subarachnoid haemorrhage, and meningitis. These changes manifest through degeneration, loss, or absence of ganglionic neurocytes in the ganglion (2, 3, 23).

Material and Methods

The research was performed on 16 one-year-old domestic turkeys of the Beltsville race and 16 domestic ducks of the Pekinese race, of both sexes (half males and half females). The animals were subjected to the examinations within 3 h after slaughter. Standard histological technique (13, 17, 19) and morphometric analysis were used. For the morphometric analysis, the histological samples were used in computer image analysing programme Multiscan 4.1. The diameter and surface area of the ganglionic cells, the diameter and cross sectional areas through the ganglia, number of neurocytes in the following cross-section through the ganglia, and percentage ratio of the individual components of ganglia were measured. In the following sections, only cells containing nucleoli were measured.

In case of the cells and ganglia of elongated shape, the longest chord was measured. The obtained results of diameter measurements are presented in the form of the bar histograms, which were done in the Microsoft Office Excel 2007. In order to create the charts presented in Figs 2 and 4, 500 ganglionic neurocytes from all individuals were randomly selected and their diameter was measured (intervals every 5 μm). The morphometric parameters were analysed using Statistica 6.1 software. The data were expressed as mean ±standard error of the mean. Statistical differences between groups were evaluated by Student's *t*-test. The significance level was set at $P<0.001$.

Results

The morphometric analysis of the domestic turkey ciliary ganglion. Histological (Fig. 1) and morphometric analyses of the ciliary ganglion in the domestic turkey showed the presence of two ganglionic cell populations of clearly different diameter. Small cells, which included neurocytes within the range of 9.6–29.6 μm, were interpreted as choroid cells, whereas large cells with diameter of 29.7–85.1 μm as ciliary cells. By choosing randomly 500 neurocytes of ciliary ganglion and measuring their diameter, a bar histogram has been created (Fig. 2). This histogram shows that the cells have the diameter from 9.6 to 77.9 μm. The vast majority constitute the cells above 29.6 μm (336 out of 500 diameter measurements of neurocytes). The mean value equaled 36.6 μm. Ciliary cells were predominant in the ciliary ganglion of turkeys (61.29%–90.41% of all ganglionic cells).

The cross sectional area of ganglionic neurocytes (μm^2) of the ciliary ganglion ranged from 54.4 to 3054.4 μm^2 of the surface area. The vast majority of cells had the surface area amounting from 804.4 μm^2 (293 out of 500). Mean value of the surface area equalled 1084.1 μm^2. The diameter of this ganglion was 0.84–1.38 mm. The cross sectional area through the ganglion was enclosed in the interval from 0.64 to 1.15 mm^2, where the ganglion cells constituted from 9.5% to 20% of the cross sectional area. The number of ganglionic neurocytes on the cross-sections through this ganglion ranged from 73 to 247.

The morphometric analysis of the domestic duck ciliary ganglion. Histological analysis (Fig. 3) and morphometry of the duck ciliary ganglion, similarly as in turkeys, demonstrated the presence of two cell populations of different diameter (choroid from 9.6 to 29.6 μm; ciliary- up to 67.8 μm). The histogram presented in Fig. 4, shows the number of cells in particular diameter intervals (μm) of the investigated duck ganglion. The obtained results demonstrated the dominance of cells of diameter from 9.6 to 29.6 μm (411 out of 500); and the mean value was 21.5 μm. In this bird species, choroid cells were predominant, ranging from 69.23 to 87.18% of all ganglionic cells in a given cross-section.

The surface area of ganglionic neurocytes in duck ciliary ganglion ranged from 49.7 to 1,924.1 μm^2. The majority of cells had the surface area up to 649.7 μm^2 (445 out of 500). Mean value of the surface area was 337.7 μm^2. In this ganglion the diameter was 0.54–0.81 mm. The cross sectional area through this ganglion ranged from 0.18 to 0.30 mm^2. In this ganglion the ganglionic neurocytes were present in 8.5%-15% of the cross sectional area. On the cross-sections through the ciliary ganglion, the presence of 78 to 97 ganglionic neurocytes was observed.

Statistical analysis. The diameter and surface area of ganglionic neurocytes, the diameter and cross sectional area through the ciliary ganglion, and the number of ganglionic cells on the cross-section through the ganglion were significantly ($P<0.001$) larger in the domestic turkeys than the domestic ducks (Table 1).

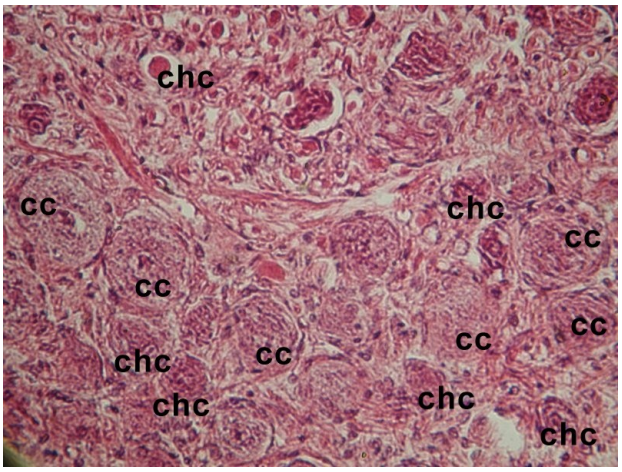


Fig. 1. The cross-section through the ciliary ganglion in the domestic turkey. H.E. Approx. 320x.
cc - ciliary cells (*cellulae ciliares*)
chc - choroid cells (*cellulae choroidales*)

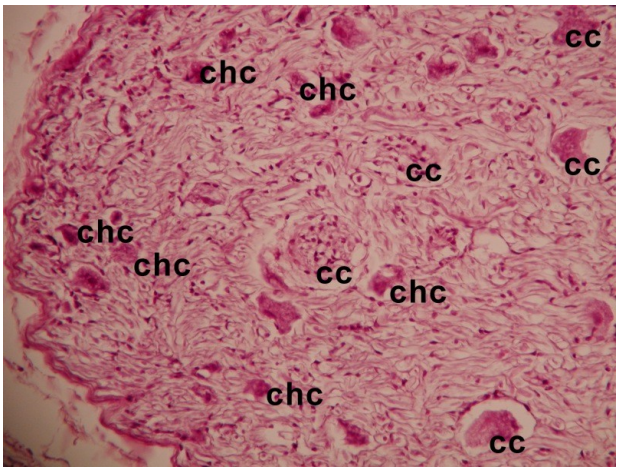


Fig. 3. The cross-section through the ciliary ganglion in the domestic duck. H.E. Approx. 240x.
Symbols as in Fig. 1

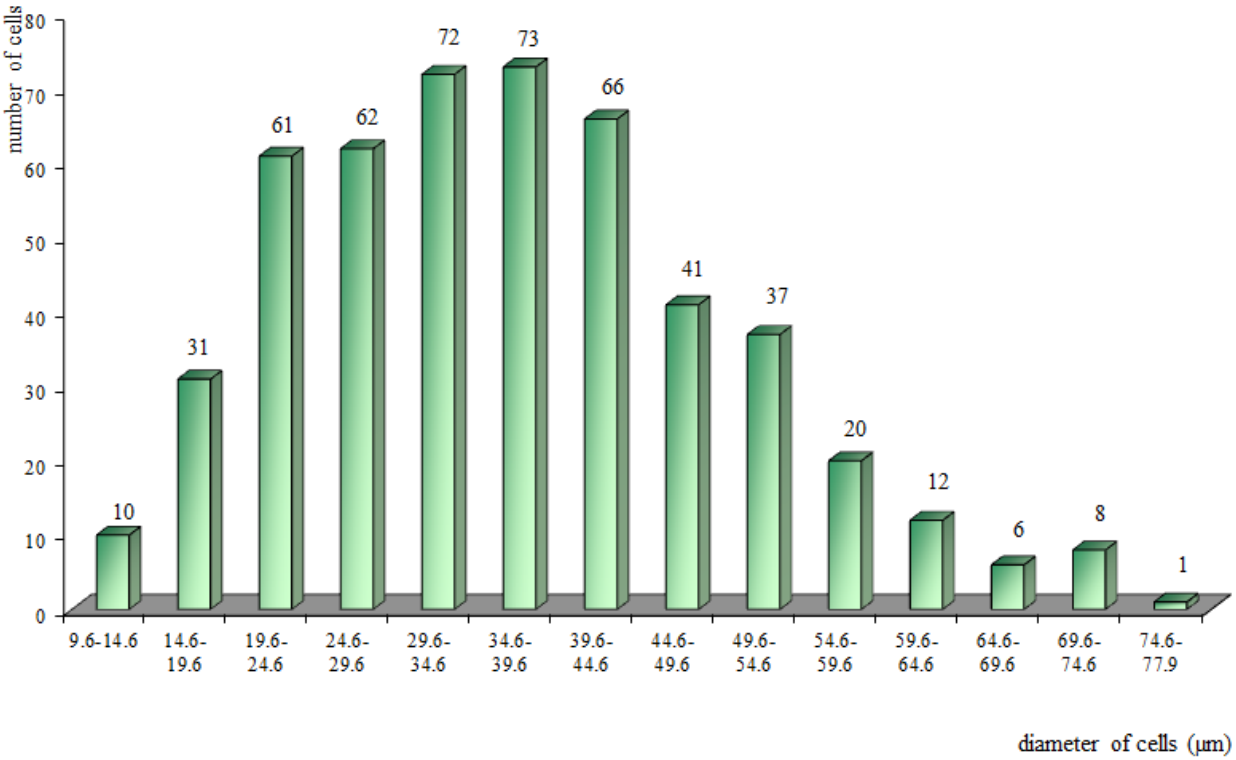


Fig. 2. The number of cells in particular diameter intervals (µm) of the ciliary ganglion in the domestic turkey, n=500.

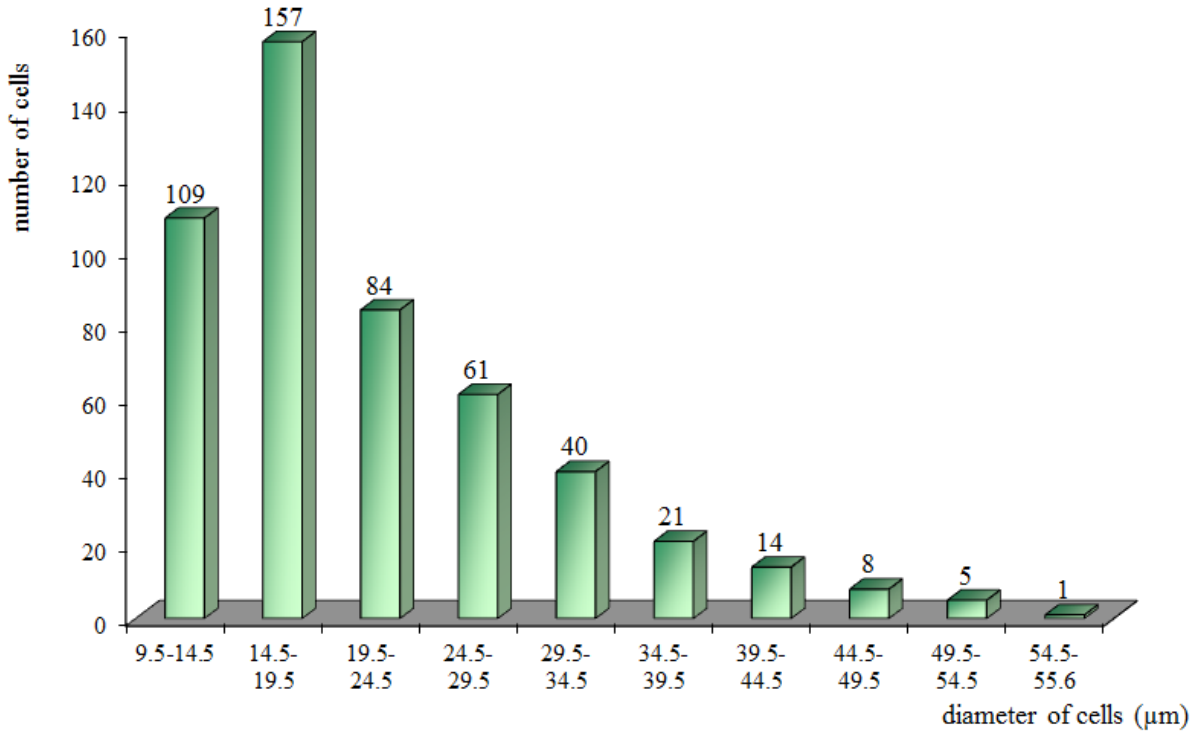


Fig. 4. The number of cells in particular diameter intervals (µm) of the ciliary ganglion in the domestic duck, n=500.

Table 1

Comparison of mean morphometric parameters of the ciliary ganglion in the domestic turkey and domestic duck (Student's –*t*-test, P<0.001); $\bar{X}_1$- domestic turkey, $\bar{X}_2$ - domestic duck, *d.f.* – degrees of freedom, *t* – t empirical

Morphometric paramater	$\bar{X}_1$±SE	$\bar{X}_2$±SE	*d.f.*	*t*	P
Diameter of ganglionic cells (μm)	36.6±0.59	21.5±0.4	998	21.1211	<0.001
Surface area of ganglionic cells (μm^2)	1084.1±29.64	337.7±13.85	998	22.8178	<0.001
Diameter of the ciliary ganglion (mm)	1.09±0.04	0.64±0.02	30	9.4653	<0.001
Cross sectional area through the ciliary ganglion (mm^2)	0.87±0.06	0.25±0.01	18	1.7749	<0.001
Number of ganglionic cells	151.1±14.5	87.1±1.66	30	4.3590	<0.001

Discussion

First data on the ciliary ganglion in birds concerned domestic birds (*Gallus gallus domesticus*, *Columba livia*). This information was, however, insufficient and the ciliary ganglion was described in regard to sympathetic structures. In these birds, a strict relation of the ganglion with the oculomotor nerve trunk was demonstrated, as well as, the presence of multiple fibre bundles leaving the ganglion, which were interpreted as short ciliary nerves, was stated (5). Later investigations, performed with the use of the most modern techniques, confirmed the topographic and functional relationship of the ciliary ganglion with nerve III, actually with its lower branch, since the ganglion is supplied by the preganglionic parasympathetic fibres of the oculomotor nerve from Edinger-Westphal nucleus in the mesencephalon. Several studies have presented that there is always a single ciliary ganglion of compact histological structure and great polymorphology in individual species within the same vertebrate class (1, 6, 16, 19, 20). The ganglion with spindle or oval shape (*Gallus gallus domesticus*, *Columba livia*, *Coturnix coturnix v. Japonica, Halcyon smyrnensis, Pterocles alchata*) is the most common. In the wild and domestic ducks, this ganglion has an elongated shape and has the form of one of the branches of the nerve III, whereas in wild and domestic turkeys, the ciliary ganglion has the barrel shape and strictly adheres to the inferior branch of the oculomotor nerve (1, 19, 20).

Numerous investigations confirmed the presence of two kinds of cells in the investigated ganglion in birds: large called ciliary and small - choroid cells (1, 4, 6, 7, 15, 16, 18-20, 22). In pigeons and hens, the diameter of large cells amounts to about 45 μm, and the diameter of small cells is about 25 μm (15). Ciliary cell axons form long ciliary nerves that reach iris smooth muscles and ciliary body, whereas the axons of the choroid cells form short ciliary nerves, reaching the sclera and choroidea. Some authors perceived the morphological criterion as insufficient to distinguish ciliary and choroid cells. Marwitt *et al.* (15) used the speed of impulse transmission in nervous fibres as the main criteria of the classification. Their investigation has shown that presympathetic fibres reach the ciliary cells in 6.9–3.04 m/s, and in case of choroid cell fibers - 3.4–0.7 m/s, at 22–24^{0}C. De Stefano *et al.* (7) applied immunocytochemical criterion for the identification of both cell populations, stating the presence of neuropeptide - somatostatin in the hen and Japanese quail. In their opinion, biologically active somatostatin allows better distinguishing of ciliary neurocytes from choroid neurocytes because it is localised only in choroid neurocytes.

The morphometric analysis performed on domestic turkeys and ducks demonstrated the presence of two ganglionic cell populations in the ciliary ganglion: choroid and ciliary cells, which clearly differed in size. In domestic turkeys, the vast majority were the ciliary neurocytes, which constituted from 61% to 90% of all cells. In domestic ducks, the choroid cells were predominant and ranged from 69% to 87% of all cells in the analysed cross-section. According to Terzuolo (22), the choroid cells are less numerous than ciliary cells in wild turkeys. This was confirmed in the research conducted on domesticated turkeys. In pigeon, however, the choroid cells constitute half of all neurocytes population (15). In the examined birds, clear differences were noted in the number of ganglionic neurocytes, diameter and surface area of ganglionic cells, and diameter and cross sectional area through the ciliary ganglion. These parameters were significantly larger in domestic turkeys than in domestic ducks.

In the majority of mammals, such as birds, the ciliary ganglion is topographically and functionally connected with the oculomotor nerve (10-14, 17, 24); however, in comparison with birds it reveals significant differences. According to the previously published data, the ciliary ganglion size in mammals depends on the development of the sight organ and the degree of its usage (9, 12, 24). It seems that similar correlation also refers to birds in which the ciliary ganglia are bigger than in mammals. The mammalian ciliary ganglion is usually represented by single, compact neurocyte cluster. However, in many species, *e.g.* cat, horse, sheep, goat, boar, pig, fox, Egiptian spiny mouse, and even human, accessory ganglia were found aside from the main ciliary ganglia (8, 10, 17, 21). In mammals, the ciliary ganglion cells reveal great differentiation of the diameter among species, *e.g.* in humans 25-36 μm, in

mice - 11-15 μm, in dogs - 34-40 μm, and in macaques - 30-43 μm (12, 24). However, choroid and ciliary cells of different size, like in birds, have not been found. Moreover, postganglionic fibre bundles form only short ciliary nerves innervating all of the pupil muscles. Thus, the difference in percentage share of the choroid cells to the ciliary cells in domestic turkeys (dominance of ciliary cells) and in domestic ducks (dominance of choroid cells) probably is an effect of species-specific eye accommodation ability. It seems that the accommodation is greater in turkeys because the ciliary muscle and ciliary body are strongly innervated by long ciliary nerves. The choroid neurocyte domination in ducks can be explained by the necessity of better fibrous membrane and eye ball choroidea supply in this bird species, as it lives on the ground and in water.

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