Praca oryginalna *Original paper*

Morphology of the pulmonary valve of chosen species of free-living birds

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Summary

The aim of the research was to describe the structure of the pulmonary valve. The study was conducted on forty-six hearts of free-living birds of four orders. Out of the examined birds only one Mute Swan from the Anseriformes order had the quadricuspid valve. Other birds had the tricuspid type of the valve. It was observed that Northern Eagle Owls, White-tailed Sea Eagles and Mute Swans have the nodules of the cusps on the free margins of the cusps of the pulmonary valve. New terms were suggested to describe the nodules and the structure of the commissure of the pulmonary valve. Such types of research may link morphological study, clinical in type, with the ecology of birds belonging to various systematic units.

Keywords: birds, heart, pulmonary valve, morphology

At the turn of the 20th and 21st centuries a lot of researchers got interested in the adaptation of the cardiovascular system to specific models of life (5, 6, 16). Some writing, which employ allometric equations, have been published. The research concerned, among other things, the hearts of nestlings of various species of birds (11, 15). In most cases the subject of the research was the influence of environment on alterations in the cardiovascular system (8, 10, 16). Only a few of the newest elaborations concerning the valvular apparatus of birds' hearts attempt to relate morphological research with imaging one as well as introducing new terms characterizing particular structures of the hearts of birds (2, 3, 13). Most of such work of was conducted on humans and dogs (1, 7, 9).

The aim of this research was to get to know the morphology of the pulmonary valve of wild birds and to suggest new terms to be applied in anatomical nomenclature of birds. In the future research of this type will allow us to prepare patterns for biomechanical and cardiological studies of wild birds belonging to various systematic and ecological groups.

Material and methods

The research was conducted on forty-six hearts of birds belonging to four orders: Northern Eagle Owl (2 hearts) *Bubo bubo* (Linnaeus, 1758) – order *Strigiformes*; White-tailed Sea Eagle (6 hearts) *Haliaeetus albicilla* (Linnaeus, 1758), Northern Goshawk (1 heart) *Accipiter gentilis* (Linnaeus, 1758) – order *Falconiformes*; Mute Swan (5 hearts) *Cygnus olor* (J. F. Gmelin, 1789); Green-winged Teal (8 hearts) *Anas crecca* Linnaeus, 1758; Gadwall (7 hearts) *Anas strepera* (Linnaeus, 175); Northern Shoveller (5 hearts) *Anas clypeata* (Linnaeus, 1758); Red-breasted Merganser (6 hearts) *Mergus serrator* Linnaeus, 1758 – order *Anseriformes*; White Stork (6 hearts) *Ciconia ciconia* (Linnaeus, 1758) – order *Ciconiiformes*.

The examined hearts were taken from adult individuals of both sexes representing free-living species. The research material came from a collection of exhibits from the Department of Morphological Sciences, Faculty of Veterinary Medicine as well as the Warsaw Zoological Garden.

The hearts were kept in 10% solution of formaldehyde with the addition of 68% ethanol (1/3 proportion). Before the examination each heart was irrigated in running water. Afterward, they were dried using filtering paper and a mechanical aspirator. Such prepared hearts had two cuts taken. One of them concerned the anterior wall of the pulmonary trunk and ran from the place of its bifurcation through the ambilateral pulmonary arteries (right and left) to the pulmonary valve. The other cut ran towards the apex of the heart through the anterior wall of the right arterial cone and the anterior wall of the right ventricle. This enabled the evaluation of the structure of the pulmonary valve along with its adjacent structures (2).

The pulmonary valve and its adjacent structures were examined with the use of a micro camera (MikroOkular 3.0MP) connected to a surgical microscope (OpM1) and a stereoscopic microscope (MsT-130) as well as a macro camera (Sony HDR-SR11E) linked to a surgical microscope (Ecleris HaloLux 150). All the cameras were computer linked during the research. The documents and photos were made in a digital format with the use of Corel pack – Graphics Suite X3.

Results and discussion

The pulmonary valve is a complex structure. In birds and humans it consists of three semilunar cusps (1, 2, 4, 9). Literature also provides descriptions of cases of the quadricuspid valve of birds and mammals (2, 4). In the studied material the quadricuspid valve was observed only in the case of a Mute Swan (one case). On account of the exceptional structure of the pulmonary valve of the species differentiating two types of the structure was suggested; type I – a valve consisting of three cusps (four cases), and type II – a valve consisting of four cusps (one case). While studying domestic and free-living birds, Bartyzel (2) demonstrated that among the first ones, the turkey had two types of the pulmonary valve (I – the tricuspid valve and II – the quadricuspid valve). The described structure of the turkey was situated between the dorsal semilunar cusp and the right semilunar cusp. The pulmonary valve of the Mute Swan was located on the left commissure between the dorsal semilunar cusp and the left semilunar cusp. The previously suggested terms concerning the following heart structures: the additional commissure, *commissura accessoria*, and the additional cusp of the pulmonary valve, *valvula semilunaris accessoria*, should be also used in this research as they best describe the structure of the quadricuspid valve (2) (fig. 1).

In the examined pulmonary valve of the Mute Swan all free margins of the four cusps created a tight structure. To adequately explain the problem some research should be conducted on a larger number of free-living and domestic birds belonging to various ecological groups (herbivores, omnivores and predators).

Strigiformes', *Falconiformes'* and *Anseriformes*' free cusps were attached to the wall of the pulmonary trunk in a similar way to the attachment of swallows' nests. In other studied species the attachment was similar, however without characteristic cuppings present in the three orders of birds mentioned above.

In the centre of each free margin of the cusp below the lunule of the semilunar cusps, *lunula valvulae semilunaris*, and the basal part, *pars basalis* (2), only Northern Eagle Owls, White-tailed Sea Eagles and swans had the nodules of the semilunar cusps (of the pulmonary valve). It has been suggested that the following terms should be introduced: the nodule of the left semilunar cusp, *nodulus valvulae semilunaris sinistri*, the nodule of the right semilunar cusp, *nodulus valvulae semilunaris dextri*, the nodule of the anterior semilunar cusp, *nodulus valvulae semilunaris anterior*. Similar observations concerning the existence and

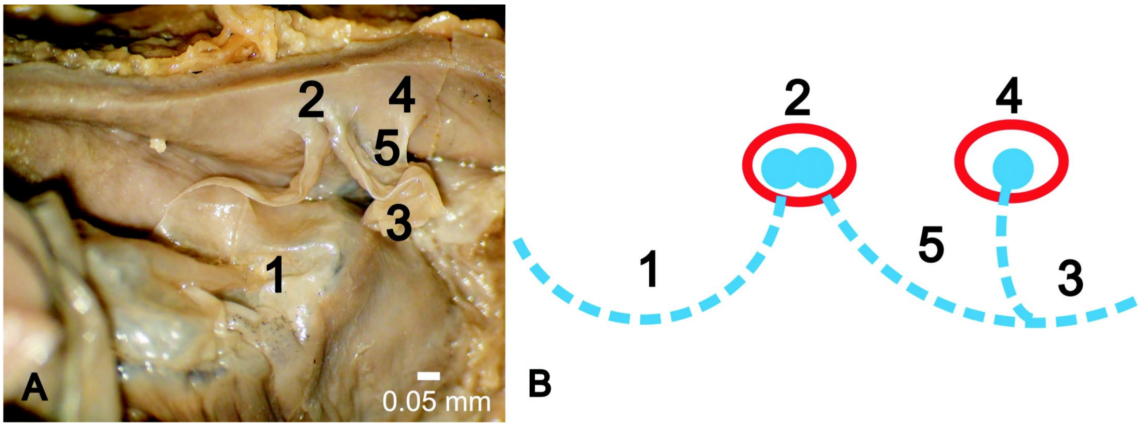

Fig. 1. Fragment of the pulmonary valve of a Mute Swan. A – preparation, B – scheme (the pulmonary trunk cut and half-open – anterior-inferior view)
Explanations: 1 – dorsal semilunar cusp; 2 – left commissure; 3 – left semilunar cusp; 4 – additional commissure; 5 – additional semilunar cusp

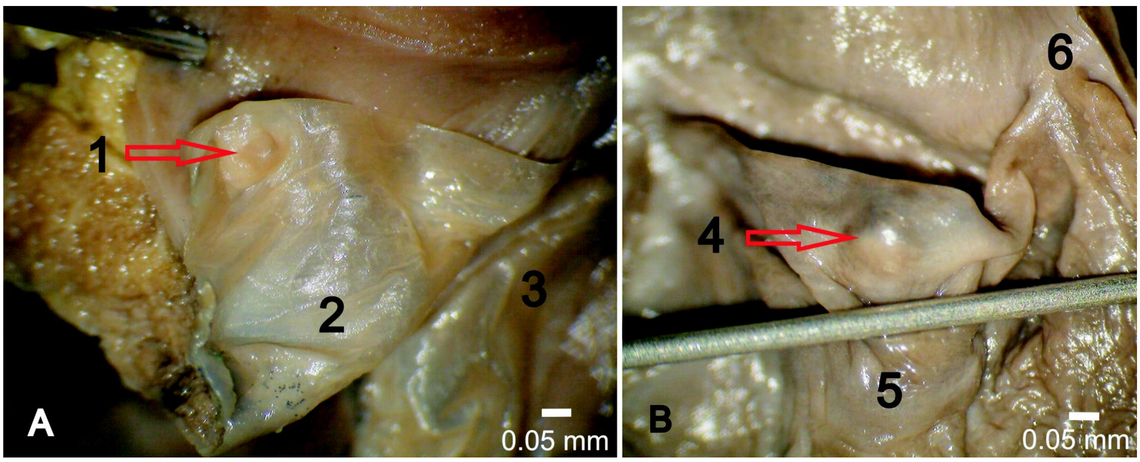

Fig. 2. Fragment of the pulmonary valve. A – Mute Swan, B – White-tailed Sea Eagle (the pulmonary trunk cut and half-open – anterior-inferior view)
Explanations: 1 – nodule of the right semilunar cusp; 2 – right semilunar cusp; 3 – dorsal semilunar cusp; 4 – nodule of the left semilunar cusp; 5 – left semilunar cusp; 6 – anterior commissure

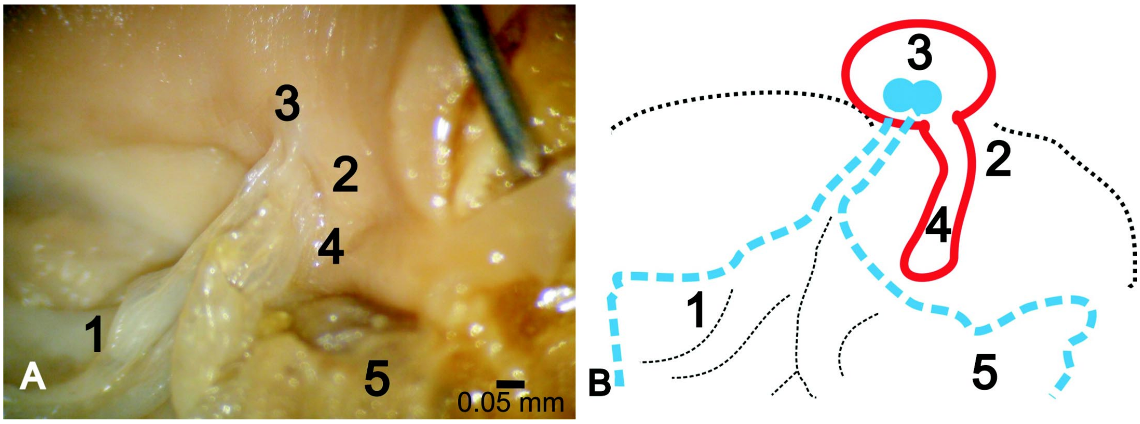

Fig. 3. Fragment of the pulmonary valve of a White Stork. A – preparation, B – scheme (the pulmonary trunk cut and half-open – anterior-inferior view)
Explanations: 1 – dorsal semilunar cusp; 2 – left commissure; 3 – head of the commissure; 4 – the trunk of the commissure; 5 – left semilunar cusp

location of the nodules of the semilunar cusps but referring to the aorta valve of birds of prey were first described by Bartyzel (the results have not been published yet, 2009) and Arancio concerning humans (Arancio nodules *nuduli Arancio*). The studied material and other mammals had the nodules in the central part of the lunule which enables the valves to become tight (1, 9). It can be assumed that the existence of these structures in birds of prey and some Anseriformes can be a way of adaptation to specific living conditions (fig. 2).

The places of contact of the particular cusps of the human pulmonary valve on its outer side formed commissures. The expression of this type was introduced by Rusted et al. (12) when describing the structure of the mitral valves of 25 women and 25 men. All the studied preparations of the commissures of the semilunar cusps *commissurae valvularum semilunarium* (2) were located between the free margin of the cusps and made the anastomosis between the apex of the heart and the interlobar incisure similar as in humans (9). In the examined valves of all species of birds, just as in the research conducted earlier (2) on 498 birds of various orders, it was possible to differentiate the three following commissures: the right, the left and the anterior one. In every commissure of all the species of the studied birds it was possible to distinguish the head of the commissure *caput commissurae* (a suggested name), to which a lunule of the semilunar cusp *lunula valvulae semilunaris* (2) was directly attached and the trunk of the commissure *corpus commissurae*, (a suggested name) situated where the two cusps were linked at their most narrow parts (fig. 3).

The conducted research did not show any differences within a species as far as the structure of the pulmonary valve was concerned. Further interspecies examination, including anatomical (e.g. the structure of the valvular apparatus), clinical (e.g. imaging diagnostics of the cardiovascular system), biochemical (e.g. tissue analysis) and physiological ones will enable us to reveal more differences in various types of ecological adaptations of birds (2, 3, 13). There is some evidence that during different types of activity wild animals use various structures of the cardiovascular system (6, 10), which also influence the size, the shape and the way of attachment of particular heart structures to each other.

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