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Anatomical and Biometrical Characteristics of the Fibrous Skeleton and Left Atrioventricular Valve of the Ostrich Heart (*Struthio camelus*)

Características Anatómicas y Biométricas del Esqueleto Fibroso y Valva Atrioventricular Izquierda del Corazón de Avestruz (*Struthio camelus*)

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RUBILAR-CUEVAS, J.; HENRÍQUEZ-PINO, J. Anatomical and biometrical characteristics of the fibrous skeleton and left atrioventricular valve of the ostrich heart (*Struthio camelus*). *Int. J. Morphol., 43(2)*:694-698, 2025.

SUMMARY: An ostrich heart has two atria and two ventricles making it similar to mammals, and a valve system similar to that of other birds. The anatomical and biometrical characteristics of the fibrous skeleton and left atrioventricular valve of the ostrich heart (*Struthio camelus*) are described, contributing to functional anatomical understanding of the ostrich. We dissected 30 hearts from ostriches aged between 12 and 15 months. The length and width of the cusps of the left atrioventricular valve were measured and any significant differences in measurements were identified. The left atrioventricular and aortic rings in the fibrous skeleton were studied, and three kinds of fibrous skeleton were identified. No fibrous ring was detected in the right atrioventricular valve or the pulmonary valve. The left atrioventricular valve is predominantly tricuspid, with a larger septal cusp. Variations in cusp length indicated three types for the left atrioventricular valve. This enabled us to define the morphological characteristics of the fibrous skeleton and the functional morphology of the left atrioventricular valve of the ostrich heart.

KEY WORDS: Ostrich; Heart; Fibrous trigone; Left atrioventricular valve.

INTRODUCTION

The cardiac anatomy of the ostrich (*Struthio camelus*) presents characteristics similar to that of mammals; it contains four chambers, and the fibrous cardiac skeleton accommodates normal heart movement as it stabilizes the ostia of the cardiac valves. Findings have been published indicating that the anatomy of the ostrich heart differs from that of both birds and mammals (Macalister, 1864; Hodgkinson, 1901; Bezuidenhout, 1981; World Association Of Veterinary Anatomists, 1993; Getty, 2002; Soares *et al*., 2010), appearing to be a combination of the two types; however there is little information in the literature on the morphological characteristics of the fibrous cardiac skeleton. Bezuidenhout (1981) discusses the qualities of the heart's valve system in a large bird, and how it has well-formed fibrous skeleton structured from the rings of the left atrioventricular and aortic root ostia (World Association Of Veterinary Anatomists, 1993). The left atrioventricular valve is tricuspid, with very thick cusps, extending from the septum to the wall in the form of irregular branches joined to each other by fine threads or bands between the trabeculae carneae of the parietal wall (Alsafy *et al*., 2009; Tajdalli *et al*., 2009). We investigated the fibrous skeleton morphology of the ostrich heart and the biometry of the left atrioventricular valve, using these and other scarce information sources.

MATERIAL AND METHOD

Thirty healthy ostrich hearts were dissected post mortem from birds aged between 12 and 15 months; the weight of the hearts ranged from 370.5 g to 1050 g. The hearts were emptied and washed with running water, and subsequently preserved in 10 % formaldehyde.

A qualitative study was carried out by simple observation and drawing descriptive diagrams of the fibrous trigone for each heart. Quantitative studies included measuring the cusp variables for the left atrioventricular valve (LAVV) with a digital calliper, including width and length (mm). The data were sorted in Excel tables (Microsoft® Office 2011) and expressed as mean ± SD. The

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D'Agostino Test was used to detect data normality, in order to evaluate the significance of differences in LAVV cusp size, between septal and right cusps, between septal and left cusps, and between right and left cusps. The Repeated Measurement ANOVA Parametric Variance Test was used for statistical analysis between groups. Tukey's Multiple Comparison Parametric Test was used to detect significant differences between groups. The Pearson Correlation Test (r) was used to define the relationship between variables, such as the length of the left atrioventricular ostium and the septal, left and right cusps. The statistical significance for all tests was established as $p < 0.05$. Data analysis was carried out using the GraphPad Prism® software version 5.0 for Mac OS x (GraphPad Software, San Diego, CA).

The following studies were performed:

- **Description of the fibrous skeleton.** The hearts were dissected with ad hoc material, extracting the atria in order to observe the fibrous trigone, the right atrioventricular ostium, left atrioventricular ostium, and the pulmonary trunk and aortic ostia. Subsequently, the muscle fibres enveloping each trigone and fibrous ring for each cardiac valve were removed. This process revealed the skeleton for examination; its shape and the arrangement of the fibrous rings and trigones were described, and a model was established of the fibrous skeleton of each heart.

- **Description of the left atrioventricular valve**; a qualitative study to determine whether there was a dominant cusp. Data were collected by direct observation after dissection, then recorded and expressed graphically.

- Quantitative description of the left atrioventricular valve using data collected by measuring the width (mm) and length (mm) of cusps.

RESULTS

Description of the fibrous skeleton

The fibrous skeleton of the ostrich heart is composed of two dense bands in the form of a ring of dense connective collagenous tissue surrounding the base of the aorta and left atrioventricular valve. The aortic fibrous ring has remarkably dense connective collagenous tissue. The left atrioventricular ring is intimately connected along its right margin with the aortic ring; the right atrioventricular ostium has a triangular mass of dense connective collagenous tissue, which is the right fibrous trigone. The left fibrous trigone begins as a strong, thick band extending from the aortic ring to the left atrioventricular ring and embracing its cranial margin.
Three types of fibrous skeletons were identified:

Type I: Fibrous skeleton with aortic and left atrioventricular rings (Fig.1). The right fibrous trigone is a thick, fibrous tissue that arises from the margins of the left atrioventricular ostium, aortic ostium, and right atrioventricular ostium, with a triangular lateral margin. This triangular fibrous tissue occupies the fold between the crease of the left and right atrioventricular valves.

A thick fibrous structure appears at the tip of the left fibrous trigone, which is perforated by the septal arteries of the left coronary artery. This fibrous tissue begins at the aortic valve ring and extends as dense connective tissue surrounding the left atrioventricular ostium, to form the left atrioventricular ring.

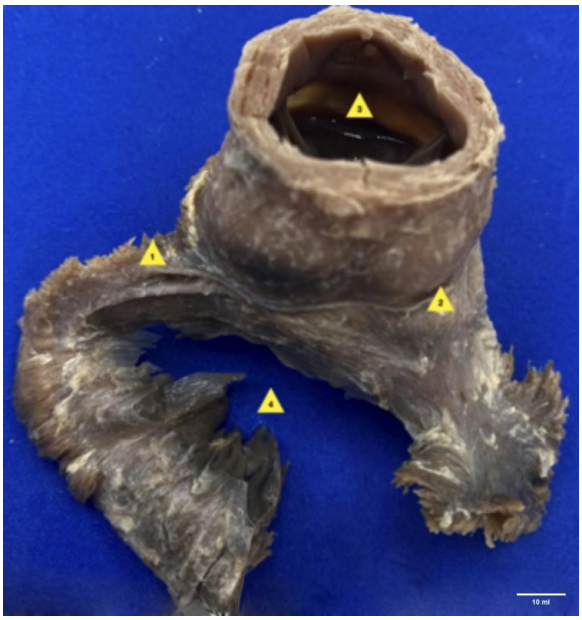

Fig.1. Type I fibrous skeleton, dorsal view. 1. Right fibrous trigone; 2. Left fibrous trigone; 3. Aortic ostium; 4. Left atrioventricular ostium.

Type II: Fibrous skeleton showing the aortic ring and the left atrioventricular ring (Fig. 2). The right fibrous trigone has a remarkable structure that begins at the aortic ring, tapering toward the intermediate zone between the right atrioventricular ostium and left atrioventricular ring, and extending to the lateral edge of the atrial face of the heart, no longer with a triangular shape, but forming a straight line between the two atrioventricular ostia.

The left fibrous trigone is directed towards the caudal, enveloping and closing the left atrioventricular ring. From the caudal tip where the fold forms the ring, a thicker, triangular extension begins of denser connective tissue with its base at the ring, and its apex toward the caudal and lateral face of the heart.

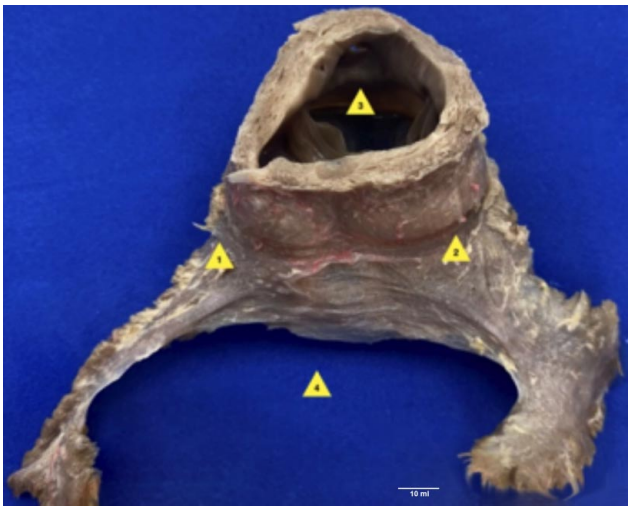

Fig. 2. Type II fibrous skeleton, dorsal view. 1. Left fibrous trigone; 2. Right fibrous trigone; 3. Aortic ostium; 4. Left atrioventricular ostium.

Type III: Fibrous skeleton showing the aortic ring and the left atrioventricular ring (Fig. 3). The right and left trigones begin at this point. The right trigone is an extension of dense connective tissue that begins at the aortic ring and extends to the lateral edge of the atrial face. The edge is rounded and reaches the lateral edge of the atrial face, with an acutely developed extension towards the caudal edge of the right atrioventricular ostium. The caudal margin of the fibrous trigone envelopes the left atrioventricular ostium, forming the left atrioventricular ring where the ostium penetrates the trigone.

The left fibrous trigone begins as dense collagenous connective tissue from the aortic ring at its caudal margin and descends as a sinewy arm that envelopes the left atrioventricular ring, forming and closing the left atrioventricular ring.

The fibrous skeletons of these ostrich hearts were classified into 11 Type I hearts, 9 Type II hearts, and 10 Type III hearts.

There were three types of cusp dominance in the left atrioventricular valves (Table I).

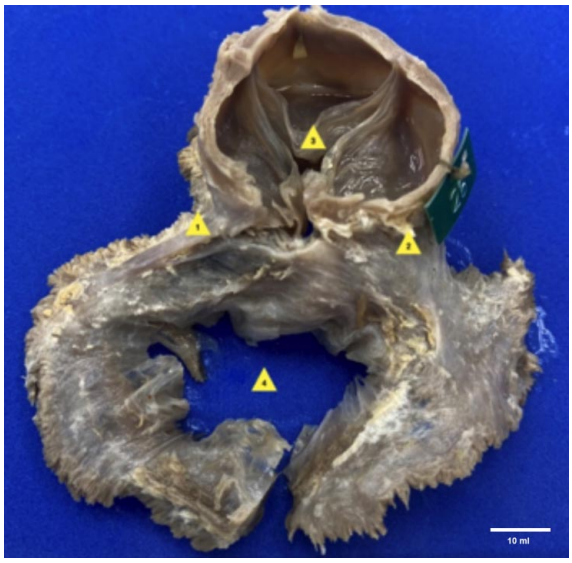

Fig. 3. Type III fibrous skeleton, dorsal view. 1. Left fibrous trigone; 2. Right fibrous trigone; 3. Aortic ostium, 4. Left atrioventricular ostium.

Cusp dominance in the left atrioventricular valve was classified into 8 Type 1 hearts, 7 Type 2 hearts and 13 Type 3 hearts, with three papillary muscles supporting the tendinous cords. Two hearts exhibited an anatomical variation as they had a bicuspid left atrioventricular valve, with two corresponding papillary muscles.

Variations in the width (mm) of the septal, right and left cusps in the left atrioventricular valve were 45±6.4, 22±5.4 and 23±4.8. The statistical analysis detected significant differences between cusps (p=0.001). Variations in the length (mm) of septal, right and left cusps in the left atrioventricular valve were 26±4.4, 17±3.4 and 16±3.3. The statistical analysis detected significant differences between septal and right cusps, as well as between septal and left cusps, but not between right and left cusps (p=0.001).

The correlation between the length of the left atrioventricular ostium and the width of the septal cusp is r=0.81; between the length of the left atrioventricular ostium and the width of the right cusp r=0.54; and between the length of the left atrioventricular ostium and the width of the left cusp r=0.43.

Table I. Types of cusp dominance in the left atrioventricular valves.

Type 1	The septal cusp dominates and is half the size of the left atrioventricular ring. The left and right cusps are the same size.
Type 2	The septal cusp dominates and is half the size of the left atrioventricular ring. The left cusp is larger than the right.
Type 3	The septal cusp dominates and is half the size of the left atrioventricular ring. The right cusp is larger than the left.

DISCUSSION

As described by Bezuidenhout (1981), the study showed that the sample birds have two fibrous trigones, with the right trigone having stronger macroscopic features than the left, and two developed fibrous rings, the aortic and the left atrioventricular rings. The fibrous trigones are located as described by Bezuidenhout (1981), with the right fibrous trigone located to dorso-caudal of the interventricular septum between the fibrous ring of the cranial aorta and to caudal of the left atrioventricular fibrous ring; it is firmly attached to the aortic ring. As described by Getty (2002), the right fibrous trigone is located between the dorsal part of the aortic ring and the two atrioventricular rings, as the ostrich does not have a right atrioventricular ring. The left fibrous trigone is located in the cranial part of the interventricular septum and attached to the left cranial portion of the aortic fibrous ring. As described by Getty (2002), the left fibrous trigone is ventral of the left atrioventricular and aortic ring, but we did not find it attached to the dorsal portion of the pulmonary ring, as this structure does not exist in the ostrich. No fibrous ring was observed in the pulmonary trunk. However, a weak development of this fibrous ring was described by Bezuidenhout (1981). Only the World Association Of Veterinary Anatomists (1993) has described this in birds, but an arterial ligament has not been described in ostriches. This is the remnant of the right foetal arterial duct, which carries blood from the pulmonary artery to the aorta. Bezuidenhout (1981) indicates that the right atrioventricular ring is very underdeveloped, which does not agree with our study, as there is only an extension of fibrous tissue into the ventricular chamber, and not precisely a fibrous ring structure.

As described for birds by Getty (2002) and for chickens by Yildiz & Cavusoglu (2004), and specifically for the ostrich by Macalister (1864), Hodgkinson (1901), Tajdalli *et al*. (2009), Guimarães *et al*. (2011), Alsafy *et al*. (2009) and Abidu-Figueiredo *et al*. (2013), ostrich hearts have three cusps in their left atrioventricular valve. We did not observe the bicuspid valve dominance in ostriches reported by (Soares *et al*., 2010). The valve cusp is attached to the walls of the left ventricle with tendinous cords as explained by Yildiz & Cavusoglu (2004) and fixed by papillary muscles as indicated by Getty (2002) and Abidu-Figueiredo *et al*. (2013), Soares *et al*. (2010) and Tajdalli *et al*. (2009). The total perimeter of the left atrioventricular valve is comparable to the results obtained by Guimarães *et al*. (2011), with the septal cusp being the largest, as described by Hodgkinson (1901).

CONCLUSION

The fibrous skeleton of the ostrich heart has two fibrous rings that surround the left atrioventricular valve and the aortic valve, and right and left fibrous trigones. There is no fibrous ring in the right atrioventricular valve, only a small layer of collagenous connective tissue that connects the aortic and left atrioventricular rings and the fibrous trigone. There is no fibrous ring in the pulmonary valve; the pulmonary valve is supported by an arterial ligament, which is connected to the aorta by the adventitia. The left atrioventricular valve presents tricuspid dominance. The right and left cusp sizes vary and result in three valve types, with the septal cusp always being the largest.

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RESUMEN: El corazón de avestruz tiene dos atrios y dos ventrículos, lo que lo hace similar al de los mamíferos, y un sistema de valvas similar al de otras aves. Se describen las características anatómicas y biométricas del esqueleto fibroso y la valva atrioventricular izquierda del corazón de avestruz (*Struthio camelus*), contribuyendo a la comprensión anatómica funcional del avestruz. Disecamos 30 corazones de avestruces de entre 12 y 15 meses. Se midieron la longitud y el ancho de las cúspides de la valva auriculoventricular izquierda y se identificaron diferencias significativas en las mediciones. Se estudiaron los anillos atrioventricular izquierdo y aórtico en el esqueleto fibroso y se identificaron tres tipos de esqueleto fibroso. No se detectó ningún anillo fibroso en la valva auriculoventricular derecha ni en la valva pulmonar. La valva auriculoventricular izquierda es predominantemente tricúspide, con una cúspide septal más grande. Las variaciones en la longitud de las cúspides indicaron tres tipos de valva auriculoventricular izquierda. Esto nos permitió definir las características morfológicas del esqueleto fibroso y la morfología funcional de la valva auriculoventricular izquierda del corazón de avestruz.

PALABRAS CLAVE: Avestruz; Corazón; Trígono fibroso; Valva auriculoventricular izquierda.

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