

## MORPHOLOGY OF THE AORTIC ARCH AND PERICARDIUM IN THE AFRICAN GIANT RAT (*CRICETOMYS GAMBIANUS*, WATERHOUSE 1840)

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### ABSTRACT

This study was aimed at evaluating the morphology of the aortic arch and pericardium in the African giant rat (*Cricetomys gambianus*, Waterhouse, 1840). The African giant rat has shown its usefulness in different areas of our daily lives. There is paucity of anatomical data on the cardiovascular system of this important rodent. Ten adult African giant rats (AGR) were used for the study. The rats were euthanized and injected with prepared polyester resin, intracardially. Thereafter, the AGR were dissected and branching pattern of arteries originating from the aortic arch was determined. The aortic arch gave off the brachiocephalic trunk, left common carotid and left subclavian arteries. The brachiocephalic trunk bifurcated into right subclavian artery and right common carotid artery which supplied the right forelimb and head respectively. The pericardium in the AGR was a fibro-serous sac which enveloped the heart. The sternopericardial ligament attached the pericardium to most parts of the sternum, while the phrenicopericardial ligament was bifid and emerged from the bilateral borders of the fibrous pericardium and attached the organ to the lateral parts of the central tendon of the diaphragm. Species-specific morphological features of the cardiovascular system in the AGR may represent structural specialization for adaptation in the giant rat. This study provides baseline anatomical data on the morphology of the aortic arch and the pericardium in the AGR. The findings of the study will be useful to researchers in different areas of biomedical sciences, and may aid in the diagnosis of diseases related to the cardiovascular system.

**Keywords:** African giant rats; aortic arch; brachiocephalic trunk; cardiovascular system; morphology; pericardium

### INTRODUCTION

African giant rat (AGR) is a large, nocturnally active muroid which is widespread in Africa (Ayodeji *et al.*, 2012). Their keen sense of smell has been explored in the detection of land mines, *Mycobacterium tuberculosis*, the etiologic agent of tuberculosis (McKee, 2003; Weetjens *et al.*, 2009; Poling *et al.*, 2011; Mahony *et al.*, 2012), and *Salmonella* bacteria; the AGR shows potentials as valuable asset in the control of illicit substances across borders (Mahony *et al.*, 2014). The AGR provides a wealth of information on the biology and behaviour of rodents (Peichi & Mountairou, 1988; Ibe *et al.*, 2010; Ibe *et al.*, 2014).

The aortic arch and pericardium are core components of the cardiovascular system. Pericardial ligaments suspend the

heart; and significant morphological variations have been reported in pericardium of different species of mammals (Stan *et al.*, 2015; Singh, 2018). The morphology of the aortic arch and the major arteries originating from it in domestic animals (Tipirdamaz *et al.*, 1998; Dursun, 2000), laboratory animals (Green, 1968; Young, *et al.*, 1979; McLaughlin & Chiasson, 1987; Popesko, *et al.*, 1990a, b) and some wild rodents (Ozdemir *et al.*, 2008; Aydin *et al.*, 2011a,b; Aydin *et al.*, 2013) have been described. Variations in pattern of branching of arteries may occur among individuals of the same species; however these variations are more evident across different species (Samuelson, 2007; Shin *et al.*, 2018). The central nervous system (Mustapha *et al.*, 2014; Olude *et al.*, 2014); reproductive system (Akinloye

& Oke, 2009; Ali *et al.*, 2011); gastrointestinal system (Ali *et al.*, 2008); aspects of the sensory system (Igbokwe & Nwaogu, 2009); and tongue (Igbokwe & Mbajiorgu, 2019) of the AGR are some studies on this important rodent.

There is general paucity of anatomical data on the morphology of the aortic arch and pericardium of the AGR. This study aimed at providing macro-anatomical data on the pericardium, aortic arch and its arterial branches in the AGR. This information will be useful to morphologists and veterinary clinician and pathologists.

## **MATERIALS AND METHODS**

### **EXPERIMENTAL ANIMALS**

Ten adult AGR consisting of both males and females weighing between 800-1300g were used for this study. The giant rats were handled in accordance with the guidelines of the American Society of Mammalogists (Gannon & Sikes, 2007). The live trapped animals were transported in metal cages, to the Department of Veterinary Anatomy research facility, University of Nigeria, Nsukka after procurement from reputable hunters within Nsukka metropolis, Enugu state, Nigeria. The animals were acclimatized for two weeks in standard laboratory cages and maintained with different omnivorous diet regimen ad libitum. The protocol was approved by the Faculty of Veterinary Medicine, University of Nigeria, Nsukka institutional animal care and use committee (FVM-UNN-IACUC-2023-11/41).

### **EUTHANASIA AND INCISIONS (ANIMAL PREPARATION)**

The animals were euthanised by overdose injection of pentobarbitone sodium (AVMA, 2013). After which an incision was made into the thoracic cavity of each euthanised animal. The thoracic incision extended from the base of the neck (thoracic inlet) through the sternochondrial joints, to reach the diaphragm, exposing the aortic arch, its branches and the pericardium. The euthanized animals were immediately exsanguinated and their arteries flushed using normal saline injected through the left ventricle, to dissolve all blood clot that may interfere with the flow of the injection mass.

### **PREPARATION AND INJECTION OF POLYESTER RESIN**

Clear gel polyester resin, accelerator, red pigments and catalyst (Gougeon Brothers Inc., Bay City, U. S. A) were used to prepare an injection mass and standardized to a ratio of 90:4:4:2 respectively. The resin accelerator and red pigments were added in parts to the clear gel polyester resin, and stirred thoroughly after each addition until a homogeneously bright red coloured solution was obtained. The catalyst was added to the solution just before injection according to industrial methods. The prepared injection mass

was injected using a scalp vein set (23G) connected to a 20ml syringe. The injection was by continuous thumb pressure (Meyer, 2007) through the left ventricle until adequate vascular distribution was achieved; determined by turgidity of the aortic arch, aorta and its branches, and even smaller arterial meshwork supplying organs were filled with the bright red coloured injection mass. The injected animals were allowed for about 3 hours; then immersion fixed in 10% formalin for about 24 hours. Thereafter arteries originating from the aortic arch and aorta were carefully dissected and examined for pattern of branching, and photographs were taken using a digital camera.

## **RESULT**

### **AORTIC ARCH AND ITS BRANCHES**

The aorta in the AGR emerged from the base of the heart and took a cranial course after its emergence as the cranial aorta. It reflected less than one centimetre from its point of origin as the aortic arch, after which it continued caudodorsally as the caudal aorta. The aortic arch gave off branches that supplied the head, neck and forelimbs in the AGR. These branches were the brachiocephalic trunk, left common carotid artery and left subclavian artery (Figure I). The first branch, brachiocephalic trunk bifurcated into the right common carotid artery and the right subclavian artery. The right common carotid artery ran cranially along the right lateral border of the trachea while the right subclavian artery (Figure II), while the right subclavian artery descended and supplied most of the right forelimb and adjacent structures.

A second branch, the left common carotid artery originated independently from the aortic arch. The left common carotid artery ran along the left lateral side of the trachea (Figure II) forming the shape of the letter 'V' with the brachiocephalic trunk over the trachea. Both common carotid arteries approximated each other as they approached and entered the head. The aortic arch showed a third branch, the left subclavian artery, which branched independently and supplied the left forelimb and adjacent structures on the right.

### **PERICARDIUM**

The pericardium in the AGR appeared as a fibro-serous sac which enveloped the heart completely. Small capillary cleft which contains serous fluid was observed between the heart and the pericardium. The pericardium had its root from the base of the heart and attached to the great vessels of the base of the heart. The visceral part of the serous pericardium was directly applied to the heart. The parietal layer had a relatively thick external covering and blends with the adventitia of the great vessels.

Figure III shows the ligaments that attached the pericardium of the AGR to adjacent structures. These ligaments include

the sternopericardial ligament which attached the pericardium to the sternum and phrenicopericardial ligament that attached pericardium to the diaphragm. The sternopericardial ligament extended from about mid-sterna to the xyphoid region. The phrenicopericardial ligament was bifid and emerged from the lateral borders of the fibrous pericardium; and attached the organ to the lateral parts of the central tendon of the diaphragm.

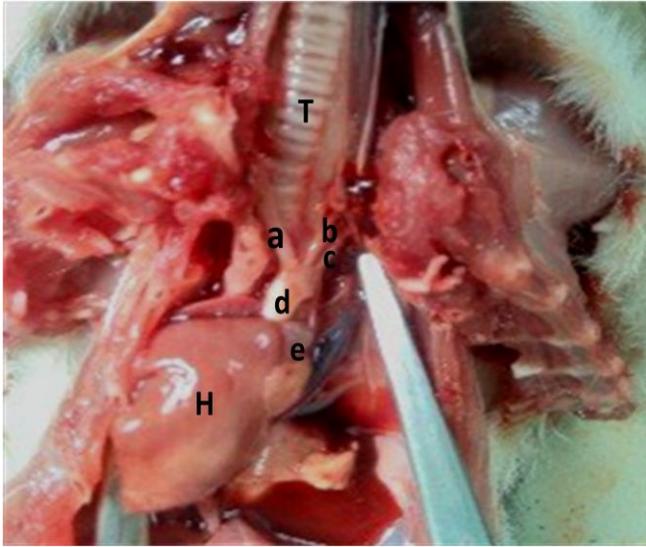


Figure I: Photograph of the thoracic region of the AGR showing the heart (H), trachea, (T), brachiocephalic trunk (a), left common carotid (b), left subclavian (c), Aortic arch (d) and pulmonary trunk (e). Note: this photograph was taken from a freshly dissected specimen without fixation.

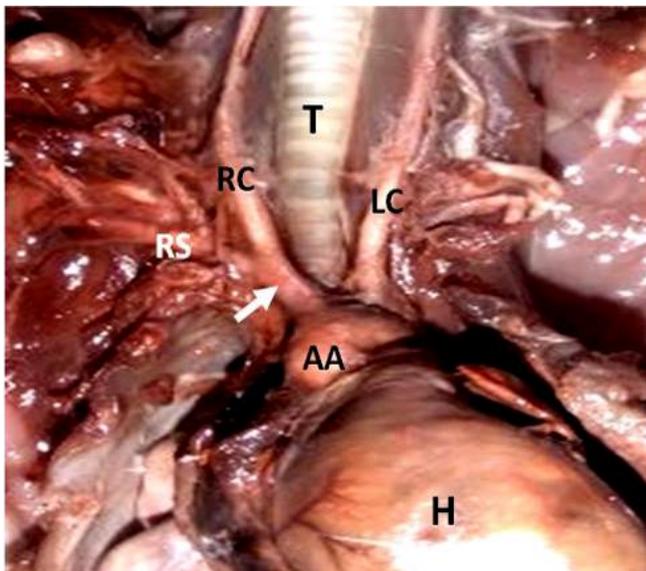


Figure II: Photograph of the thoracic cavity of the AGR showing Trachea (T) Heart (H), Aortic arch (AA), brachiocephalic trunk (Arrow), Right subclavian (RS), Right common carotid (RC) and Left common carotid (LC) arteries

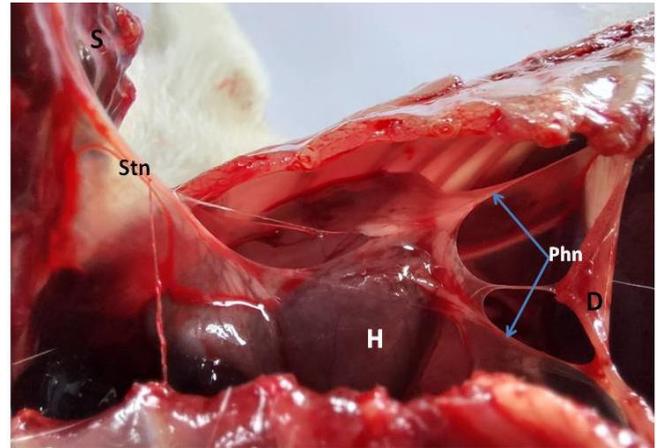


Figure III: Photograph of the thoracic cavity of the AGR showing the Heart (H) Sternum (S), Diaphragm (D), sternopericardial ligament (Stn) and bifid phrenicopericardial ligaments (Phn) attaching the pericardium to the margins of the central tendinous portion of the diaphragm.

## DISCUSSION

The morphology of the aortic arch and its arterial branches in many species, especially mammals, has been topical in cardiovascular studies. In spite of the similarities in mammalian cardiovascular structure, incidental peculiarities exist, which may be attributed to taxonomy, environment and activities (Shin *et al.*, 2018; Bae *et al.*, 2022; Murray & Meguid, 2023). In this study, the aortic arch gives off three principal branches in the AGR, namely; brachiocephalic, left common carotid and left subclavian arteries. Similar aortic arch morphology have been reported in rats and mice (Popesco *et al.*, 1990b; Monnereau *et al.*, 2005), porcupines (Atalar *et al.*, 2003), mole-rats (Aydin *et al.*, 2013), giant armadillo (Santos *et al.*, 2020), ringed seal, *Pusa hispida* (Smoldlaka *et al.*, 2009), *Chinchilla lanigera* (Martonos *et al.*, 2018) and humans (William & Warwick, 1980; Putz & Pabst, 2008). However, these reports vary from what has been demonstrated in many other animal species; such as ruminants and equine (Getty, 1975; Dursun, 2000; Shin *et al.*, 2018; Singh, 2018) where only the brachiocephalic trunk originates from the aortic arch. In other animals like the pig (Getty, 1975; Nickel, *et al.* 1981; Dursun, 2000; Singh, 2018), carnivores (Dursun, 2000; Singh, 2018), red-squirrels (Aydin *et al.*, 2011a), ground-squirrels (Aydin *et al.*, 2011b) rabbits and guinea pigs (Popesco *et al.*, 1990a), both brachiocephalic trunk and the left subclavian artery arise from the aortic arch. Common observation among these species, where the three arteries (brachiocephalic, left common carotid and left subclavian) arise individually from the aortic arch, is the relative level of dependence on the forelimbs in these species. The pattern of origin of arteries from the aortic arch may be to extent of use and/or dexterity of the fore limb. This may be related to the presence of the clavicle bone, and may present a ground for prediction of

arterial pattern in species. Also, this is believed to have some direct relevance in surgical anatomy.

In the AGR, the brachiocephalic trunk divided into right common carotid and right subclavian arteries. Reports in ruminants and equine species (Getty, 1975; Dursun, 2000) show that the arterial branches of the brachiocephalic trunk were left subclavian, right subclavian and the bicarotic trunk. In pigs it divides into the right subclavian artery and the bicarotic trunk (Getty, 1975; Nickel *et al.*, 1981; Dursun, 2000). Whereas in dogs (Getty, 1975; Singh *et al.*, 1983; Dursun, 2000; Evans & de Lahunta, 2010), rabbits (Singh *et al.*, 1983; McLaughlin & Chiasson, 1987), Guinea pigs (Cooper & Schiller, 1975), red squirrels (Aydin *et al.*, 2011a), and ground squirrels (Aydin *et al.*, 2011b) it branches into the left and right common carotids, and the right subclavian arteries. There are discrepancies in the point at which each branch arises in different species; some branches arise at different levels in some species, while in other cases they may arise at the same point (Chiasson, 1980; Popesko *et al.*, 1990a, b; Putz & Pabst, 2008).

The right subclavian artery branched off from the brachiocephalic trunk after which it continued cranially as the right common carotid artery in the AGR. This is arguably so, considering the fact that the right subclavian artery branched off earlier than the right common carotid artery, to supply the limb unlike right common carotid artery which represents the cranial continuation of the brachiocephalic trunk. This corroborates the report by Martonos *et al.* (2018) in *Chinchilla lanigera*, with similar aortic arch morphology, represented the right common carotid as the continuation of the brachiocephalic trunk. This is the case in ruminants and equine species (Habel, 1989; Dursun, 2000; Singh, 2018) where the brachiocephalic trunk is the only artery originating from the aortic arch; giving off the left and right subclavian arteries and terminating as the bicarotic trunk.

Considerable variations in the morphology of the aortic arch have been reported among individuals of the same species, with variable prevalence (Wang *et al.*, 2016; Murray & Meguid, 2023), with the dominant pattern showing the highest prevalence. Such variations were not recorded in this study. This may be attributed to the number of subjects employed. The brachiocephalic trunk, left common carotid and left subclavian arteries supply the head, neck, forelimbs and adjacent structures. This agrees with the reports of many authors on the vascular supply to these structures.

The pericardium envelops the heart in the AGR, and is composed of fibrous and serous parts. The serous part has a visceral and a parietal layer. The visceral layer of the serous pericardium is directly applied unto the heart, while the parietal layer is applied to the fibrous part of the pericardium, leaving a potential space which contains serous fluid. This is similar to the reports in other mammalian

species (Samuelson, 2007; Singh, 2018). The pericardium blends with connective tissues of the outer coat (tunica adventitia) of large vessels of the base of the heart. The connective tissues which surround and blend with the tissues of the tunica adventitia of blood vessels in the heart, especially along the paraconal and subsinuous grooves are believed to be derived from the pericardium. This may serve to cushion the effect of the contracting heart against these vessels. Reports of similar connective tissues exist in man (Boland *et al.*, 2021).

The fibrous pericardium envelops the heart and provides attachments for the pericardial ligaments which attach the heart to adjacent structures. In the AGR, there are two ligaments; the sternopericardial ligament and the Phrenicopericardial ligament. The sternopericardial ligament is extensive and attached the heart to most parts of the sternum while the bifid phrenicopericardial ligament attaches the heart to the central tendon of the diaphragm. Similar findings have been documented in humans (William & Warwick, 1980) and guinea pigs (Stan *et al.*, 2015). However, this contradicts the reports in most domestic species where either of the ligaments is absent (Singh, 2018). These ligaments appear to play important roles in anchoring and stabilizing the heart in the AGR. This may be important during burrowing and other activities that require tortuous body movements, considering their extensive attachments. This morphological adaptation in the AGR is believed to compensate for the less fibrous nature of the pericardial ligaments. This corresponds to the report in man where loose fibro-aerolar connective tissues constitute the tissue of the phrenicopericardial ligament (William & Warwick, 1980). The pericardium has been alluded to play important functional roles in anchoring and stabilizing the heart, as a components of the cardiovascular system (Stan *et al.*, 2015; Singh, 2018). This finding validates this functional allusion to the pericardium.

## CONCLUSION

In conclusion, this study has provided information on the morphology of the aortic arch and pericardium in the AGR. Species-specific morphologic features of these key organs of the cardiovascular system in the AGR may represent structural specialization for adaptation in the AGR. The morphology of the aortic arch and pericardium demonstrated by our study provides foundational information on these key organs of the cardiovascular system in the AGR.

In addition, our study will be useful for explorative surgical procedures and in recognizing or identifying structural anomalies in this species, especially following increasing interest in AGR for biomedical research.

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