

HEART HISTOLOGY OF THE FOUR CHAMBERS IN THE SPOTTED SCAT, *SCATOPHAGUS ARGUS*, DURING THE JUVENILE STAGE

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Received: July 21, 2016; Revised: September 24, 2016; Accepted: September 26, 2016

Abstract

The heart structure of the spotted scat, *Scatophagus argus*, was observed from the Paknam Pranburi Estuary, Thailand, using histological and histochemical techniques. The results revealed that the heart structure consisted of 4 chambers comprising the sinus venosus, the atrium, the ventricle, and the bulbus arteriosus which were basically structured into 3 layers (the epicardium, the myocardium, and the endocardium). The feature of the sinus venosus was structured similarly to the atrium. It had 2 layers which were a thin layer of the epicardium and the endocardium. However, the myocardium in the atrium had much more cardiac muscular tissue than was found in the sinus venosus. The ventricle in this species was thicker than that of the atrium and it was composed of the thickest layer of the cardiomyocytes. The localization of the bulbus arteriosus with the ventral aorta was the final observation of the heart organ and had a thicker layer of the myocardium than the other layers.

Keywords: Blood vessel, fish, heart, histology, spotted scat

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Introduction

In relation to functional structures, the cardiovascular system (including the heart, blood vessels, and blood components) of a number of teleost species has an important role in the blood pressure, the chemical components, and the transport of nutrients and oxygen (Olson, 2000; Roberts, 2012). Therefore, the anatomy and histology of the cardiovascular system has been studied in *Perca fluviatilis* (Pollak, 1960), and *Prochilodus lineatus* and *Hoplias malabaricus* (Rivaroli *et al.*, 2006), which provided not only structural information but also information that was

applied to further studies, for example histopathology and physiology. However, there have been no investigations of the histology and histochemistry of the *Scatophagus argus* during the juvenile stage. It is an important mangrove species and is dominantly found in the Paknam Pranburi Estuary, Thailand. Additionally, this species is considered to be very important, both commercially and in the food web/food chain.

Materials and Methods

Ten specimens of *Scatophagus argus* with a total length about 3.4 ± 0.21 cm were collected

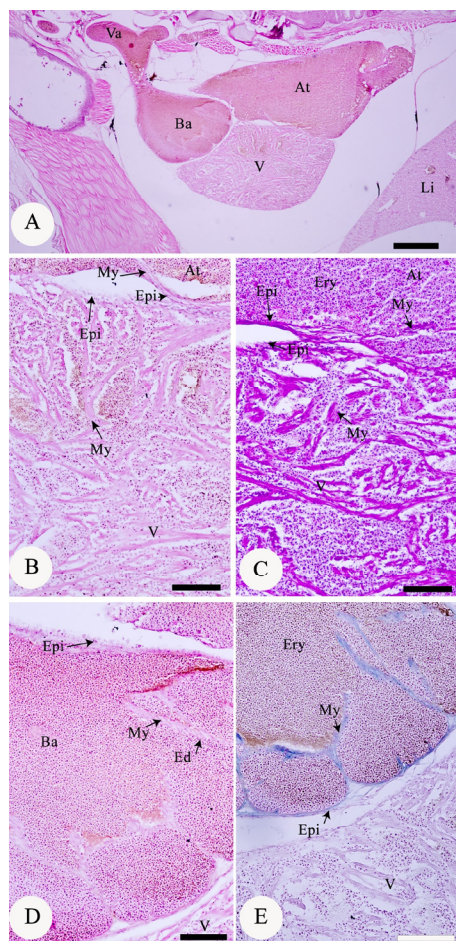


Figure 1. Figure 1. Anatomy and light micrograph of the heart in *Scatophagus argus*; 200 μ m (A), 20 μ m (B-D). At = atrium, Ba = bulbus arteriosus, Ed = endocardium, Epi = epicardium, Ery = erythrocytes, My = myocardium, V = ventricle, Va = ventral aorta. Harris's haematoxylin and eosin (A, B, D), periodic acid-Schiff (C) and Alcian blue (E)

from 2 stations (the first at N 12°24'15.8" / E 099°58'25.6" and the second at N 12°24'21.6" / E 099°58'37.1") in the Paknam Pramburi Estuary, Thailand. All the fish were euthanized with a rapid cooling shock (Wilson *et al.*, 2009). They were then fixed in Davidson's fixative (for about 24-36 h) and transferred into 70% ethanol. The hearts of the fish were collected and subsequently subjected to standard histological techniques (Presnell and Schreibman, 1997; Suvarna *et al.*, 2013). Sections at 5-6 µm thickness were subsequently stained with Harris's haematoxylin and eosin (H&E), Alcian blue (AB) and periodic acid-Schiff (PAS) (Presnell and Schreibman, 1997; Suvarna *et al.*, 2013).

Results and Discussion

Morphology and Histology of the Heart

Morphological observation of the heart in *S. argus* showed that it was located anteriorly in the peritoneal cavity and caudoventrally to the gill. It is likely that this has been investigated in some teleosts (Pope and Ferguson, 2006; Senarat *et al.*, 2016). Under a light microscope, it was revealed that the heart structure typically consisted of 4 chambers including the sinus venosus (data not shown), the soft atrium, the muscular ventricle, and the bulbus arteriosus (Figure 1(a-e)). Similarly, the heart morphology of *Rastrelliger brachysoma* (Senarat *et al.*, 2016) and *Poecilia reticulata* (Genten *et al.*, 2008) was studied.

Based on histology and histochemistry, the heart wall was normally composed of 3 layers; the outermost epicardium, the middle myocardium and the innermost endocardium in longitudinal sections (Figure 1(b-c)). The outermost epicardium originated from the pericardial sac. A single sub-layer of flattened epithelial cells was tightly packed in this layer; however, a prominent loss of connective tissue was observed. The middle layer was composed of the thickness of the middle myocardium. Within this layer, the specialized cardiac muscle was mainly seen around the heart wall. Each cardiac muscle contained a large syncytium of anastomosing fiber (cardiomyocytes). As a result, the function of the cardiomyocytes is an important process in the binding of natriuretic peptides (Cerra *et al.*, 1997) and the anti-freeze

mucins (Icardo, 2012). The innermost endocardium showed that a thin layer of loose connective tissue and epithelial cells was observed.

The structure of the sinus venosus was likely seen in the general structure. A thin sinus venosus wall was divided into 2 layers (a thin layer of the epicardium and the endocardium) (data not shown). However, the myocardium layer was markedly found, as previously seen in *R. brachysoma* (Senarat *et al.*, 2016). On the other hand, the sinus venosus in *Anguilla anguilla* and *Pleuronectes platessa* was found (Santer and Cobb, 1972; Yamauchi, 1980). The function of this structure has been reported to be concerned with the storage of the incoming venous blood from the hepatic portal vein (Genten *et al.*, 2008). The wall of the atrium was thin-walled and histologically similar to the sinus venosus (Figure 1(a-c)). However, some characterization of this chamber was different; that is, the myocardium had much more cardiac muscular tissue than the sinus venosus. The cardiac muscular tissue reacted positively with the PAS (Figure 1(c)) indicating the presence of glycoprotein. The atrium is known to play an important role in supporting the atrial architecture and blood pump (Icardo, 2012). The blood from the fish's body enters the atrium via the sinus venosus. The atrium contains the cells that initiate the contractions for pumping the blood into the ventricle (Icardo, 2012). It was known that the ventricle chamber is thicker than that of the atrium (Figure 1(b)). Interestingly, the thickest layer of cardiomyocytes was observed in the ventricular myocardium, which reacted positively with the PAS reaction (Figure 1(c)). This agreed with previous reports on *Echiichthys vipera*, *Oncorhynchus mikiss*, and *Salvelinus alpinus* (Icardo, 2012). It is possible that the roles of the structure were concerned with supporting the pumping action in teleosts (Genten *et al.*, 2008; Roberts, 2012). Additionally, in our study 2 layers, an outer compact layer and an inner layer of the abundant spongy layers in the ventricle, were also observed similar to those of *Danio rerio* (Menke *et al.*, 2011). The bulbus arteriosus was the final region of the heart. The wall of this chamber histologically revealed that the epicardium and the endothelium formed a thin layer; in contrast, the myocardium was a thick layer (Figure 1(a), 1(d)) and reacted positively

with the AB (Figure 1(e)). The functional structure of the bulbus arteriosus is to regulate the pressure of the blood leaving the heart (Genten *et al.*, 2008).

Histology and Histochemistry of the Aortas

The blood vessels in both the dorsal and ventral aortas were clearly seen in *S. argus* (Figure 2). Histological localization of these vessels was formed, in which the ventral aorta was jointed with the bulbus arteriosus and ran to the mandibular region via the afferent bronchial arteries. The sinus venosus was connected by the dorsal aorta. The dorsal aorta had a similar structure that could be classified into 3 layers, the tunica intima, tunica media, and tunica adventitia (Figure 2(a-c)). This was supported by studies of higher vertebrates (Genten *et al.*, 2008). In the tunica intima, its epithelium was lined by 2 sub-layers (the endothelial epithelium and subendothelial sub-layers). The internal elastic layer was not observed. The tunica media lay between the tunica intima on the inside and the tunica adventitia on the outside. The prominent

elastic, reticular fibers and a few smooth muscles formed the majority of the layer in the tunica media. It is possible that this characterization has important roles in the constriction and dilation of the vessels (Groman, 1982; Roberts, 2012). Lastly, the outer layer of the tunica adventitia was covered by a thin connective tissue and a few collagen fibers. The adventitia function is a fibroblast and stem cell progenitor reservoir and allows the rapid influx of these cells into the aortic wall (Psaltis *et al.*, 2011).

Conclusions

The present study showed that the heart structure of *S. argus* was typically composed of 4 chambers, comprising the sinus venosus, the soft atrium, the muscular ventricle, and the bulbus arteriosus, which is newly reported. Our histological results will be applied to

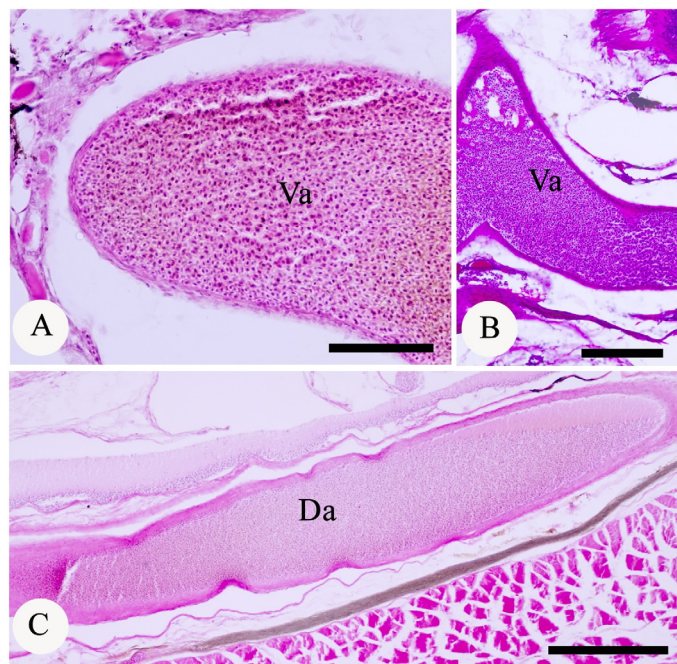


Figure 2. Light micrograph and schematic diagram of ventral aorta (A-B) and dorsal aorta (C) in *Scatophagus argus*; 30 μ m (A-C). Da = dorsal aorta, Va = ventral aorta. Harris's haematoxylin and eosin (A, C), periodic acid-Schiff (B)

further study, for example the ultrastructure, histopathology, and physiology.

Acknowledgement

We thank the members of the Microtechnique and Histology laboratory, Department of Biology, Faculty of Science, Prince of Songkla University, Thailand for their technical support in the laboratory.

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