

Study of Glomerular Vasculature in Teleosts with the Resin-Replica Method

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Abstract Glomerular vasculature was investigated in the carp *Cyprinus carpio*, the scorpionfish *Sebastiscus marmoratus*, and the marine catfish *Plotosus lineatus* with the resin-replica method. An afferent arteriole was connected with a glomerulus in every fish. It was slender in the carp, whereas the scorpionfish and marine catfish possessed thick afferent arterioles. The glomerular capillaries were sinusoidal. The divergences, convergences, and windings of these capillaries were not well developed in any of the fish. The glomerular capillaries converged into an efferent arteriole in the carp and scorpionfish. In the marine catfish, on the other hand, most of the glomeruli had two efferent arterioles.

In a teleost, the glomerular capillary has a fenestrated endothelium (Bulger and Trump, 1968; De Ruiter, 1980). Many podocytes surround the outside of the capillary (Brown et al., 1983). It is also known that there is a difference in the wall thickness of the glomerular capillary between freshwater and seawater teleosts; the latter is thicker than the former. The thick capillary wall perhaps serves as a filtration barrier in seawater teleosts (Hickman and Trump, 1969). Thus, the capillary wall has been well examined in the teleostean glomerulus. However, the glomerular vasculature itself in teleosts is uncertain (Casellas and Mimran, 1981; Brown, 1985; Brown, 1988). This study examined the glomerular vasculature in three species of teleosts with the resin-replica method.

Materials and methods

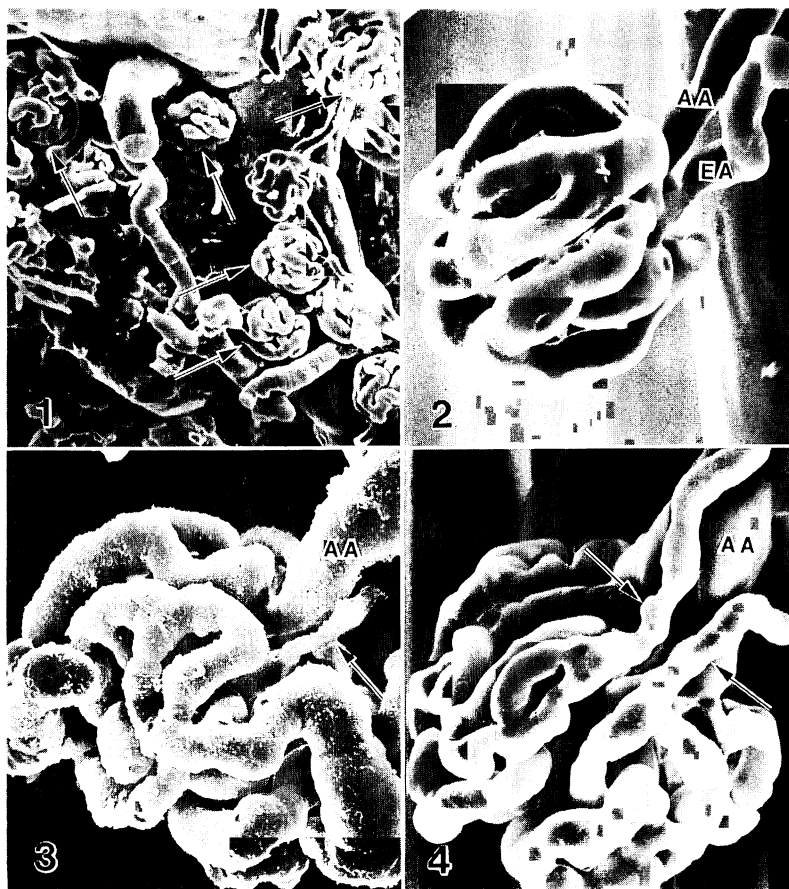
One carp *Cyprinus carpio* (body weight 45 g), 2 scorpionfish *Sebastiscus marmoratus* (body weights 320 g and 160 g), and 2 marine catfish *Plotosus lineatus* (body weights 114 g and 60 g) were used in this study. Each fish was anesthetized with ethyl carbamate and placed ventral side up for dissection. After the hearts were exposed, a physiological saline solution, which is designed for the freshwater or seawater fish and contains 0.125% sodium heparin and 1.5% ethyl carbamate, was perfused via the aortic bulbs for 30–60 min at a perfusion pressure of 22–40 mmHg. Then a resin mixture was infused into the fish for 10–15 min

at a 7–15 mmHg higher pressure than the pressure of the physiological saline perfusion. The resin mixture was composed of 60% Mercor (Dainippon Inki Kagaku, Tokyo), 40% methyl methacrylate (monomer), and 0.01 g/ml benzoyl peroxide. The procedures for making replicas of the renal vessels were performed as described by Murakami (1971). The replicas were coated with gold by an ion sputter (JEOL JFC-1100) and observed with a scanning electron microscope (JEOL JSM T-20).

Results and discussion

The slightly higher pressure in the resin infusion than in the physiological saline perfusion made it possible to form replicas of the renal arteries and the glomerular capillaries of the kidneys of each fish (Fig. 1). An afferent arteriole in each fish was usually connected with a glomerulus. The carp had a slender afferent arteriole comparable to the efferent arteriole in diameter (Fig. 2). In the scorpionfish and marine catfish, however, the afferent arterioles had very large diameters in comparison with their efferent arterioles (Figs. 3, 4).

Several glomerular capillaries diverged from the afferent arteriole in each fish. The glomerular capillaries were sinusoidal. There were fewer divergences, convergences, and windings of the capillaries in all the fish (Figs. 1, 5, 6) when compared to those of a rat (Murakami et al., 1971; Murakami, 1972). Although the kidney principally performs the excretory functions in mammals,



- Fig. 1. Replicas of some glomerular capillaries (arrows) in the carp *Cyprinus carpio*. Slightly higher pressure in the resin infusion than in the physiological saline solution made it possible to make the replicas. $\times 125$.
- Fig. 2. The afferent (AA) and efferent (EA) arterioles in the carp *Cyprinus carpio*. Both are slender and almost of the same size. $\times 610$.
- Fig. 3. The afferent arteriole (AA) of the scorpionfish *Sebastiscus marmoratus*. Its diameter is larger than that of the efferent one (arrow). $\times 450$.
- Fig. 4. Two efferent arterioles (arrows) observed in a glomerulus of the marine catfish *Plotosus lineatus*. The afferent arteriole (AA) is very thick. $\times 495$.

the excretory functions in fish partially take place in the kidney (Schmidt-Nielsen, 1977). The less-developed divergences, convergences, and windings of the teleostean glomerular capillaries are probably related to their partial contribution of the fish kidney to the excretory functions.

Although the marine catfish is a seawater fish, the distal segment exists in its renal tubule, as it does in freshwater fish (Ogawa, 1959). In the marine catfish, there were two efferent arterioles in most of the glomeruli (Fig. 4). On the other hand, the glomerular capillaries converged into

an efferent arteriole in the carp and scorpionfish (Figs. 2, 3). Thus, the marine catfish has a specific glomerular vasculature as well as the renal tubular components.

The diameters of the efferent arteriole replicas of all the fish approximated the short axis of their oval red blood cells, judging from the report on fish blood cells by Ikeda et al. (1986). As mentioned before, the afferent and efferent arterioles were almost of the same size in the carp, whereas the scorpionfish and marine catfish had thick afferent arterioles in comparison with their efferent



Fig. 5. The glomerular capillaries of the marine catfish *Plotosus lineatus*. There are few divergences, convergences, and windings in terms of the looping. $\times 460$.

Fig. 6. The glomerulus in the scorpionfish *Sebastiscus marmoratus*. The divergences, convergences, and windings are less developed. $\times 345$.

ones. In the scorpionfish and marine catfish, therefore, the blood joins the glomerular capillaries through the thick afferent arteriole, and then goes to the narrow efferent arteriole. In general, it is a possible belief that the thick afferent and the narrow efferent arterioles fit the high filtration pressure in the glomerular capillaries (Guyton, 1986). However, the glomerular filtration rate in the seawater fish is very low in order to maintain water within the body (Hichman and Trump, 1969). The very low glomerular filtration rate might be accomplished by the morphological features of the glomerular capillary wall. Further elucidation of this problem must await data on hormonal regulation in the blood supply to the glomerular vasculature.

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樹脂鑄型法を用いた真骨魚の糸球体血管系に関する研究

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コイ, カサゴ, およびゴンズイの糸球体血管系を樹脂鑄型法を用いて調べた。検討したすべての魚種において1本の輸入細動脈が一つの糸球体に連絡している。コイにおいて輸入細動脈は細く, 輸出細動脈とほぼ同じ直径であった。一方, カサゴとゴンズイの輸入細動脈は, 輸出細動脈より非常に太かった。真骨魚の糸球体毛細血管は洞様毛細血管で, ラットのそれと比較して分岐, 吻合, および曲折が少ない。輸出細動脈はコイとカサゴでは, 一つの糸球体において1本であったが, ゴンズイの糸球体の多くは2本の輸出細動脈を持っていた。

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