Bulgarian Journal of Veterinary Medicine (2007), **10**, No 3, 147–154

SCANNING ELECTRON MICROSCOPIC STUDY ON RENAL GLOMERULAR ARTERIOLES IN PIGS

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Summary

Vodenicharov, A., 2007. Scanning electron microscopic study on renal glomerular arterioles in pigs. *Bulg. J. Vet. Med.*, **10**, No 3, 147–154.

A scanning electron microscopic (SEM) study was performed on 1620 glomerular arterioles (870 from the cortical and 750 from the juxtamedullary zone) in order to elucidate the peculiarities of haemodynamics and the potential for regulation of blood flow in the renal cortex. SEM showed that afferent arteriole (AA) in most cases separated under a sharp angle and relatively less frequently – at a right and obtuse angle. The length of AA was different; some of them exhibited convoluted at various extent course and cone- or ring-shaped constrictions. These features were more commonly observed in the peripheral zone of the cortex. The efferent arteriole (EA) usually had an arched course, variable length and degree of convolution. Cases when EA sharply changed its direction in the area of the vascular pole, thus forming a right angle over the glomerulus, have been observed. The present study adds to the data about the peculiarities of architectonics of renal glomerular arterioles in domestic pig, which could be of importance for blood flow regulation through glomeruli.

Key words: glomerular arterioles, kidney, swine, SEM

INTRODUCTION

The data about renal glomeruli and the AAs and EAs related to them in mammals are mainly about laboratory animals and humans. Relatively more numerous are the investigations on AA as it is well known that this vascular segment is essential for glomerular haemodynamics (Caselas & Moore, 1993; Navar *et al.*, 1996).

The studies upon the branching of AA in rabbits, rats, men, macaques and rhesus monkeys showed that it is generally divided into two vessels with almost equal diameter. These initial branches of AA are often referred to as "primary branches" although other names have been used beforehand: "principal branches", "afferent roots" or "lobular branches" (Hall, 1955; Elias, 1957; Elias *et al.*, 1960; Murakami *et al.*, 1971; Anderson & Anderson, 1976; Nopanitaya, 1980; Unehira, 1989; Winkler *et al.*, 1991).

According to data reported by Moore *et al.* (1992) and Vodenicharov & Simoens (1998), the AA of renal glomeruli in domestic pigs divides into two branches in the region of the vascular pole, and the EA emerges between them. Moore *et al.* (1992) states that in 50% of studied glomeruli, AAs increased their diameter before their bifurcations into primary branches. The EA has a larger diameter of the lumen in its beginning that then decreases, and outside the glomeruli it changes slightly or not at all. The course of the EA to the adjacent capillary network is usually creased. The studies of Anderson *et al.* (1988) have shown that EAs in the black bear are short, with reducing lumen diameter and exhibit a slight convolution.

In pigs and cows, Ohtsuka *et al.* (1982) described constrictions in the AA's wall that are mainly encountered at its separation from the interlobular artery and its entry in the vascular pole of the glomerulus. Although less frequently, ring-shaped constrictions along the course of the arteriole were also observed. These constrictions are thought to be areas where the blood flow to renal glomeruli is controlled. In contrast, in similar studies in pigs, Moore *et al.* (1992) found no constrictions in the wall of the AA at the glomerular vascular pole.

It is acknowledged that the porcine kidney is very similar to human one as well as that this animal species is a very appropriate model for a number of medico-biological studies, including investigations of human vasculature and with regard to transplantology too (Anestiady & Nagornev, 1982; 1983; Dobyan & Bulger, 1988; Pennington, 1992; Vollmerhaus, 1999).

Taking into consideration the increasing interest to kidney morphology in domestic pigs during the last years and the conflicting data reported in the literature, we aimed to obtain a more detailed characteristic about the architectonics of AAs and EAs by scanning electron microscopy with regard to the elucidation of the peculiarities of renal haemodynamics in this animal species.

MATERIALS AND METHODS

The material for the study was taken from corrosion casts used in recently performed morphometric studies (Simoens *et al.*, 2000). Segments of about 1 mm^3 were prepared by microdissection with a stereoscope from the superficial and juxtamedullary cortical zones. The suitable segments were further prepared for a scanning electron microscopy by mounting on aluminium stubs with a double-sided adhesive tape, sputtering and coating with gold in a Balzer and SCD 020 ion sputtering devices.

A total number of 1620 glomeruli were studied, 870 from the cortical and 750 from the juxtamedullary zone, 290 and 250 from each of three resins: Technovit 7100 (Kulzer & Co, Bad Homburg, Germany); Batson's # 17 (Anatomical Corrosion Compound, Polysciences Inc., Warrington, USA) and Mercox CL-2B (Okenshoji Co, Tokyo, Japan), respectively, together with the adjacent AAs and EAs. The observations were done on scanning electron microscopes Philips 505 Scanning Electron Microscope (Holland) and Digital Scanner Microscope DSM 940, Zeiss, Germany.

As the abovementioned study (Simoens *et al.*, 2000) reports detailed statistical data about the dimensions of glomeruli and the adjacent arterioles, in this study were measured only several, more distinguishing features observed along the course of single arterioles. That is why, morphometry and the respective statistical analysis were not an object of this study.

RESULTS

The AAs of renal glomeruli from the both cortical zones in most cases separated under a sharp angle and were at a different distance each from the other. The angle at their separation from the interlobar and interlobular arteries varied from 15 to 75 degrees and was observed in 612 (70%)

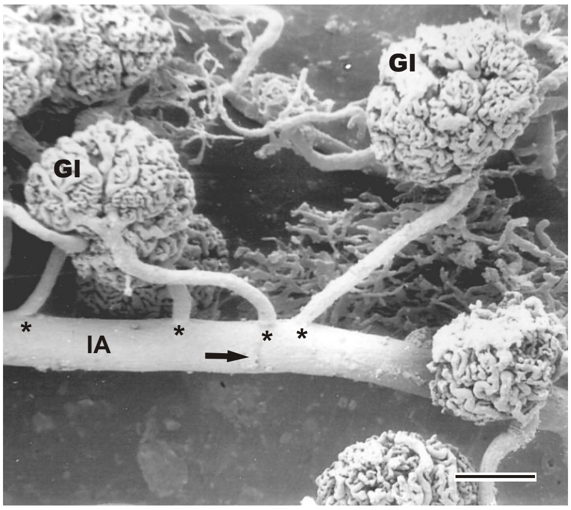

Fig. 1. Renal interlobular artery (IA), from which emerge afferent arterioles (*) of cortical glomeruli (Gl) under a various angle. The arrow shows the direction of blood flow; Mercox, bar = 150 µm.

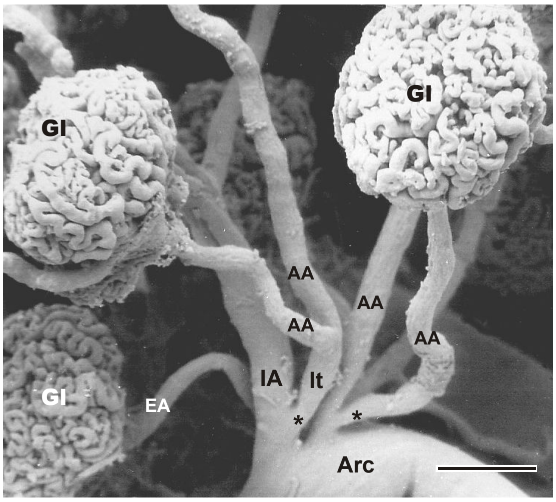

Fig. 2. Corrosion cast of the renal superficial cortical zone. Gl – glomerulus; Arc – arch artery; IA – interlobular artery; It – intralobular artery; AA – afferent arteriole; EA – efferent arteriole; * – constriction in the beginning of It and AA; Mercox, bar = 100 µm.

cortical and 450 (60%) juxtamedullary glomeruli. In the other instances, AA separated at a right (21% for both types, 182 and 158 respectively) and more rarely, at an obtuse angle (9% and 19%, respectively). In these cases, some arterioles, mostly those separating at obtuse angles, exhibited a retrograde course with regard to the interlobar artery (Fig. 1).

The length of AA was different, and in some instances, the distance from the site of separation to its entry in the vascular

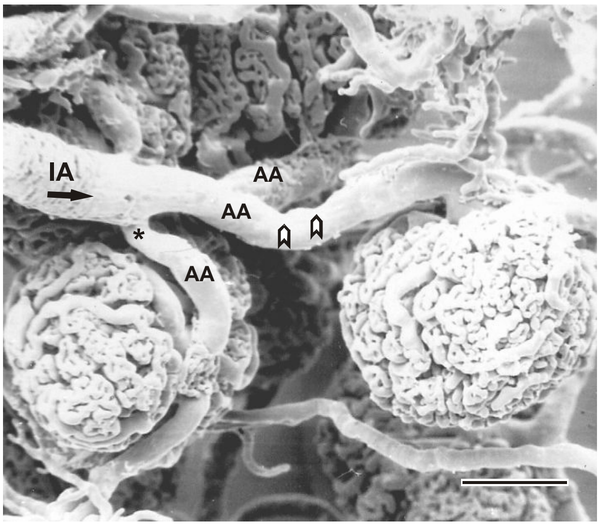

Fig. 3. Corrosion cast of the middle zone of the renal cortex. Constriction (*) in the beginning of an afferent arteriole (AA), followed by a dilatation and another constriction; arrow heads – ring-shaped constrictions in the beginning of the AA; IA – interlobular artery. The arrow shows the direction of blood flow; Mercox, bar = 100 µm.

pole reached 580 µm. Along the course of some of AAs – 15.4 % (134 cases) in the superficial and medium and 23 % (195 cases) in the juxtamedullary zone, variously shaped constrictions were observed – ring- or cone-shaped. Such constrictions were observed at the separation of arterioles and before their entry in the vascular pole. In the superficial zone of the cortex, 47 cases had a cone-shaped constriction in the beginning of the AA whose diameter then increased and after the middle of its length, became gradually reduced in the direction of the vascular pole. It should be noted that the course of these arterioles was irregularly convoluted, and the greatest thickness of the cast was observed in the first half of the arteriole. Similar cone-shaped constrictions were observed in the beginning of some interlobular arteries. It should be emphasized that immediately after the vessel constriction (27 µm) the artery size sharply increased (52 µm), and after that it divided in two afferent arterioles, usually with a different size (Fig. 2). Constrictions, dilatations, followed by a gradual reduction of the diameter of casts were observed also in the beginning of AAs from the middle zone of the cortex. For example, the dimensions of casts from single AAs were as followed: in the beginning 33.3 µm, in the next dilated part – 58.3 µm, and in the region of the vascular pole – 50.0 µm. Along the course of some AAs, usually two ring-shaped constrictions at a distance of 40–50 µm between were observed, the size of constricted areas being approximately by 15–20% lower (Fig. 3). In afferent arterioles of juxtamedullary glomeruli, the constrictions were primarily observed near the vascular pole before the branching of the arteriole. The constrictions were usually two, located near one to another: 25–40 µm (Fig. 4), and the size of these areas was by 20–25% lower than that of the adjacent part of the arteriole.

On conserved reprints from connective tissue sheaths of smooth muscle cells in the media of inter- and intralobular arteries, it was established that the casts of connective tissue sheaths of leiomyocytes did not change their circular situation and passed from the artery on the beginning of the arteriole at the site of separation of AAs (Fig. 5).

The casts of nuclei of the endothelial cells of AAs in the vascular pole area, were with an oval shape and axis-oriented, and their length was usually about 3 µm.

The EA was most commonly with an

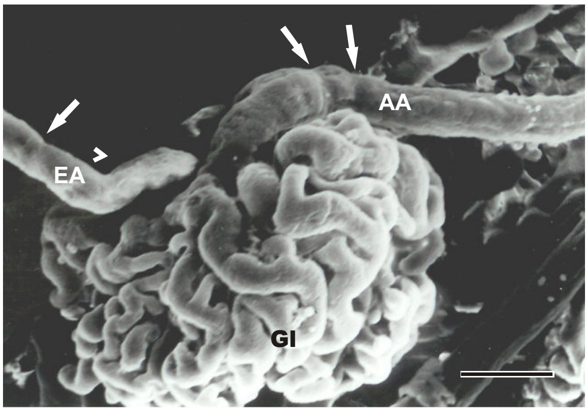

Fig. 4. Glomerulus (Gl) from the renal juxtamedullary cortical zone. The arrows designate the constrictions of the afferent (AA) and efferent (EA) arterioles near to the vascular pole; (<) – a right angle in the EA; Mercox, bar = 70 µm.

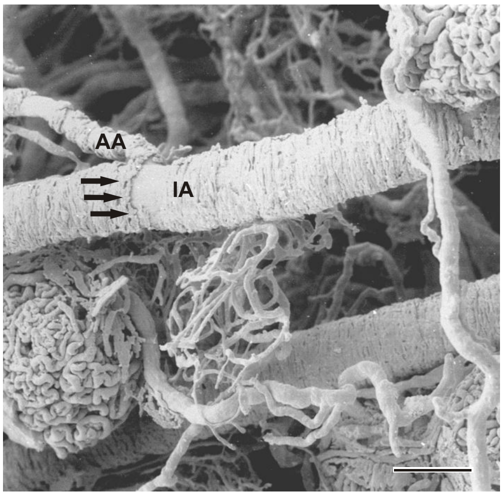

Fig. 5. Corrosion cast from the middle zone of the renal cortex. Initial part of an interlobular artery (IA) with preserved reprints of connective tissue sheaths of smooth muscle cells of the media; AA – afferent arteriole. The arrows show an area of transition of artery's cast to arteriole's media; Technovit 7100, bar = 80 µm.

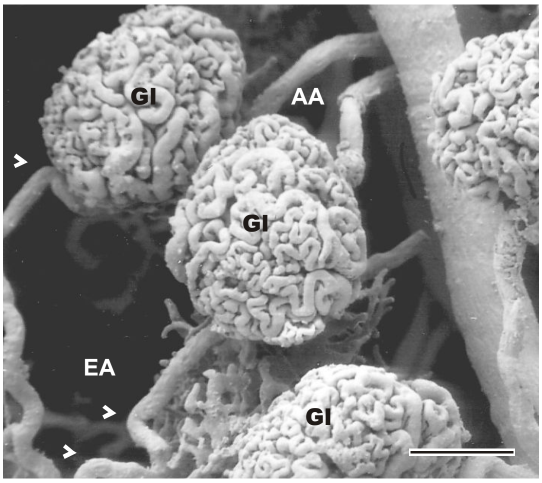

Fig. 6. Glomeruli in the middle zone of the renal cortex (Gl) with various course of their efferent arterioles (EA). AA – afferent arteriole; (>) – areas with right angles; Mercox, Bar = 100 µm.

arc-shaped course, with a various length and degree of convolution, without a visible reduction of the lumen's diameter.

In a total of 325 cases (20%), the EA changed sharply its direction in the area of the vascular pole under a right angle and then, formed the same angle once again in an area located near to the glomerulus (Fig. 4 and Fig. 6). Relatively rarely, in the middle zone and also in the superficial zone as single findings, there were cases where the course of EA was highly convoluted or exhibited U-shaped curves (Fig. 6). Almost in all EAs, there was a dense localization of separated capillaries, some of them having provoked a marked concavity inward of their wall (Fig. 6). Also, in almost all studied EAs, ring-shaped constrictions were observed (Fig. 4 and Fig. 6).

Differences in the observed features in AAs and EAs, determined by their localization in the cortical or juxtamedullary zone, apart the described ones, were not found out. There were neither differences in findings among the various types of resins.

DISCUSSION

Although the number of SEM studies on the vascular anatomy of renal glomeruli in domestic pigs and their afferent and efferent arterioles are relatively few, it could be yet concluded that there were a lot of similarities byt also some peculiarities in comparison with those of other mammalian species and men.

The observed peculiarities in the separation and the course of the AA add to the data from a previous study of ours (Vodenicharov & Simoens, 1998), made mainly on cleared and stained histological preparations. The data obtained then allowed us to assume that the different course of these arterioles could have an impact on the rate and the redistribution of the blood flow in the kidney. This assumption is now supported by the present results, confirming convincingly that the separation of AAs occurs at different intervals and at all types of angles, even obtuse, when the blood is supposed to move in a way similar to that in the socalled recurrent arteries. Also, considering the peculiarities of the cortical haemodynamics and particularly the time blood takes to reach the glomerulus, the different length of AA, visualized much better by SEM than on histological and cleared preparations, should also be taken into consideration. This allowed us to further add to the views of Ohtsuka *et al.* (1982) and Vodenicharov & Simoens (1998), that not only the length, but also the pattern of separation of AA could be important for the rate of blood flow toward the glomerulus.

Our studies generally agree with the data of Ohtsuka *et al.* (1982) about the presence of circularly located constrictions along the course of the AA, including the point prior to its entry in the glomerular vascular pole, but these were not observed by Moore *et al.* (1992), despite the substantial number of studied glomeruli. With this connection, we agree with the view of Anderson & Anderson (1978) and Ohtsuka *et al.* (1982), that such constrictions should be considered as formations, regulating the blood flow towards the glomerulus.

Both in previous studies of ours (Vodenicharov, 1991) and in the present SEM observations, no double or multiple EAs were found out, similarly to those described by Murakami *et al.* (1971; 1985) in the kidney of the rat. It should be however noted that EAs in domestic pigs showed some features, related mostly to their course at the site where they exit the vascular pole and in close vicinity to the glomerulus. The described differences in the course of EAs as well as the observed concentric constrictions of lumen casts could also be regarded as morphological peculiarities, that could, under given circumstances, regulate the blood flow rate to the capillary network.

In conclusion, the results of the present study add to the data about the peculiarities of architectonics of renal glomerular arterioles in domestic pigs that could be involved in blood flow regulation throughout and after the glomeruli.

ACKNOWLEDGEMENTS

The author would like to acknowledge the valuable help of Prof. Dr. D.h.c. Rudolf Leiser from the Faculty of Veterinary Medicine at the Giessen University, Germany and Prof. Dr. D.h.c. Paul Simoens from the Faculty of Veterinary Medicine at the University of Ghent, Belgium, in the performance of the observations and their very helpful suggestions.

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Paper received 26.06.2007; accepted for publication 03.07.2007

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Bulgarian Journal of Veterinary Medicine (2000),**3**, No 14, 1