RESEARCH ARTICLE

Adaptations in the kidney of Palm Civet, *Paradoxurus hermaphroditus* (Schrater)

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ABSTRACT

The kidneys of *Paradoxurus hermaphroditus hermaphroditus* were simple, typically bean shaped, possessing single papillary cone in the central region surrounded by thick medullary tissues. The medulla further differentiated into outer and inner regions; which was distinguished by the varying diameter and orientation of the uriniferous tubule. The outer thin cortex mainly consists of Bowman's capsules enclosing the glomerulus and surrounded by the dense convolutions of proximal and distal tubules which were distinguished by vary in luminal diameter and the presence of microvillar brush border in the proximal tubules; the medulla is further differentiated histologically into outer and inner zones. From the outer medullary zone the large number of long medullary rays invades deep into the cortical region; sometimes up to the outer border of the kidney. The thick medulla and long medullary rays represents the long loop of Henle adapted for maximum water reabsorption and urine consentration. The distinct dense network of branches of renal vessels and the capillaries on the outer surface of kidneys indicate the rich supply to the Bowman's capsule and increased filtration rate.

Key words: Adaptations; Palm Civet; Kidney; Uriniferous Tubule.

INTRODUCTION

Paradoxurus hermaphroditus hermaphroditus distributed in south Asia diversely roosts in caves, tunnels, under bridges, cleft and crevices of mountains etc. and carnivorous in dietary habit. In the carnivorous animals the morphological adaptations in the renal bodies is also influenced by the diversity in habitats and food they consume. Patil *et al.*, (2010) examined the morphological structure of kidney in palm civet, *Paradoxurus hermaphroditus hermaphrodites*.

They noticed that the kidney was differentiated histologically into outer cortex; inner papilla and the intermediate thick medulla which was further divided into outer and inner zones. The length of loop of Henle is proportional to the medullary thickness, responsible for urine concentrating function by reabsorbing maximum possible water and electrolytes from the filtrate. In mammals the kidneys physiologically plays an important role in maintaining the volume and the concentration of body fluids. Sperber (1944) presented a comparative study of mammalian kidneys and introduced the concept for estimation of urine concentration capacity and he was the first to demonstrate the relationship between ecological distribution of a mammal and its ability to conserve urine water, species living in arid habitats tend to have kidneys with more prominent medullae than those from more humid regions. In the developing kidneys of Indian Megachiropteran bat, *Rousettus leschenaulti* the thick microvillar brush border of the proximal tubules indicate its absorptive nature for water glucose, minerals etc. The proximal convoluted tubule is one of the most important sites for active absorption of minerals (Patil and Janbandhu, 2011). The uriniferous tubules in the kidney of mammals are able to produce significantly concentrated urine as compared to the plasma. The ecological distribution and type of diet has already been correlated with the urine concentrating mechanism by the kidneys in several mammals (Sperber, 1944). The kidneys with relatively thick medullae subdivided into outer and inner zones indicating the presence of long loop of Henle for maximum re-absorption and conservation of water in the animals with high protein rich diet; which is an adaptation in most of the mammals with animalivorous feeding habits studied so far (Al-kahtani *et al*., 2004).

MATERIALS AND METHODS

The kidneys of adult female *Paradoxurus hermaphroditus hermaphroditus* were used for this study. The kidneys were collected from the female palm civet which was previously captured from the southern state of Kerala, India. The weight and measurements of both the kidneys were taken and then photographed to examine the capillary network present on the surface area. Alcoholic Bouin's fluid was used to fix the tissue. The kidneys were washed overnight in running tap water and dehydrated by passing through different grades of ethyl alcohol, cleared in xylene and embedded in paraffin (58-60^{o}C). The sections containing different regions were cut at 5-7 µm with the help of rotary microtome. For anatomical and histological observations the sections containing different zones were stained with Haematoxylin-eosin technique. The stained sections of the tissue containing different regions, tubular and cellular components were selected and observed under light microscope. The measurements of microscopic structures were taken with the help of ocular micrometer scale.

RESULTS

The urinary system of *Paradoxurus hermaphroditus hermaphroditus* like other mammals is composed of the kidney proper, ureters, urinary bladder and urethra. The kidneys were simple, bean shaped and covered with a thin collagenous capsule. The kidneys were placed on the posterior wall of the abdominal cavity beneath the peritoneum and were almost similar in size and weight. At the hilus the renal blood vessels and the ureter are encapsulated by fat. The right kidney weighing 6.19g with a of 31x19x11mm in size, while the left weighing 6.20g and measures 29x21x12mm in length, width and thickness respectively. The renal blood vessels are prominent which divided and further subdivided into anterior, lateral and posterior branches. The capillary network arises from the renal vessels were distributed on the entire surface of the kidney supplying rich supply to the cortical components (Figure 1). Anatomically the kidneys were divided into an outer cortex, the intermediate medulla further divided into outer and inner zones and an inner papilla open into the hilus through the calyx. In the sagittal section of the right kidney the cortex of measure 4.4mm, medulla 3.1mm and the papilla 3.2mm in thickness. The medulla can be differentiated into an outer zone 2mm and an inner zone 1.1mm in thickness. The papilla surrounded by the calyx space of 0.3mm which open outside through the hilus of 0.6mm diameter. The long medullary rays arises from outer region of medulla and invade deep into the cortical tissue forming the longitudinal bundles of straight uriniferous tubules which sometimes penetrates up to 3mm towards the outer boarder of cortex (Figure 2). Large arcuate vessels and its branches are well distribited in the region of cortico-medullary junction.

The Bowman's capsules (about 150μm in diameter) enclosing glomeruli having 120μm diameter are equally distributed in the cortical region. Large number of irregular glomerular cells with prominent dark, round nuclei occupies the spaces in between the glomerular capillaries. The thick glomerular arterioles and darkly stained juxta glomerular apparatus (55μm in thickness) are observed at the vascular pole of the Bowman's capsules. The Bowman's capsules are surrounded by the dense tissue of the renal tubules which can be differentiated into the proximal (55μm in diameter) and distal (35μm in diameter) convoluted tubules, but this differentiation is well defined in the region of outer medulla. The proximal convoluted tubules have a narrow lumen, are lined by the columnar epithelial cells of 22μm in height with central round nuclei and possess number of microvilli at the luminal space. The microvillar brush border is a characteristic feature of the proximal tubules. The distal convoluted tubules have wide lumen and are lined by the cuboidal epithelial cells of 6μm with central, round, dark nuclei. The medulla consists of the different types of the uriniferous tubules with varying outer and luminal diameter and different cell types. The large collecting tubules of 51μm diameter having the wide lumen and lined by the cuboidal epithelial cells of 6μm size with central, round nuclei. The narrow tubules of loop of Henle (22μm in diameter) with very narrow lumen are lined by the squamous epithelial cells of 7μm with spherical nuclei. The proximal and the distal tubules possesses the intermediate diameter to that of collecting tubules and the thin loop of Henle. The distal tubules possess comparatively wide lumina than that of the proximal tubules. The collecting tubules and the thin loop of Henle are also observed in the papilla. The uriniferous tubules in the medulla and papilla are surrounded by the extra tubular spaces which are covered by the connective tissue matrix with a network of renal capillaries. The wide collecting ducts (66μm in diameter) lined by the cuboidal epithelial cells of 16μm size with central, round nuclei open into the wide calyx. Extra tubular spaces are characteristically present around the uriniferous tubules of medulla and papilla region (Figure 3).

Figure 1

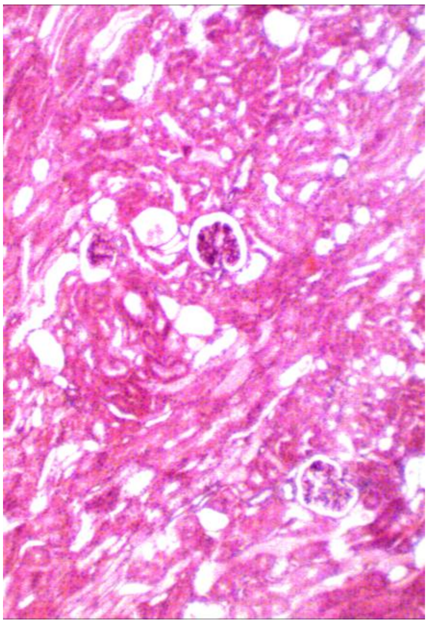

Figure 2

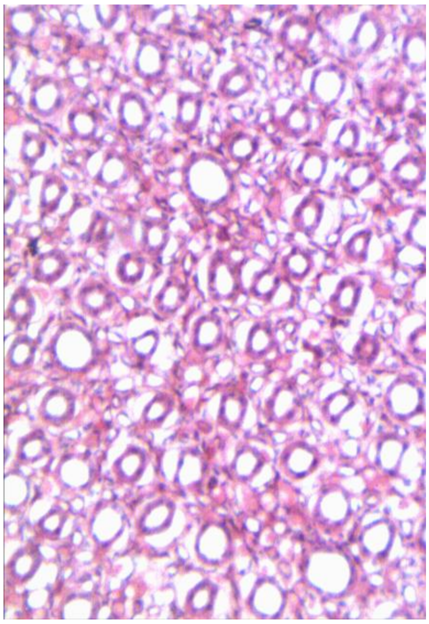

Figure 3

Figure 1: Photograph of the right kidney of an adult female of *Paradoxurus hermaphroditus hermaphroditus*. The Typical bean shaped kidney is supplied with the rich vasculature of renal circulation on the outer sueface.

Figure 2: Photomicrograph of the kidney of *P. hermaphroditus hermaphroditus* through the cortical region showing the medullary rays invading the cortical tissue. The cortex shows the presence of darkly stained Bowman's capsules enclosing the darkly stained glomeruli; which are surrounded by the glomerular space. The Bowman's capsules are surrounded by the cortical proximal and distal convoluted tubules in which are seen a few lobular blood vessel.

Figure 3: The magnified part of papillary region of the kidney of *P. hermaphroditus hermaphroditus* showing the large collecting ducts with wide lumen are lined by epithelial cells. In the papilla also some collecting tubules are covered by extra-tubular spaces. But these spaces are not observed around the collecting ducts and the loop of Henle. The interstitial cells are observed in between the tubules.

The vascular network on the external surface of the kidney is embedded in the outer border of the cortex bellow the layer of collagenous capsule. The capillaries penetrated into the cortical tissue forming the dense network around the uriniferous tubules. Rich vasculature was noticed around the Bowman's capsules and the region of macula densa. Longitudinal blood vessels are observed parallel to the medullary rays forming the network around straight parts of uriniferous tubules. In the region of medulla and papilla the branches of arcuate vessel embedded in the connective tissue of basement membrane around the uriniferous tubules, supplies to the different parts of tubules as well as surrounding tissue. Number of large sized spherical interstitial cells with spherical nuclei noticed, embedded in the connective tissue around the tubules, in the region of papilla as well as inner medullary zone.

DISCUSSION

Like other mammalian species the urinary system of Indian palm Civet; *Paradoxurus hermaphroditus hermaphroditus* is composed of the kidney proper, ureters, urinary bladder and urethra. The kidneys of *P. hermaphroditus hermaphroditus* are located dorsally deep in the thoracic cavity. Both the kidneys are of approximately same dimension and weight. The kidneys are typically bean shaped, simple and are divided into an outer cortex, middle medulla and a single terminal papilla (Gerhardt, 1911). In *P. hermaphroditus hermaphroditus* the medulla divided into an outer and an inner zone and a large papilla protruding outside the kidney which may be an adaptation with the diet they consume as well as the urine concentrating ability (Patil *et al*., 2010; Patil 2013). Similar structural adaptations are noticed in the medulla and papilla of the kidneys of some other carnivores, insectivores, marsupials, microchiropterans and rodents (Sperber, 1944; Al-kahtani *et al*., 2004; Patil and Janbandhu 2012; Patil 2014).

In the kidneys the production of urine mainly involves glomerular filtration, reabsorption of water and minerals through different parts of uriniferous tubules and the tubular secretion. The glomerular filtration appears to be a passive process, without any cellular activity. In most of the mammals about 80-85% of the glomerular filtrate is reabsorbed through tubular active reabsorption. In the kidney of *P. hermaphroditus hermaphroditus* the large number of convolutions of the proximal tubules suggest that the proximal convoluted tubules is also the longer part of the uriniferous tubule the region of renal cortex. Presence of dense microvillar brush border at the luminal surface of the columnar epithelial cells; lining the proximal convoluted tubules facilitate more reabsorption of glucose, phosphates, minerals etc from the filtrate passing through it. All mammals secrete hypertonic urine which can be correlated with the activity within the loop of Henle. The thick medulla and the papilla is directly proportional to the length of long loop of Henle (Bankir and de Rouffignac, 1985; Beuchat, 1990, 1991, 1993) and the urine becomes more concentrated as it passes along the loop of Henle (Schmidt-Nielsen and O'Del, 1961, Schmidt-Nielsen, 1977; Brownfiled and Wunder, 1976; Gottschalk, 1987; Greenwald and Stetson, 1988; Greenwald, 1989 and Abrahams *et al*., 1991). In the kidney of *P. hermaphroditus hermaphroditus* the thick medulla and the medullary rays penetrating the cortical tissue and reach sometimes up to the outer surface of the cortex, suggesting that in such condition the narrow loop of Henle are the longest part of uriniferous tubules measuring at least three times longer than the width of the kidney (Patil *et al*., 2010). Thus the thick medulla and papilla representing the long loop of Henle is directly proportional to the water re-absorption and the urine concentrating ability of the animal (Robson, 1963; Agduhr 1917; Al-kahtani *et al*., 2004).

According to Vimtrup and Schmidt-Nielsen (1952) the papillary sphincters noticed in the kidney of kangaroo rat, *Dipodomys spectabilis* (a desert animal) is related with the water retention phenomena; no such structures are noticed in *Paradoxurus hermaphroditus hermaphroditus*. The characteristic extra tubular spaces mainly present around the medullary and papillary tubules may be an adaptation to maintain the equilibrium of electrolytes against the concentration gradient and also help to neutralize the absorption pressure caused due to active transport across the tubules (Patil *et al*., 2010).

The very well developed juxtaglomerular apparatus at the vascular pole of the Bowman's capsule mainly composed the epitheloid cells of the vas efferens (distal tubules), the macula densa and the pseudo-Meissnerain cell mass of Goormaghtigh. The Large juxtaglomerular apparatus suggest its role in the secretion enzyme rennin. Also the presence of fine capillary network around these structures indicate its active role in supplying the Bowman's capsule through the afferent arteriols which aids in glomerular filtration as well as the transport of enzyme secreted and the substrate re-absorbed. The vascular web on the entire kidney surface suggests the increased transportation of substances across the kidneys; which may be an adaptation according to the carnivorous feeding habits of *P.s hermaphroditus hermaphroditus*.

Number of large interstitial of cells were noticed embedded in the connective tissue around the uriniferous tubule of present in the papillary and medullary region. Physiological role of these cells is not fully understood, but their presence coincides with the observation of Stevens and Lowe (1993), who suggested that the interstial cells may act as bridges in between the uriniferous tubules and the vasculature present around. It is presumed that these cells might be function as temporary reservoir for the substrates reabsorbed because histochemical observation reveals high intensity of proteins as well as glycogen (Patil and Janbandhu, 2011a and 2011b). However, further studies may reveal the significance of these interstitial cells reported here. Histologically, the presence of tissue fluid, lymphatic vessels around the blood capillaries and uriniferous tubules are responsible for transfer of material within the kidney.

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