Histochemical Characterization of Dehydrogenases in the Nephron of the One-humped Camel (Camelus dromedarius)

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Abstract: A histochemical investigation on the distribution and localization of nine dehydrogenases in the nephron of the one-humped camel, Camelus dromedarius was undertaken. The histoenzymological tests employed in this study detected glucose-6-phosphate, α-glycerophosphate, succinate, lactate, malate, glutamate, isocitrate, NADH and NADPH dehydrogenases. The functional significance of the findings is discussed in accordance with the adaptation of the species under study to its harsh desert habitat.

Key words: Renal tubule, glomerulus, macula densa, dromedary, hypertonic urine

INTRODUCTION

The general features of the one-humped camel kidney are not different from those of other mammals [1], but show some unique modifications to permit it's remarkable drinking capacity and the production of hypertonic urine under extreme conditions of water deprivation. The kidney of C. dromedarius has thicker renal capsule, higher number of glomeruli and wider medulla than for other studied mammals [2-4]. These modifications help in tolerating the abrupt blood dilution to which the camel is subjected during phases of water deprivation and sudden rehydration without disruption of the normal osmotic and electrolyte function [5-9].

The histological and ultrastructural nephron structure of the dromedary camel has already been investigated [34]. The microanatomy and the ultrastructure of the one-humped camel nephron are modified to cope with the need to conserve water under extreme variations in temperature and water availability.

A survey of the literature revealed that little, if any, has been published on the renal histochemistry of the dromedaries. The present histochemical study deals with the localization and distribution of nine dehydrogenases in the nephron of the one-humped camel, Camelus dromedarius is an attempt to throw some light on the role of these enzymes on the renal physiology of this mammal.

MATERIALS AND METHODS

Portions of fresh kidney (cortex and medulla) from twelve adult healthy one-humped camels were cut out rapidly at the slaughter house of Riyadh during January-May, 2003. These portions were frozen in liquid nitrogen and stored in air tight tubes at -80°C until use. Cryostat sections (8-10 µm thick) were cut at -25°C.

Dehydrogenases were histochemically demonstrated in the present study according to tetrazolium method [6,9]. The activities of the soluble NAD-dependent dehydrogenases were demonstrated by means of the optimized polyvinyl alcohol technique according to Rieder et al. [7] method. Phenazine methosulphate, an intermediate electron acceptor was added to the incubating media of the soluble dehydrogenases in the rate of 1 mg mL⁻¹ of the medium [8,9].


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RESULTS

Glucose-6-phosphate dehydrogenase: Considerable activity was detected in the proximal convoluted tubules especially in the outer cortical portion while the highest activity of this enzyme was seen in the macula densa and the pars recta (Fig. 1A). The activity was faint in the distal tubules and the pars convoluta of the proximal convoluted tubules but absent in the juxtaglomerular cells. A faint reaction for this enzyme was also detected in the mesangial cells.

α-Glycerophosphate dehydrogenase: No reaction was demonstrated in the thin descending of Henle’s loop and the collecting ducts of the papillary inner medulla (Table 1). The activity was weak in the glomeruli, distal convoluted tubules and juxtaglomerular cells and was moderately demonstrated in the intercalated dark cells of cortical collecting tubules and the outer zone of the medulla as well as in the medullary interstitial cells. A strong reaction of this enzyme was demonstrated in the pars recta, ascending loop of Henle and macula densa (Fig. 1B).

Succinate dehydrogenase: No activity was observed in the glomeruli and the inner stripe of the medulla while strong activity of this enzyme was demonstrated in the proximal convoluted tubules and the macula densa. A faint activity was detected in the distal tubules, the juxtaglomerular cells and the ascending thick loop of Henle (Fig. 1C).

Lactate dehydrogenase: Weak reaction appeared in the glomeruli and juxtaglomerular cells while considerable activity was detected in the epithelial lining of the pars convoluta of distal convoluted tubules and in the intercalated dark cells of the cortical collecting tubules. The highest reaction of lactate dehydrogenase was demonstrated in the macula densa and pars recta of the renal tubule (Fig. 1D). The activity of this enzyme was also seen in the thick ascending limb of Henle’s loop in the outer stripe of the medulla.

Malate dehydrogenase: Weak activity was seen in the macula densa and juxtaglomerular cells while no activity was observed in the glomeruli (Table 1). The activity of this enzyme was strongly demonstrated in the pars recta and to lesser extent in the distal convoluted tubules and ascending loop of Henle (Fig. 1E).

Glutamate dehydrogenase: A moderate reaction was detected in the intercalated dark cells lining the collecting tubules and to a lesser extent in the intraglomerular mesangial cells while the reaction was faint in the interstitial medullary cells. A strong activity of this enzyme was observed in the epithelial lining of the pars recta and the ascending thick segment of the loop of Henle (Fig. 1F).

Isocitrate dehydrogenase: A considerable activity was seen in the beginning of the pars convoluta and to a lesser extent in posterior and the cortical straight portions of the proximal convoluted tubule. Strong reaction of this enzyme was demonstrated in the epithelial lining of the distal convoluted tubules and to a lesser extent in the macula densa (Fig. 1G).

NADH dehydrogenase: Almost no activity was demonstrated in the juxtaglomerular cells, thin loop of Henle and collecting tubules. A moderate activity was observed in the straight portions of the renal tubules. The prominent activity of this enzyme was noticed in the distal convoluted tubules and to a lesser extent in the macula densa (Fig. 1H).

NADPH dehydrogenase: As shown in Table 1, weak reaction was noticed in the juxtaglomerular cells and the posterior portion of the pars recta (Table 1). The highest

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* Negative, ±: Weak; +, Moderate; ++, Intensely positive; ?, Doubtful. ALH, Ascending Loop of Henle; CT, Collecting Tubule; DCT, Distal Convoluted Tubule; DH, Dehydrogenase; DLH, Descending Loop of Henle; G, Glomerulus; JG, Juxtaglomerular cells; MD, Macula Densa; PCT, Proximal Convoluted Tubule.
Fig. 1: Light micrographs in the nephrons of adult healthy one-humped camels (Camelus dromedarius) showing the activity of: A: Glucose-6-phosphate dehydrogenase; B: α-Glycerophosphate dehydrogenase; C: Succinate dehydrogenase; D: Lactate dehydrogenase; E: Malate dehydrogenase; F: Glutamate dehydrogenase; G: Isocitrate dehydrogenase; H: NADH dehydrogenase; I: NADPH dehydrogenase
activity of NADPH dehydrogenase was seen in the beginning of pars convoluta and to a lesser extent in the macula densa, distal convoluted tubules and the cortical portion of pars recta (Fig. 11).

**DISCUSSION**

The results of the present investigation show high activity of dehydrogenases in the macula densa, the proximal convoluted tubule and the ascending loop of Henle. This finding copes with the fact that the epithelial lining of these portions of the dromedary nephron contain numerous mitochondria. This might also explain the higher activity of dehydrogenases in the intercalated dark cells than the principal light ones of the collecting tubules where the former cells contain more mitochondria than the later ones.

The macula densa is the osmoreceptor of the nephron while the proximal convoluted tubules reabsorb most of the water and ions of the glomerular filtrate. The ascending loop of Henle constitutes a countercurrent mechanism generating a high osmotic pressure in the extracellular fluid of the renal medulla which helps in reabsorption further fluid from the glomerular filtrate and producing hypertonic urine with respect to plasma. Accordingly, the high activity of dehydrogenases in these portions of the dromedary nephron with their high content of mitochondria might indicate a role for this enzymatic group in the production of hypertonic urine.

The results of the present investigation indicate less activity of dehydrogenases in the distal tubules in comparison with the proximal ones while the glomeruli and the juxtaglomerular cells demonstrate weak activity. This finding is in agreement with the fact that the distal tubules reabsorb small quantities of the filtrate while the glomeruli and the juxtaglomerular cells play a minor role in reducing the glomerular filtrate.

Glucose-6-phosphate dehydrogenase generates NADPH under the oxidative stress conditions such as heat and water deprivation. The high activity of this enzyme in the macula densa as seen in the present study might indicate a role for it in monitoring the nephron filtrate rate as an adaptive tool to enable the camel withstand severe dehydration, loosing up to 30% of body weight without fatal results.

The present study show high activity of succinate dehydrogenase and isocitrate dehydrogenase in the cells of the macula densa and cortical portion of the renal tubule. These two enzymes are bounded to the inner mitochondrial membrane and participates in the aerobic oxidation of carbohydrates in the citric acid cycle. This might suggest a role for carbohydrate metabolism in monitoring filtrate rate of the dromedary nephron.

Lactate dehydrogenase plays an important role in intermediary metabolism as a link between amino acid metabolism and the citric acid cycle where it converts lactate into pyruvate. The results of the present study show high activity of this enzyme in the macula densa the osmoreceptor of the nephron. This may indicate a role for this enzyme in monitoring the nephron filtrate rate.

High activity of α-glycerophosphate dehydrogenase is demonstrated in most portions of the dromedary renal tubule. This might suggest that this enzyme play a role in NAD-NADH shuttle between the cytoplasm and mitochondria where water is produced by fat oxidation enabling the camel to gain more moisture from metabolizing the fat.

Camels use acetate much more than glucose as a substrate for endogenous fatty acid synthesis. Malate dehydrogenase converts malate to oxaloacetate, the final reaction in the Krebs cycle. This might explain the high activity of this enzyme in the proximal convoluted tubules where most of the water and ions of the glomerular filtrate are reabsorbed. NADH and NADPH dehydrogenases play an essential role in the intracellular oxidation. The high activities of these enzymes in the cortical portion of the renal tubule as shown in the present study might indicate their involvement in reabsorbing most of the water and ions of the glomerular filtrate.

In conclusion, the distribution patterns, sites of activities and intensity of dehydrogenases in the dromedary nephron as are demonstrated in the present study might reflect contribution of this enzymatic group in the maximum utilization of water and production of hypertonic urine.

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**REFERENCES**


