EFFECT OF PERISTALTIC CONTRACTIONS OF THE RENAL PELVIC WALL ON THE SOLUTE CONTENT OF THE RENAL PAPILLA IN HAMSTERS. *Misocricetus auratus*

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The renal pelvic wall surrounding the papilla shows regular peristaltic contractions which cause a pulsatile flow in the collecting ducts similar to that seen in the ureters (L.N.Reinking and B.Schmidt-Nielsen, Kidney Int. 20:55-60,1981). It also causes an interrupted flow in the papillary blood vessels and the loops of Henle (B.Schmidt-Nielsen and B.Graves, Kidney Int. 22:613-625,1982). Thus, in a normally functioning papilla with intact pelvic wall the blood flow in the capillaries and vasa recta is stopped 30% of the time. For these reasons it seemed very likely that the milking of the papilla would have an effect upon the concentrating mechanism of the kidney. Oliver et al. (J. Clin. Invest. 69:157-164,1982), however, failed to find any effect upon urine osmolality when the pelvic contractions were stopped by the application of verapamil. In the present experiment we used three different methods of abolishing pelvic contraction in one kidney and compared the solute concentrations and amounts of the experimental with the control kidney.

Hamsters were treated as described before (B.Schmidt-Nielsen et al., Kidney Int. 18:419-431,1980). Briefly, the anesthetized hamster was placed on a heated operating table. The jugular vein was catheterized, the abdomen was opened and the right kidney exposed. The fat from the pelvis was gently removed and a small fiberoptic light placed so that the papilla was transilluminated. This made it possible to see the collecting ducts clearly through the microscope. A bolus of 0.1 ml of 0.2% lissamine green in 0.9% saline was injected via the jugular vein. When green urine boluses were clearly visible in the papillary collecting ducts one of four treatments was initiated. These four types of experiments were: 1. Sham:this group consisted of 13 hamsters in which the pelvic wall was cleared of fat and left untreated to contract normally. 2. Xylocaine: consisted of 11 hamsters in which a 2% xylocaine solution was applied to the pelvic wall with a micropipette. Because of the oil in the pelvic cavity the xylocaine solution clings to and spreads over the tissue to which it is applied. The pelvic peristaltic contractions were completely inhibited by this treatment as evidenced by an uninterrupted flow of the green urine in the collecting ducts. The application of xylocaine did not affect the peristalsis in the ureter, which continued to send urine boluses toward the bladder. 3. Heat: consisted of 6 hamsters in which heat was applied to the pelvic wall using an AccuTemp cauterizer. Care was taken to apply only enough heat to the pelvic wall to destroy sufficient muscle tissue to inhibit pelvic peristalsis. Again the criterion used was that the flow of urine in the collecting ducts changed from peristaltic to continuous. 4. Pelvis removed: consisted of 12 hamsters in which the pelvic wall covering the papilla was removed by lifting the ureter with forceps just below the papilla and gently pushing up the papilla with a pair of scissors and cutting the pelvis off as close to the rim of the cortex as possible. This treatment also resulted in a continuous flow of urine in the collecting ducts. The protocol continued in each case as follows: after the particular treatment had been implemented the hamster was left for one hour. Saline was continuously infused i.v. at 10 µl per min. In the xylocaine experiments it was necessary to repeat the application of xylocaine every 10-15 min in order to maintain complete inhibition of pelvic contractions. After 1 hour both kidneys were removed and the inner medulla isolated and divided into segments for weighing, drying and analysis as previously

described (B.Schmidt-Nielsen et al. Am. J. Physiol. 244:F472-F482,1983). The designations IM2 and IM3 refer to the upper and lower part of the renal papilla as shown before (B.Schmidt-Nielsen et al. Am. J. Physiol. 248:F31-F42,1985). The following determinations were made on the tissue: osmolality, urea, Na and K. The results of the tissue analysis were calculated as solute concentrations (mM/l tissue water) and amounts in mMoles per g solute free dry tissue (mMoles/g s.f.d.t.). The comparisons between experimental and control kidneys were made by dividing the concentration or amount measured in the experimental kidney with that of the control kidney. The data shown in Fig. 1 are presented as Mean$\pm$SEM. Significance of the difference of the means from unity were determined by the Students t-test. The bars are labeled with stars in Fig. 1 if $P<0.05$.

The concentration ratios (presented in Fig. 1) showed that clearing of fat, but leaving the pelvic contractions intact (sham) resulted in a significant increase in the osmolality of the tip of the papilla and a significant increase in the urea concentration in both IM3 and IM2. No significant change was observed in Na and K concentrations. The two groups in which pelvic contractions were abolished both showed a significant decrease in osmolality of both the tip and the upper part of the papilla. Similarly, the Na concentration was highly significantly decreased in both IM3 and IM2, while no effect was observed on the K and urea concentrations. The group with the pelvis removed, however, showed a less pronounced decrease in the Na concentration and a significant decrease in the urea concentration of both IM3 and IM2.

Calculations of the ratios of amounts of solutes in the tissues (mMoles/g s.f.d.t.) revealed the following significant differences between experimental and control kidneys. In the sham-operated hamsters the amounts of urea were significantly higher in experimental compared to control kidneys. There were no significant differences in any other solute amounts. In the xylocaine and in the heat-treated kidneys the amounts of Na were significantly lower in the experimental kidneys, but there was no difference in any of the other amounts of solute. In the kidney with pelvis removed the only significant difference was in the amount of urea which was lower in the experimental kidney than in the control.

Discussion. In the sham series the finding that the osmolality and the amount of urea was increased in the experimental kidneys simply by the removal of fat from the pelvic wall may indicate an increased delivery of urea to the papilla under these circumstances. It is possible that the removal of the pelvic fat causes an increased contact and thereby an increase in urea diffusion from pelvic urine to papilla. In contrast, the papillae from which the pelvic wall was removed showed a decreased amount of urea in the papillary tissue indicating a loss of urea. This was also found in earlier studies (K.-H.Gertz et al. Fed. Proc. 25:327,1966) and may indicate a urea loss by diffusion to the outside. The data from the two series in which peristalsis of the pelvic wall was abolished by either xylocaine or cauterization of the pelvic musculature show that the peristaltic contractions of the pelvic wall around the renal papilla does affect the concentrating mechanism. Thus, when peristalsis is abolished the osmolality, Na concentration and amount of Na decreases in the entire renal papilla. The finding that there was no difference in the results, of abolishing pelvic contractions, with either xylocaine or heat application to the pelvic musculature indicates that the changes we see in papillary solute concentrations and amounts resulted from the fact that the peristalsis was abolished and not from any chemical effect of the

xylocaine upon the kidneys. A decrease in the total amount of Na in the papilla suggests either a decreased rate of delivery of Na to the papilla or an increased rate of removal from the papilla. Because of the profound effect that the peristaltic milking of the renal pelvis has on fluid movement in loops of Henle and capillaries it seems likely that the rate of Na delivery to the papilla could be reduced when the peristalsis ceased.

It is concluded that the milking action of the pelvis on the renal papilla increases the delivery of Na to the papilla and thereby the osmotic concentration of the papilla. Na transport, passive or active, out of the thin ascending limbs of the loops of Henle is thought to be the most important force in creating the osmotic gradient in the renal medulla, but there is no consensus on the driving forces for this transport (Berliner). The present results suggest that the milking action on the loops of Henle may be one of the driving forces although the manner in which this is accomplished is still obscure.

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Fig. 1