

The Secretion of Electrolytes by the Pilocarpine-Stimulated Canine Prostate Gland¹ (34184)

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There have already been a number of studies on the electrolyte content of canine prostatic fluid. Previous experiments have shown that the canine prostate gland characteristically produces a resting or basal secretion at the rate of approximately 1–2 ml/hr (1–3) and while the sodium and potassium concentrations of this fluid do not appear to have been determined, a mean chloride concentration of 104 meq/liter has been found in some samples of this fluid (1). In addition, analyses conducted upon much larger samples of prostatic fluid obtained by digital manipulation or the systemic administration of pilocarpine to dogs with prostate fistulas revealed sodium, potassium, and chloride concentrations of 156–162, 5.2–7.0, and 148–156 meq/liter respectively (3, 9).

Despite these studies there is still little indication as to what processes are involved in the secretion of electrolytes in prostatic fluid. In one experiment, however, Huggins analyzed small serial samples of prostatic fluid provoked by pilocarpine and found that the chloride concentration varied during the course of the secretion (3). Since such variations in composition must reflect the nature of the underlying secretory processes, experiments have been performed which were similar to that of Huggins except that the prostatic fluid samples were analyzed for osmolality and for sodium and potassium as well as chloride concentration.

Methods. These experiments were performed on six unanesthetized dogs which

¹ Supported in part by the Cancer Chemotherapy National Service Center, National Cancer Institute, USPHS, Contract PH 43-65-6.

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weighed between 13.2 and 15.4 kg. To obtain prostatic fluid uncontaminated by urine, prostatic fistulas were produced by cystopreputiostomy; this consisted of removing the penis from the sheath at its proximal attachment, separating the bladder and the prostate gland, and uniting the preputial sheath and the bladder (5). The dogs were castrated and given 5 mg of testosterone subcutaneously each day.

Experimentation was begun only after recovery from the surgical procedures. During each experiment the dog was restrained on a table in a standing position and the prostatic fluid was collected in graduated centrifuge tubes. Analysis of the prostatic fluid samples for electrolytes was done only after the secretory responses to 0.7 mg/kg of pilocarpine hydrochloride, given intravenously once or twice a week, had stabilized. This dose of pilocarpine previously had been found to stimulate the secretion of approximately 35 ml of prostatic fluid within 1 hr without producing severe undesirable effects (7). For analysis, clotted blood samples collected from the jugular veins and the prostatic fluid samples were centrifuged and sodium and potassium concentrations were determined by flame photometry (model 21 Coleman flame photometer, Coleman Instruments, Inc., Maywood, Illinois); chloride determinations were made according to the method of Shales and Shales (6); and the osmolality of some samples was determined by freezing point depression using an Advanced osmometer (Advanced Instruments, Inc., Newton Highlands, Massachusetts).

Results. 1. Resting secretion. When prostatic fluid was collected for periods of 1–2 hr under resting conditions—that is, when pilocarpine was not given—volumes of 0.4–0.9

TABLE I. Composition of the Basal Secretion of the Canine Prostate Gland.

Parameter	No. of dogs	Prostatic fluid (PF)	Serum (S)	Ratio (PF/S)
Rate of secretion (ml/min)	6	0.011 ± 0.001 ^a		
Sodium (meq/liter)	6	71 ± 11	152 ± 2	0.47 ± 0.07
Potassium (meq/liter)	6	3.2 ± 0.5	4.7 ± 0.1	0.68 ± 0.10
Chloride (meq/liter)	6	59 ± 12	113 ± 2	0.52 ± 0.10
Osmolality (mOsm/kg H ₂ O)	3	197 ± 26	310 ± 2	0.64 ± 0.08

^a All values represent mean ± SE.

ml/hr were secreted. The analyses conducted on such samples and on serum samples taken at the same time are summarized in Table I. The concentration of sodium, potassium, and chloride in this resting fluid was lower than in serum and this secretion was hypotonic.

2. *Pilocarpine-induced secretion.* In initial experiments on two dogs, prostatic fluid samples were collected in five 15-min serial samples starting at the time of intravenous administration of 0.7 mg/kg of pilocarpine hydrochloride. Analysis of these samples revealed that large amounts of potassium had been secreted during the first 15-min interval. Subsequently additional experiments were performed on four other dogs in which this first interval was subdivided into three 5-min intervals. In these four experiments which are summarized in Fig. 1, the rate of secretion immediately rose following the administration of pilocarpine to a mean maximum value of 1.9 ml/min and then progressively declined during the remainder of the period of observation. The sodium and chloride concentration rose to values of approximately 147 and 160 meq/liter, respectively, and remained at these values until near the end of the observation period. The potassium concentration was high in the first two samples collected after pilocarpine but subsequently fell to values near that found in the resting secretion. No changes were observed in the sodium and chloride concentration of serum samples collected at the same time as the prostatic fluid samples, but 15 min after administration of pilocarpine there was a decrease in the serum potassium concentration from 4.7 ± 0.1 to 4.1 ± 0.2 meq/liter,

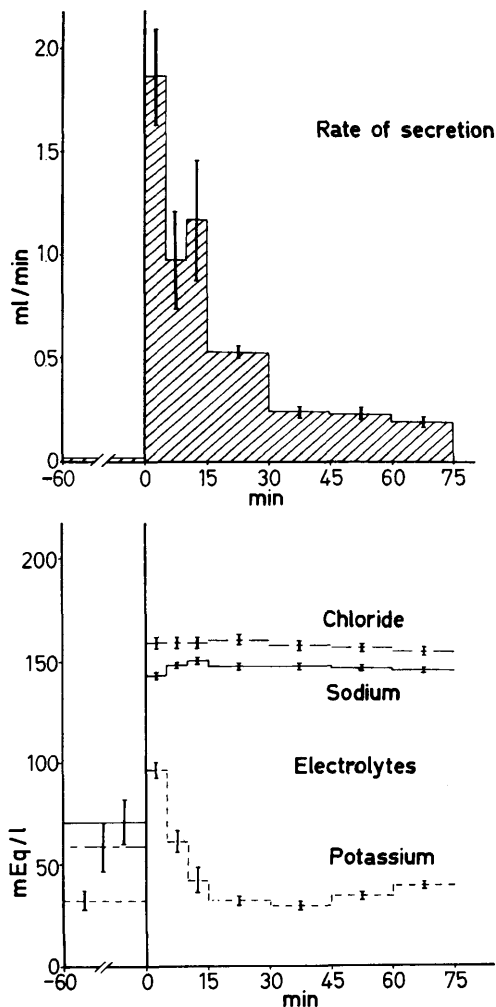


FIG. 1. The secretion of electrolytes by the pilocarpine-stimulated canine prostate gland: (abscissae), time (min) after pilocarpine hydrochloride (0.7 mg/kg), given intravenously. (ordinates, top), rate of secretion (ml/min); and (bottom), concentration of electrolyte in prostatic fluid (meq/liter). For convenience the potassium concentrations were multiplied by 10 before plotting.

and all subsequent mean values were between 4.0 and 4.2 meq/liter.

Finally, additional experiments were performed on two of these same dogs in which only osmolality was measured. It was found that the prostatic fluid samples collected following the administration of pilocarpine were isotonic with serum.

3. *Relationship between rate of secretion and electrolyte concentration. a. Sodium and chloride.* The results of these experiments were further analyzed by plotting the sodium, potassium, and chloride concentrations of each prostatic fluid sample against the rate at which the particular sample was secreted. It was found that distinct and similar relationships existed between the rate of secretion and both the sodium and the chloride concentrations. These are shown in Fig. 2. The sodium and chloride concentrations were low in fluids secreted at very low rates but rose to limiting maximum values at higher rates of secretion. The mean limiting values (\pm SE) were 147 ± 1 and 160 ± 1 meq/l, respectively.

b. *Potassium.* In contrast to these distinct relations between rate of secretion and sodium and chloride concentrations, no distinct relation was found between the secretory rate and the potassium concentration.

c. *Osmolality.* As shown in Table I, the osmolality was low in the resting or basal secretion. At the higher secretory rates, following the administration of pilocarpine, it rose to a mean limiting value of 313 ± 8 mOsm/kg H₂O at rates of secretion above 0.5 ml/min (12 determinations from two dogs). Thus, at these rates of secretion, the prostatic fluid was essentially isotonic with serum (Table I).

Discussion. The results of these experiments on the prostate gland are to some extent similar to observations made on the secretory responses of salivary glands to pilocarpine (8). Since it has been speculated that these glands secrete a fluid which is modified by the addition or removal of constituents as it passes through the ducts of the gland (4), a similar sequence of events might be postulated for the prostate gland.

Obviously the secondary modification of the primary secretion would depend upon how long the fluid remained in the ducts and at high flow rates the effects of these secondary processes would be minimal. Since at high flow rates the sodium and chloride concentrations become fixed at approximately 147 and 160 meq/liter, respectively, these represent the best estimates of the sodium and chloride concentration of the postulated primary secretion; in addition, this secretion would also appear to be isotonic. If the resting secretion resulted from the modification of this primary secretion as it passes through the ducts of the gland, such ductile modification must have involved the reabsorption of sodium and chloride and the reabsorption of solute in excess of water for the fluid secreted at low flow rates was hypotonic and had low sodium and chloride concentrations.

Despite a lack of knowledge concerning

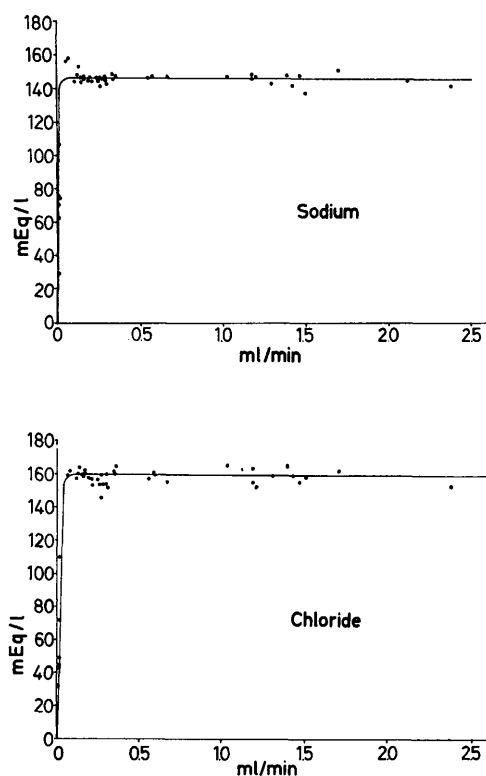


FIG. 2. Relationship between the rate of secretion (ml/min; abscissae) and the sodium and chloride concentrations (meq/liter; ordinates) in samples of canine prostatic fluid.

the ultimate mechanics involved in the formation of canine prostatic fluid, it seems reasonably clear that the secretion of sodium and chloride are probably closely linked to the secretion of water by this gland, for at high rates of secretion sodium and chloride together account for approximately 98% of the osmotically active solute. On the other hand, the secretion of protein (3, 7) and potassium are independent of the secretion of water and are probably not involved in this activity. It is important to note that at high secretory rates the sodium concentration in prostatic fluid approaches and equals, but never exceeds, the serum sodium concentration. However, at high secretory rates the chloride concentration reaches a limiting value of approximately 160 meq/liter, a value which is approximately 1.4 times the serum concentration. This concentrating of chloride might be the primary process involved in the formation of canine prostatic fluid.

Summary. Under resting conditions, castrated, testosterone-treated, unanesthetized dogs with prostatic fistulas secreted prostatic fluid at a very low rate; fluid collected under these conditions was hypotonic and its concentrations of sodium, potassium, and chloride were lower than those of serum. After the intravenous administration of pilocarpine the rate of secretion immediately increased and then slowly declined during 75 min of observation. At the same time the fluid became isotonic and the concentrations

of sodium and chloride rose to 1.0 and 1.4 times those of serum, respectively, and remained at these values. The potassium concentration rose immediately after pilocarpine to 2.1 times that of serum but fell within 15 min to values near that found in the resting secretion. On the basis of these results, the secretion of sodium, potassium, and chloride by the prostate gland are discussed, and it is concluded that the secretion of chloride might be the primary process involved in the formation of canine prostatic fluid.

It is a pleasure to acknowledge the assistance of Dr. Vladimir Ilievski, Miss Beverly Blake, Mr. Steven Gould, and Miss Helen Peters.

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Received Feb. 18, 1969. P.S.E.B.M., 1969, Vol. 132.