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Effect of Kidney Surface Temperature on Single Nephron Filtration Rate (40363)

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In 1970, McDonald and Sparks (1) reported in a preliminary communication that blood flow to the decapsulated area prepared for micropuncture appeared to be slower than was flow to the superficial cortex in the normal dog kidney with an intact capsule. Shortly afterward, Clapp and his associates (2, 3) suggested that nephron function was significantly improved during dog micropuncture studies, if the exteriorized kidney was wrapped in saline-soaked sponges and insulated against heat loss by an "overall covering wrap of clear and light weight plastic." Kidney surface temperature was well maintained at 37° with these protective features but fell promptly to 35° when the plastic wrap was not utilized. Later, Deetjen and Silbernagl (4), reported that a decrease in whole body temperature of rats is accompanied by a decrease in both cardiac output and renal cortical blood flow; mean arterial blood pressure (BP) remained constant. Extrapolation from their data at both 37° and 35° suggests that the magnitude of the decrease in outer cortical blood flow was about 30%.

Taken together, these observations imply that an exteriorized kidney prepared for micropuncture studies might function at levels that are below normal, possibly to a greater degree in the decapsulated area. Thus, reduced nephron blood flow and/or filtration rate at the micropuncture site might occur. Whole kidney clearance measurements however, might not reflect this local diminution in function. The current studies were designed to reevaluate the reports of Clapp (2, 3) and to quantitate any improvement in single nephron glomerular filtration rate (SNGFR) that may accompany the preservation of surface temperature at a near normal value.

Methods. Mongrel dogs of both sexes weighing 18–26 kg were anesthetized with sodium pentobarbital (30 mg/kg, iv) and intubated with a cuffed endotracheal tube. Peripheral catheters were placed in superficial veins to infuse inulin and para-aminohippurate (PAH) at 1.0 ml/min and a maintenance infusion of isotonic saline at 2.0 ml/min. A catheter was placed in each femoral artery, one to measure mean arterial blood pressure (MABP) with a Harvard transducer (model 377) and to collect blood samples. The other catheter was advanced into the aorta and its tip positioned just above the left renal artery. Small volumes (0.5–1.0 ml) or 10% lissamine green dye were injected through this catheter to visualize proximal and distal tubules. The right ureter was catheterized via a suprapubic incision.

Via a flank incision, the left kidney, renal artery and vein were exposed. The left renal vein was catheterized from a gonadal vein to quantitate PAH extraction. In addition, a flow probe (Carolina Medical Electronics, Inc., King, NC) placed on the left renal artery permitted direct measurement of renal blood flow (RBF) at endogenous MABP. An adjustable brass clamp was placed on the aorta above the left renal artery in order to reduce renal perfusion pressure to determine the RBF autoregulatory capability of the kidney (5–9). This test was performed after completion of surgery. All experiments were conducted at endogenous MABP which was above the lower limit of autoregulation. Finally the left ureter was catheterized near the hilus.

The left kidney was mounted in a plastic cup attached to a steel micropuncture table above the dog. A small 1–2 cm^2 area of capsule was removed from the surface of the mounted kidney in order to visualize tubules. Warm (37°) oil was dripped on the decapsulated surface. A fiberoptic (Dolan-Jenner Industries, Inc.) was used to illuminate the micropuncture field. A small (1.0 mm diameter) thermistor connected to an electronic thermometer was placed on the exposed surface near the border between the decapsulated and intact capsule to monitor kidney surface temperature. At this point the dogs were di-

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vided into two groups. In the first (group I; n=10) the exteriorized kidney was covered with warm saline-soaked sponges and wrapped with a loose insulating plastic wrap to prevent heat loss and evaporation from the exposed organ (Fig. 1). Micropuncture was performed through a small "window" in the plastic wrap. Three to four collections from proximal nephrons and as many distal collections as possible were obtained during the study. Each tubular fluid (TF) collection was followed immediately by a collection of arterial blood in order to measure plasma inulin concentration; collections from proximal or distal nephrons were obtained randomly. The entire collection period which lasted about one hour was begun sixty minutes after placing the kidney in the cup and initiating the infusion of inulin and PAH. During the micropuncture study, two 30-min collections of urine were obtained from each kidney along with mid-point arterial and renal vein blood samples. In group II (n = 9) the kidney was not wrapped. Urine and tubular fluid collections were obtained with a protocol that temporally was identical to group I.

Analytic methods. Plasma (P) and urine (U) inulin and PAH were both measured by an autoanalyzer technique (10). Hematocrit was measured by microcentrifugation. Tubular fluid (TF) inulin concentration was estimated by the fluorometric method of Vurek and Pegram (11). SNGFR was calculated from the formula

$$\frac{TF_{In}}{P_{In}} \times \dot{V}\,(\text{nl/min}) = \text{SNGFR}\,(\text{nl/min})$$

where V is the quantitative collection rate of TF expressed in nl/min. V in nl was measured with a constant bore capillary tube. Standard clearance formula was used to calculate inulin and PAH clearance. Renal plasma flow (RPF) was estimated by both PAH clearance and extraction and by flowmeter estimates of RBF and hematocrit measurements in most experiments. In an occasional dog, two renal arteries prevented the use of the flow probe; however when both techniques were used simultaneously, estimates of RBF agreed to within 4% in any single experiment. All measurements of RPF and RBF reported in this study are based upon clearance and extraction of PAH. At the end of each experiment kidneys were removed, blotted dry, decapsulated and weighed. Standard statistical techniques (paired and unpaired t test) were used to determine significant differences. Individual SNGFR values were averaged to provide a single mean value for each site (proximal or distal) from each dog. Values are mean ± one SE.

Results. Renal clearance and hemodynamic measurements. Table I demonstrates there were no significant differences in either inulin

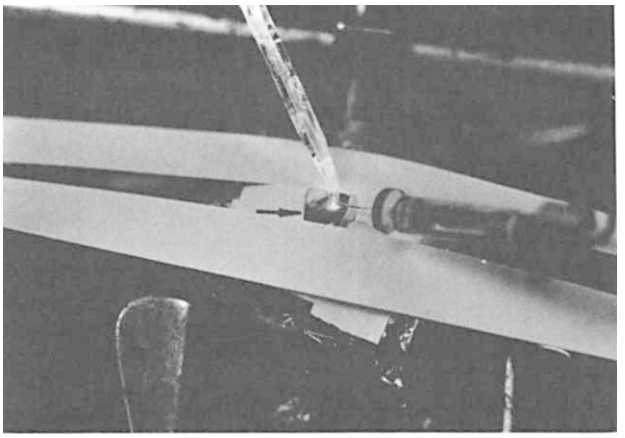

FIG. 1. The clear plastic wrap (overlying the warm saline soaked sponges) covering the entire kidney is shown. White tape secures the wrap to the kidney holder and is stretched over the kidney and secured to the sides of the micropuncture table. Micropuncture is performed through a small "window" in the plastic wrap. The decapsulated area is indicated by the arrow and approximately 1 cm^2.

clearance, RPF, RBF or MABP among the two groups. However, temperature at the surface of the kidney was consistently and significantly lower ($P < 0.002$) when the plastic wrap was omitted.

Micropuncture-group I (Fig. 2). In 10 dogs, proximal SNGFR averaged 72 ± 7 nl/min (range: 46–108 nl/min) and significantly ($P < .01$) exceeded distal SNGFR which averaged 46 ± 4 nl/min (range: 23–68 nl/min). Distal $\dot{V}$ averaged 14.8 ± 1.8 nl/min and TF/P_{In} averaged 3.37 ± 0.32. MABP averaged 112 ± 7 mm Hg (range: 80–140 mm Hg).

TABLE I. RENAL FUNCTION, MEAN ARTERIAL BLOOD PRESSURE AND KIDNEY SURFACE TEMPERATURE.

	C_{In}	RPF[a] (ml/min·g KW)	RBF[a]	MABP (mm Hg)	Temp. °C
Group I (n = 10)					
W	0.57[b] ±0.06	1.99 ±0.16	3.70 ±0.24	113 ±7	37.6 ±0.1
Group II (n = 9)					
U	0.58 ±0.09	2.66 ±0.29	4.40 ±0.50	112 ±7	35.7 ±0.1
P	>.9	>.05	>.2	>.6	<.002

[a] RPF was determined by PAH clearance and extraction; RBF was determined from RPF and hematocrit. Flow rates are ml/min·gram kidney weight.

[b] Mean ± SE; C_{In} = inulin clearance; RPF = renal plasma flow; RBF = renal blood flow; MABP = mean arterial blood pressure; Temp. = surface temperature in °C of kidney prepared for micropuncture; U = unwrapped; W = wrapped.

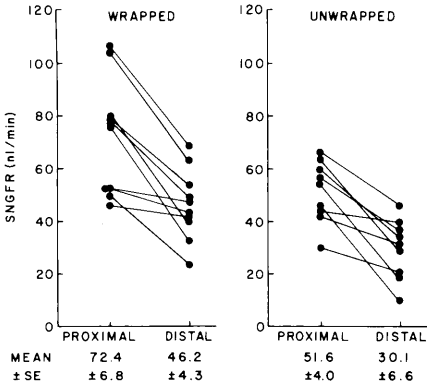

FIG. 2. Comparison of individual proximal and distal SNGFR values from 10 dogs in which the kidney was wrapped with plastic (WRAPPED) and from nine dogs in which the plastic wrap (UNWRAPPED) was not used. Blood pressure, GFR and RBF were similar between the two groups (see Table I).

Micropuncture-group II (Fig. 2). As in group I, proximal SNGFR also significantly ($P < .02$) exceeded distal SNGFR. In nine dogs, proximal SNGFR averaged 52 ± 4 nl/min (range: 29–66 nl/min) which was significantly lower ($P < .02$) than average proximal SNGFR in wrapped kidneys (group I). The average distal SNGFR of 30 ± 7 nl/min (range: 10–46 nl/min) was also significantly lower ($P < .02$) than that of wrapped kidneys (group (I). Distal $\dot{V}$ was lower by more than 50% averaging 6.1 ± 1.0 nl/min ($P < .001$) and TF/P_{In} was higher averaging 5.43 ± 0.48 ($P < .01$). MABP was similar to group I averaging 113 ± 7 mm Hg (range: 84–150 mm Hg).

Discussion. The results of these studies suggest the exteriorized wrapped kidney prepared for micropuncture maintains a more normal surface temperature and the nephrons demonstrate higher values for both proximal and distal SNGFR compared to the unwrapped kidney. Cooling of the outer kidney surface by exposure to room temperature might induce the type of vasoconstriction characteristic of other vascular beds exposed to cold (12). The effects of cooling could be more pronounced in the area of micropuncture where the capsule has been removed as has been suggested by McDonald and Sparks (1). The apparent local reduction in flow in that study was not accompanied by measurable changes in whole kidney function which is consistent with the present observations. Moreover, these results suggest also that only a small region of the exteriorized kidney could be significantly influenced by exposure to room temperature and overall renal hemodynamics including RBF might remain within normal limits. However, any substantial RBF decrease at the area prepared for micropuncture could well proved an appropriate explanation for the lower SNGFR we have observed. The lower surface temperature (2, present study), apparent decreased local blood flow (1), and lower proximal and distal SNGFR (present study) all suggest that diminution in nephron function might occur in the decapsulated area if appropriate caution is not taken in preparing the kidney for micropuncture studies.

Clapp *et al.* (2, 3) have reported a similar qualitative interpretation of nephron function in the wrapped versus the unwrapped kidney.

Although providing no quantitative data, these investigators report "renal function was more improved following wrapping of the kidney." Our present data provide some measure of the improvement induced in the wrapped kidney. Distal SNGFR averaged about 30 nl/min in unwrapped kidneys which is approximately 35% lower than the average dog distal SNGFR (44–47 nl/min) reported for wrapped kidneys (8, present study).

Finally, the difference between proximal and distal SNGFR in the same kidney whether wrapped or unwrapped, appears to indicate that orthograde flow to the macula densa is an important factor which regulates afferent arteriolar tone and thus SNGFR (8, 9, 13). The data also suggest that a tubuloglomerular feedback system sensitive to changes in "distal delivery" (13) does exist and can be demonstrated even in unwrapped kidneys, where proximal SNGFR exceeds distal SNGFR by about 21 nl/min. However, the reduced surface temperature might have led to local vasoconstriction thereby impairing assessment of normal distal and proximal nephron function in the dog.

In conclusion, the results of these studies indicate that an improvement in nephron function does occur in the exteriorized kidney which is protected against exposure to room temperatures. Quantitatively, superficial single nephron glomerular filtration rate (SNGFR) measured at distal nephron sites averaged about 35% less in unwrapped kidneys (surface temperature average 35.7°) compared to similar studies in wrapped kidneys (surface temperature average 37.6°); whole kidney GFR, RBF and BP were similar in both studies. When surface temperature is maintained by an insulating plastic wrap, we agree with Clapp and coworkers (2, 3) that " . . . stability of function was significantly improved . . . ".

Summary. In dog kidneys prepared for micropuncture experiments, the thesis that exteriorized organs with an intact circulation may demonstrate reduced function due to exposure to cool (21–23°) room temperatures, was tested by measuring superficial proximal and distal SNGFR on the surface of kidneys either protected against heat loss with a plastic wrap or unwrapped and exposed to room temperature. No significant differences in GFR or RBF could be detected between these conditions. However, temperature at the kidney surface was 37° in wrapped kidneys but fell ($P < .002$) to 35° in the unwrapped state. The lower surface temperature was associated with reduced values for proximal SNGFR, 72 ± 7 vs. 52 ± 4 nl/min ($P < .02$) and distal SNGFR, 46 ± 4 vs. 30 ± 7 nl/min ($P < .02$). The results indicate that the uninsulated kidney prepared for micropuncture may have decidedly lower values for superficial SNGFR measured by total collections of tubular fluid from either proximal or distal sites. These data also suggest that the reductions may be local because whole kidney function does not indicate a similar quantitative reduction in function.

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