Renal Fluid Dynamic Changes Produced by Renal Arterial Infusion of Acetylcholine[1] (35937)

JOHN T. FREIE AND R. D. BELL
(Introduced by A. K. Weiss)
With the technical assistance of L. Lee Beverage
Department of Urology, University of Oklahoma Medical Center
Oklahoma City, Oklahoma 73104

Koester *et al.* (1) have demonstrated venous stenoses located at the junctions of the arcuate and interlobar veins of the canine kidney. These physiological restrictions to venous outflow may be responsible for the unusually high (24 mm Hg) venous pressure found at the level of the arcuate veins, as opposed to the lower pressure (7 mm Hg) of the contiguous interlobar veins (2). In addition, it has been reported that intrarenal venous pressure (IRVP) is related to arterial pressure, renal tissue pressure (3), and renal lymph formation (4). The present investigation was designed to provide additional information concerning the interrelationships of these parameters.

Methods. Mongrel dogs (20–30 kg) were anesthetized with intravenous sodium pentobarbital (30 mg/kg) and the left kidney was exposed through a flank incision. The ureter was catheterized for collecting urine, and the femoral vein was catheterized to facilitate administration of additional anesthetic, as needed. After establishing an extracorporeal circuit between the renal vein and the external jugular vein, a catheter was inserted into the intrarenal venous system using the method and criteria for catheter placement of Hinshaw (5). Catheters were secured into the femoral artery, renal venous circuit, and a capsular and/or hilar renal lymphatic vessel for measurement of pressures in these areas. Catheters for lymph pressure measurement were especially prepared from Clay Adams PE 60 by drawing the tip small enough to enter the lymphatic vessel lumen. Renal arterial infusion was accomplished using a Harvard syringe pump set to deliver 0.1 ml/min via a 20 gauge needle inserted into the renal artery. The infusion consisted of 0.9% saline solution delivered during control and recovery periods and acetylcholine (ACh) (0.01 mg/min/kg of body wt) in saline during experimental periods.

Renal subcapsular pressure was monitored as an estimate of renal tissue pressure (TP). This parameter was obtained using a wafer type miniature pressure transducer (Sensotec Model M-7BW) inserted through a small slit in the renal capsule to lie between the capsule and the renal parenchyma (6). All pressures were continuously recorded using appropriate strain gauges and a multichannel polygraph. Renal blood flow (RBF) was measured at 5 min intervals throughout each experiment by timed blood collections obtained by diverting the renal venous outflow into a graduated cylinder. Urine osmolality was obtained using an Advanced Instruments model 3W osmometer.

Renal resistances were calculated as follows:

$$\text{Total renal resistance} = \frac{\text{arterial pressure} - \text{renal venous pressure}}{\text{RBF}},$$

$$\text{Prevenous resistance} = \frac{\text{arterial pressure} - \text{IRVP}}{\text{RBF}}, \text{ and}$$

$$\text{Venous resistance} = \frac{\text{IRVP} - \text{renal venous pressure}}{\text{RBF}}.$$

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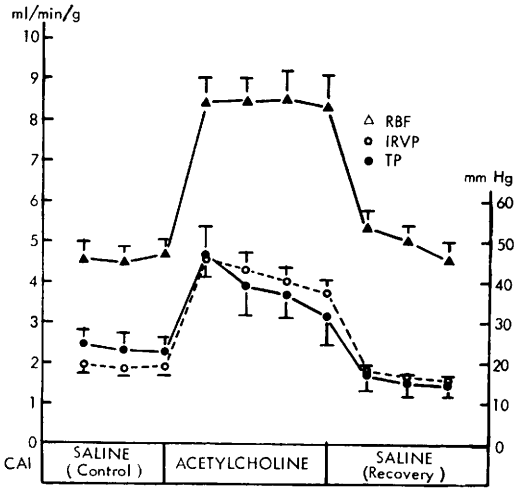

FIG. 1. Renal blood flow (RBF), intrarenal venous pressure (IRVP) and renal tissue pressure (TP) before, during and following close arterial infusion (CAI) of acetylcholine.

Results. As shown in Fig. 1 RBF ($n = 8$), IRVP ($n = 11$) and TP ($n = 5$) increased in response to renal arterial infusion of ACh, and remained elevated throughout the ACh infusion. The capsular ($n = 5$) and hilar ($n = 6$) renal lymph pressure responses to acetylcholine infusion (Fig. 2) appear similar to those of TP and IRVP. Mean capsular lymph pressures observed during ACh infusion were similar to the corresponding values for TP and IRVP, while hilar lymph pressures were somewhat less. During recovery periods both capsular and hilar lymph pressures rapidly returned to control levels, as did RBF, TP, and IRVP.

In Fig. 3, derived from 6 animals, renal

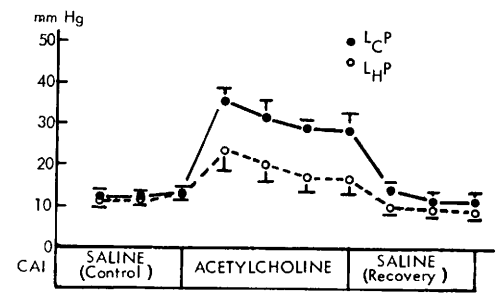

FIG. 2. Capsular and hilar renal lymph pressures (L_CP and L_HP, respectively) before, during and after close arterial infusion (CAI) of acetylcholine.

prevenous and venous resistances are plotted together with total renal resistance. Total renal resistance fell to about one half of the control values and returned to control during the recovery periods. The marked decrease in total resistance was almost entirely due to a decrease in the prevenous component. In contrast, little or no change occurred in the renal venous resistance component.

As shown in Table I, ACh infusion caused increased urine flow and decreased urine osmolality. A slow return toward control was observed during recovery periods.

Discussion. In the present experiments renal tissue pressure was observed to rise as renal blood flow increased. The tissue pressure rise was found to be accompanied by the expected increase in IRVP (3), but no significant change in venous resistance was found. The present experiments thus demonstrate that renal tissue pressure, when increased above resting levels, does not cause venous compression. Rather, IRVP increases as a result of increased renal blood flow through an unaltered venous outflow resistance. The primary effect of acetylcholine infusion appears to be dilation of prevenous blood vessels resulting in a greatly augmented renal blood flow. Renal tissue pressure changes thus appear to be secondary to IRVP when the latter is experimentally elevated. While renal tissue pressure may, in part, develop due to vascular filtration caused by IRVP, it is probable that other factors are of importance as well (3).

Increased urine flow and decreased urine

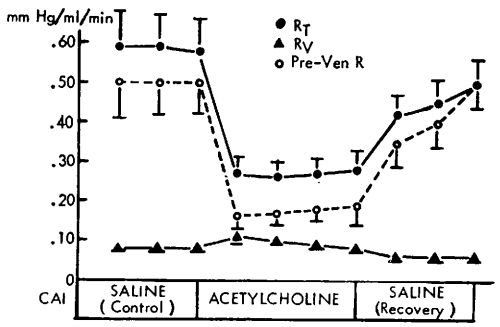

FIG. 3. Total renal resistance (R_T), renal venous resistance (R_V) and renal prevenous resistance (Pre-Ven R) before, during and after close arterial infusion (CAI) of acetylcholine.

TABLE I. Urine Flow and Osmolality for Consecutive Samples Before, During and After Renal Arterial Infusion (CAI) of Acetylcholine.

CAI	Saline (control)	Acetylcholine				Saline (recovery)	
Duration of collection (min)	15	5	5	5	5	5	5
Urine flow ($n = 6$)							
Mean ml/min	.22	1.37	1.79	1.88	1.72	.43	.24
SE	.05	.50	.50	.53	.50	.06	.04
Urine osmolality ($n = 6$)							
Mean (mOsm/liter)	1382	1015	588	481	482	507	660
SE	170	224	105	60	63	66	74

osmolality are consistent with medullary solute washout (7) via an increased vasa recta blood flow (8). The observed changes may also be due in part to increased glomerular filtration (9) and increased delivery of fluid to the distal tubule.

Both capsular and hilar renal lymph pressure were found to increase in parallel to tissue pressure and IRVP in the present study. It is thus reasonable to postulate that renal lymph may be derived as a vascular filtrate with IRVP as a principle variable in its formation. It has already been suggested that the renal lymphatic vessels relieve the kidney of excess pressure (10). It is not surprising, therefore, that both tissue pressure and lymph pressure follow changes in IRVP. Pressures recorded from capsular lymphatic vessels during acetylcholine infusion more closely approximate IRVP and TP than do hilar lymph pressures. These observations are consistent with the findings that capsular lymphatic vessels arise directly from cortical lymphatic capillaries, while hilar lymphatic vessels drain an extensive lymphatic plexus around the arcutate blood vessels (11).

Summary. The effects of renal arterial infusion of acetylcholine (ACh) on renal fluid dynamics were studied. It was found that ACh caused prevenous vascular dilation with no change in venous outflow resistance. A pronounced rise in intrarenal venous pressure resulted from increased renal blood flow through an unchanged venous outflow resistance. Marked increases in capsular and hilar renal lymph pressures as well as renal tissue pressure were also observed, but were probably secondary to the increased intrarenal venous pressure.

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