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Lymphology 3 (1974) 143-148

Influence of Renal Fluid Dynamics on Renal Lymph Pressure, Flow and Composition[1]

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Summary

The effects of decreased RBF on renal lymph formation and TP were investigated during experimentally maintained IRVP. It was found that this procedure is effective in maintaining TP and L_CP at or above control even in the absence of RBF. While lymph PAH and creatinine concentrations were unchanged under these circumstances, lymph protein concentration was increased. It is concluded that IRVP is a major factor determining lymph and tissue pressure and that increases above control may be due to a combination of physical factors and tissue ischemia.

[1] This work was supported by National Institutes of Health Grant HE 12832 and the Veterans Administration Hospital, Oklahoma City, Oklahoma.

Previous investigators have suggested that renal lymph may be derived from both tubular reabsorbate and renal blood plasma (1). These components could be derived simultaneously as a filtrate of renal venous blood (2). This hypothesis is supported by the close relationship of renal lymph pressure to intrarenal venous pressure (IRVP), and the remarkable stability of renal lymph composition under widely varying circumstances (2, 3, 4). Differences in composition between renal lymph and renal venous plasma suggest however that a portion of renal lymph may be derived from a non-venous source (4). In the present study, alterations in renal fluid dynamics are used to further investigate the factors involved in renal lymph formation.

Methods

Twenty mongrel dogs (20-30 kg) were anesthetized with intravenous sodium pentobarbital (30 mg/kg), and the left kidney exposed through a flank incision. The gonadal and femoral veins were catheterized for collection of renal venous blood and for administering infusion, respectively. Intrarenal venous pressure (IRVP), tissue pressure (TP), and capsular lymph pressure (LCP) were monitored as previously described (3), while an electromagnetic flowmeter[2] was used to monitor renal blood flow (RBF). Renal artery pressure was monitored using a Statham P23Db transducer attached to a 20 gauge needle inserted through the wall of the renal artery. Renal hemodynamics were altered by tightening a suture around the renal artery until RBF either ceased or was reduced by approximately 50%. Alterations in IRVP were accomplished by tightening a suture passed around the renal vein. The ureter was catheterized for experiments in which renal pelvic pressure was to be elevated. Pelvic pressure elevations were accomplished by attacing the ureteral catheter to a mercury manometer via a saline filled aspirator bottle. Capsular lymphatic vessels were chosen for pressure measurements since these vessels appear to arise directly from cortical lymphatic capillaries, while hilar lymphatic vessels drain an extensive lymphatic plexus around the arcuate vessels (5). For lymph collections, an 18 in. length of polyethylene tubing[3] was tied into either a capsular or hilar renal lymphatic vessel. Both capsular and hilar lympatic vessels were used for these experiments, since it has been shown that lymph from these two sources is similar in composition (6, 7) and is derived essentially from the cortical area of the kidney (5). Timed lymph collections were obtained under mineral oil to prevent evaporation, since lymph collections varied from 6 to 80 min. Renal venous blood was drawn at equal intervals of not more than 30 min throughout each lymph collection. Dogs used for lymph collection experiments received a constant intravenous infusion (2 ml/min) of 0.9% saline containing sufficient creatinine and p-amino hippurate (PAH) to maintain suitable plasma concentrations of these substances. Concentrations of the following substances were determined in plasma and lymph: protein with a biuret method, creatinine by the Jaffe reaction and PAH by the method of *Smith* et al. (8).

Results

Mechanical constriction of the renal artery is followed by decreases in all parameters measured (Fig. 1). Experimental return of IRVP to control level during renal artery constriction caused return of TP to control, a significant increase above control of LCP and no change in RBF. It was noted that all changes observed following renal artery constric-

[2] Micron Instruments model RC 1000.
[3] Clay Adams PE 10.

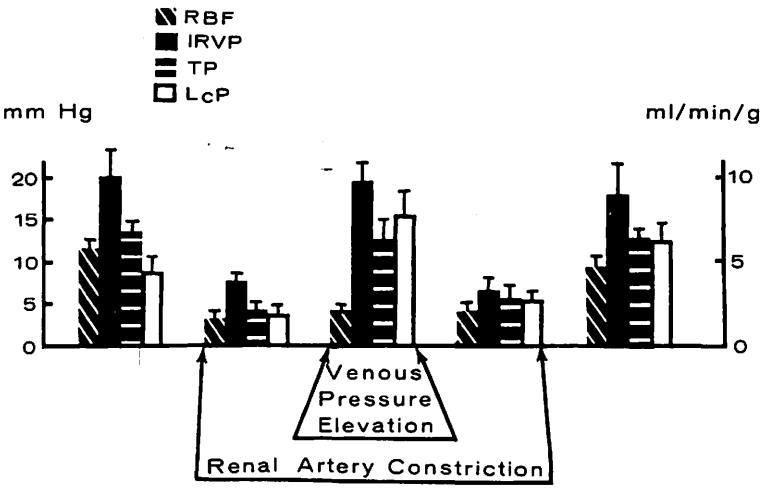

Fig. 1 Renal blood flow (RBF), intrarenal venous pressure (IRVP), tissue pressure (TP) and capsular renal lymph pressure (L_CP) are shown to decrease following renal artery constriction and, with the exception fo RBF, to return to or above control following venous pressure elevation. Means and standard errors for 5 animals are shown.

tion and IRVP manipulation were readily reversed when renal vein and artery sutures were relaxed. Similar responses were observed when these experiments were repeated using complete rather than partial occlusion of the renal artery (Fig. 2).

As shown in Table 1, decreased RBF with IRVP experimentally returned to control caus-

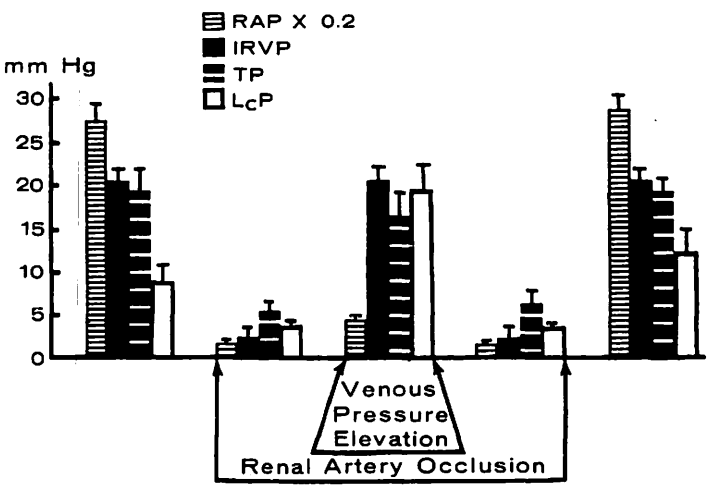

Fig. 2 Renal artery pressure (RAP x 0.2), intrarenal venous pressure (IRVP), tissue pressure (TP) and capsular renal lymph pressure (L_CP) are shown to decrease following renal artery occlusion and, with the exception of RAP, to return to or above control following renal venous pressure elevation. The plot of RAP is reduced by a factor of 0.2 in order to simplify the presentation. Means and standard errors for 5 animals are shown.

Table 1 Renal lymph to renal venous plasma concentration ratios for PAH, creatinine and protein in 5 dogs. Ratios are shown for control periods and for experimental periods (decreased renal blood flow but normal IRVP).

	PAH		Creatinine		Protein	
	Mean	S.E.	Mean	S.E.	Mean	S.E.
Control	1.64	0.19	1.07	0.09	0.42	0.04
Experimental	1.28	0.14	0.99	0.05	0.71*	0.04

* $p < 0.05$

Table 2 The effects of elevated renal pelvic pressure on renal lymph pressure, tissue pressure and IRVP in the absence of renal perfusion (n = 5).

		Control	Renal Artery Occlusion	Pelvic pressure elevation (mmHg) 25	75	125	175
Capsular lymph	mean	8.6	3.0	3.6	4.5	5.4	6.2
Pressure mmHg	S.E.	0.5	0.5	0.7	0.7	1.4	1.6
Tissue	mean	16.8	3.2	3.8	5.8	6.0	6.6
Pressure mmHg	S.E.	3.1	1.1	0.9	1.4	1.3	1.6
IRVP	mean	17.0	3.6	5.2	7.6	8.2	8.8
mmHg	S.E.	1.4	1.1	1.5	1.7	2.2	2.4

ed little change in the renal lymph to renal venous plasma concentration ratios (L/P) for PAH and creatinine but the L/P ratio for protein was significantly increased ($p < 0.05$). Mean renal lymph flow was significantly ($p < 0.05$) increased from 0.012 ml/min ± .003 S.E. for control collections to .035 ml/min ± .005 S.E. during the experimental period

In the absence of renal perfusion, elevating renal pelvic pressure from 0 to 175 mmHg caused LCP, TP and IRVP to approximately double (Tab. 2). Nevertheless, the highest values observed for these parameters were still well below those observed during the control period.

Discussion

Previous investigations (2) suggest that a major portion of renal lymph is formed as a filtrate from the intrarenal veins, and that IRVP provides the pressure gradient necessary for that filtration. The present investigation demonstrates that renal tissue pressure and lymph pressure are adequately maintained during reductions in renal blood flow as long as IRVP is not allowed to fall. These experiments thus confirm the previous conclusion that renal lymph and tissue pressures are directly related to IRVP (3). Since renal lymph flow and pressure increase above control in the present experiments, it appears that maintaining IRVP by renal vein obstruction may alter the mechanism of renal lymph formation. The increased lymph production may, in part, be due to increased vascular permeability secondary to tissue anoxia and buildup of toxic metabolites, but changes associated with decreased tubular filling may also be of importance. When perfusion pressure is lowered below the autoregulatory range intratubular volume will decrease due to lowered capillary and venule transmural pressures. Subsequent experimental return of IRVP to control is followed by a similar return of TP. Thus the kidney appears to have regained its "functional distention" (9) even with a decreased tubular volume. Presumably, decreased tubular filling is compensated for by additional filtration of fluid from interlobular

veins with an increase in renal interstitial fluid space. If the intrarenal veins and capillaries of the kidney expand as the interstitial fluid space increases, then increased lymph pressure and flow may result from mechanical changes in the walls of the blood vascular elements of the kidney. This hypothesis would also explain the unusual increase in lymph protein concentration observed. The fluid dynamic data of the present study do not suggest a change in the primary site of renal lymph formation. This conclusion is further supported by the minimal changes observed in PAH and creatinine L/P ratios (Table 1).

Since the kidneys studied were subjected to 50-100% reductions in RBF it might be expected that the data obtained may be altered by endothelial changes secondary to reduced tissue oxygen tension or buildup of toxic metabolities (10). Such effects combined with the mechanical effects discussed above would further explain the observation that renal lymph pressure increased above control during elevated venous pressure with decreased or absent RBF (Fig. 1 and 2). The finding that lymph protein concentration is increased under similar circumstances (Table 1) may also suggest toxic or anoxic endothelial changes. Even so, some investigators have shown that such changes may be expected even without decreases in renal perfusion (11). The effect appears to persist into the recovery phase of the experiments as shown by the slightly increased lymph pressure in the last set of columns in Figs. 1 and 2. Even though changes occur in renal lymph pressure which could result from an anoxic or toxic changes, the effect is not sufficiently severe to alter TP even during complete renal artery obstruction (Fig. 2).

In contrast to the dramatic effects of renal venous pressure changes, renal pelvic pressure is relatively ineffective in maintaining parameters of renal fluid dynamics in the absence of blood flow. The present study demonstrates that renal pelvic pressure is poorly transmitted to the renal parenchyma (TP) and intrarenal veins (IRVP). Similarly, renal pelvic pressure is poorly transmitted to the renal lymphatic system. The small increment in LCP shown in Table 2 probably reflects the tissue pressure increase rather than suggesting a direct pelvico-lymphatic communication. Thus, the dramatic increases in TP, LCP, IRVP (2) and lymph flow (12) observed following increases in pelvic pressure in the normally perfused kidney are due almost entirely to intrarenal venous obstruction (2).

Acknowledgements

The authors wish to thank Ms. L.Lee Beverage for technical assistance.

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