EFFECT OF THE COLLATERAL CIRCULATION IN THE KIDNEY ON RESTORATION OF ITS FUNCTION AFTER ACUTE RENAL ISCHEMIA

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Experiments on dogs showed that the collateral blood flow in the kidney after ligation of the renal artery amounts on the average to 1.6% of the original volume of the renal circulation. Blood vessels of the ureter supply 19.9% of the total collateral renal blood flow. After ischemia of the left kidney for 4 h and simultaneous right-sided nephrectomy, a relatively favorable outcome is observed if the principal sources of the collateral renal circulation are maintained during the ischemia. If the flow of blood to the kidney is totally interrupted or the collateral circulation is severely restricted, ischemia leads to the development of a severe form of acute renal failure and to death of the animals.

With improvements in methods of diagnosis and treatment of thrombosis and embolism of the renal arteries [1-4] the assessment of the collateral circulation in the kidney during the period of its acute ischemia is now of considerable interest. This is because the level of the collateral blood flow in the kidney may have a substantial effect on the sequelae to temporary acute occlusion of the renal artery.

This paper describes a study of the effect of the collateral circulation in the kidney on its function in the postischemic period.

EXPERIMENTAL METHOD

In acute experiments on 12 dogs under pentobarbital anesthesia the initial renal blood flow and the extent of the collateral blood flow to the kidney after ligation of its artery were investigated. For this purpose, the left kidney was exposed extraperitoneally through a lumbar incision. A rubber catheter was introduced into the renal vein, by means of which blood flowing from the kidney could be redirected into the greater saphenous vein of the left hind limb. Blood clotting was prevented by heparin. By means of a three-way cock, the volume velocity of the renal blood flow was measured at the required moment, after which the blood flow from the kidney to the greater saphenous vein was restored.

In 8 of the experimental animals the role of the ureteric vessels in maintaining the renal collateral circulation was studied. For this purpose, all possible sources of blood supply to the kidney except the ureteric vessels were occluded by means of soft vascular clamps.

To study the dependence of the state of renal function in the postischemic period on the intensity of the collateral circulation in it during acute renal ischemia, the following series of investigations was carried out in experiments on dogs with the ureteric orifices exteriorized on to the skin. In group 1 (6 dogs) total ischemia of the left kidney was produced by application of soft vascular clamps to its pedicle, excluding the vein. In group 2 (5 dogs) the pedicle of the left kidney, except the vein and ureter with its vessels, was clamped. In this series the flow of blood to the kidney took place entirely along the ureteric arteries. In group 3 (6 dogs) a vascular clamp was applied to the isolated renal artery, leaving the main sources of collateral blood supply to the kidney intact.

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TABLE 1. Dynamics of Recovery of Function of Left Kidney after Occlusion of Its Artery for 4 h and Simultaneous Right-Sided Nephrectomy (M ± m)

Index studied	K excretion (in percent of filtration load)	Before ischemia (initial values)		
		1 day	60 days	270 days
Plasma flow	262,7±13,86	34,2±16,22[2]	222,1±65,19	263,6±49,94
Filtration	44,4±6,78	18,6±7,89[1]	50,1±0,93	53,0±10,79
Secretion (in mg/min/m^2)	20,6±2,42	2,1±0,54[2]	16,8±2,47	18,9±3,41
Urea clearance (in ml/min/m^2)	37,0±3,24	9,9±3,58[2]	40,5±3,00	30,2±2,57
Filtration load of Na (in meq/min/m^2)	6,40±0,290	2,47±0,997[1]	7,12±0,794	8,58±1,483
Na excretion (in $^0/_{00}$ filtration load)	5,6±0,78	44,5±10,34[2]	10,4±3,18	5,4±1,20
Filtration load of K (in μeq/min/mg)	209±16,9	76±22,2[1]	249±33,7	322±59,3
K excretion (in percent of filtration load)	27,4±5,85	95,8±7,69[2]	47,9±11,27	21,1±7,08

[1] $P<0,05$,
[2] $P<0,01$.

Occlusion of the renal vessels continued for 4 h. Immediately after removal of the clamps from the vessels of the left kidney the right kidney was removed.

To assess the state of kidney function, the minute renal plasma flow and the tubular secretion were determined by the cardiotrust method, the glomerular filtration was determined relative to endogenous creatinine, the urea clearance, filtration load, the absolute and relative excretion, and the reabsorption of sodium and potassium were measured.

EXPERIMENTAL RESULTS

During the acute experiment the renal blood flow was 388.7 ± 24.55 ml/min/100 g kidney tissue. After ligation of the renal artery the volume of the collateral circulation was 6.28 ± 1.16 ml/min/100 g, or 1.6% of the initial renal blood flow.

The collateral blood flow to the kidney, supplied by the ureteric vessels, was 1.25 ± 0.23 ml/min/100 g, or 0.32% of the initial renal blood flow and 19.9% of the total collateral blood flow in the kidney.

The intensity of the collateral blood flow in the kidney during acute ischemia of the organ had a marked effect on the dynamics of kidney function in the postischemic period. This is shown by the results of tests carried out on dogs with the ureteric orifices exteriorized on the skin.

All the animals of groups 1 and 2 died within a few days from acute renal failure, with manifestations of oliguria or anuria, marked uremia, and hyperkaliemia. Histological investigations revealed severe changes in the convoluted tubules of the ischemic kidneys with necrosis of their epithelium.

In the animals of group 3 the course of the postischemic period was more favorable. Only two dogs died from acute renal failure. In the other four dogs there was merely a temporary disturbance of the function of the ischemic kidney, expressed as a decrease in the minute renal plasma flow, secretion, filtration, urea clearance, filtration loads of sodium and potassium, and an increase in the relative excretion of these ions, on the day after occlusion of the renal artery (Table 1). From 1 to 2 months later the function of the ischemic kidney in all the animals was restored to its original level.

Preservation of the principal sources of the collateral circulation in the kidney, despite its relatively small extent (less than 2% of the initial renal blood flow) thus has a favorable effect on the course of the postischemic period.

This effect may due to an increase in the extraction of oxygen by the kidney from each unit volume of blood flowing through its vessels, to a compensatory increase in the intensity of anaerobic processes with an increase in the consumption of glucose brought by the blood, and also to a decrease in the oxygen

demand of the kidney through the cessation of active reabsorption of sodium after occlusion of the renal artery, a process which under normal conditions requires the consumption of a considerable proportion of the energy used by the kidney [6].

The favorable results of operative treatment of thrombosis and embolism of the renal artery observed in clinical practice [2-5] may evidently be due to a large extent to the existence of the collateral blood flow in the kidney during its ischemia, which as a rule lasts for several hours.

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