PATHOLOGICAL PHYSIOLOGY AND GENERAL PATHOLOGY

COMPENSATORY CAPACITY OF THE RESECTED KIDNEY

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When treating certain bilateral disorders of the kidneys the surgeon is obliged to operate on both kidneys in turn,—to resect one and remove the other. Clinical physicians are interested in discovering to what extent a resected kidney is capable of providing for the vital requirements of the organism.

Clinical observations giving a positive answer to this question [2, 6, 7] were verified by experiments [1, 3, 4, 5] in which it was demonstrated that if the intact kidney was removed the resected kidney was liable to undergo hypertrophy. Morphological and certain functional changes in the resected kidney (residual nitrogen in the blood, indigo-carmine tests, determination of creatine) are described in these works. However, as is well known, these characteristics do not give a complete picture of the state of the glomeruli and the kidney tubules.

We set up experiments with the aim of ascertaining the compensatory possibilities of the resected kidney and of studying the functions of the glomeruli and tubules in the resected kidney after the opposite kidney had been removed.

EXPERIMENTAL METHOD

The experiments were made on four dogs provided with Pavlov-Orbeli exteriorized ureters. After initial tests had been performed on two of the dogs one pole of the right kidney (0-54-0.84g kidney parenchyma/kg body weight) was resected and in the other two dogs two lobes (1.05-1.32g kidney parenchyma/kg body weight) were resected at one time. The functions of the resected and intact kidneys were studied for two months, after which the left intact kidney was removed. The compensatory changes taking place in the functions of the resected kidney were investigated during the first few days after left nephrectomy and, subsequently, at weekly intervals over a period of three months. Glomerular filtration and the resorption of water were determined by the inulin method and the effective renal blood flow and the excretion from the tubules by the diodrast method. For comparison all data were estimated on the basis of one square meter of body surface.

EXPERIMENTAL RESULTS

The diuresis of the right kidney in the different animals in their original condition ranged from 3.1-5.4 ml/min/m^2. After resection of one pole of the right kidney it fell to 2.1-2.8 ml/min/m^2. Already during the first few days after left nephrectomy diuresis in the resected kidney amounted to 4.4-6.9 ml/min/m^2; in the first month it rose to 6.1-8.5 ml/min/m^2 and remained at that level during the rest of the observation period, that is it exceeded the level of diuresis after resection by 2.5-3 times. After resection of two poles the diuresis of the right kidney sank to 1.3-2 ml/min/m^2. Following left nephrectomy, diuresis in the same kidney also sharply increased; during the first few days it rose to 3.8-5.3 ml/min/m^2 and in the first month to 3.6-6 ml/min/m^2, keeping at this level until the end of the observations, that is, it increased 2.7-3 times.

However, diuresis is indicative of the total excretory capacity of the kidney. We determined the condition and function of the kidney glomeruli from the rise in filtration, the blood flow, and the filtrated fraction.

Filtration from the glomeruli of the right kidney in its original condition was equal, on an average, to 46-52.6 ml/min/m^2. After resection of one pole it dropped to 29.4-31.9 ml/min/m^2. Following removal of the opposite

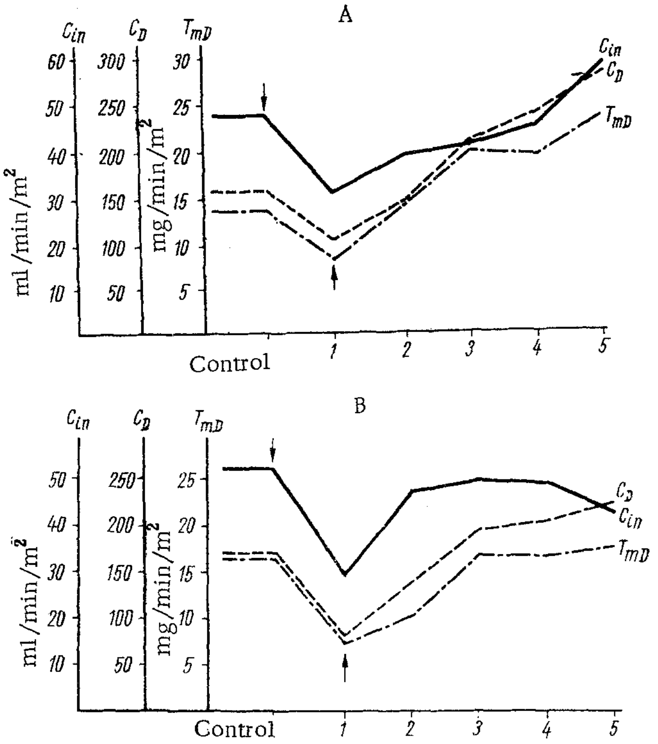

Fig. 1. Function of the right kidney after resection of one pole (↓) and after left nephrectomy (↑) in Pushka (A) and Zhuka (B). Axis of ordinates:— C_{in} = inulin clearance; C_D = diodrast clearance; T_{mD} = maximum excretion of the tubules by the diodrast method. Axis of abscissae:— 1) kidney function two months after resection; 2) during the first few days after left nephrectomy; 3, 4, 5) in the first, second, and third months respectively after left nephrectomy.

kidney, the filtration from the resected kidney rose already during the first few days to 38.4-47.8 ml/min/m^2, during the first month to 41.7-50.3 ml/min/m^2 and at the end of the experiment to 42.3-60.2 ml/min/m^2, that is, amounted to 143.8-188.5% of the level of filtration after resection and exceeded that in the original condition.

After resection of both poles the filtration diminished to 15.9-25 ml/min/m^2. Already during the first few days after removal of the opposite kidney, it rose to 24.8-27.8 ml/min/m^2. Subsequently, in one of the dogs (Laska) this characteristic gradually increased during the whole period of observations to 43.8 ml/min/m^2, which was 175.8% of the filtration registered after resection and which only just failed to reach the original level. In the other dog (Dozor), filtration from the resected kidney, rising to 24.8 ml/min/m^2 during the first few days following removal of the opposite kidney, again decreased during the first and second months to 14.7 ml/min/m^2. When observations were terminated the filtration had risen to 24.4 ml/min/m^2, which was 153.4% of the level of filtration after resection and only half that of the original flow.

The effective blood flow in the right kidney in its original condition was, on an average, 155.4-190.4 ml/min/m^2. After resection of one pole it dropped to 78.9-107.1 ml/min/m^2. After removal of the opposite kidney, the flow reached 137.6-148.1 ml/min/m^2 during the first few days and 196.9-213.6 ml/min/m^2 in the first month, while at the end of observations it was 223.7-283.5 ml/min/m^2, which is 2.7-2.8 times the level of the blood flow after resection and 1.4-1.5 times that of the original flow.

After resection of both poles the blood flow through the right kidney dropped to 65.4-76.1 ml/min/m^2, but during the first few days after left nephrectomy it rose to 94.4-108.6 ml/min/m^2. Subsequently, in one of the dogs, the blood flow progressively increased throughout the whole of the period of observations, reaching 172.9 ml/min/m^2, which was 2.2 times the level of the blood flow registered after resection and was only just below that of the original flow.

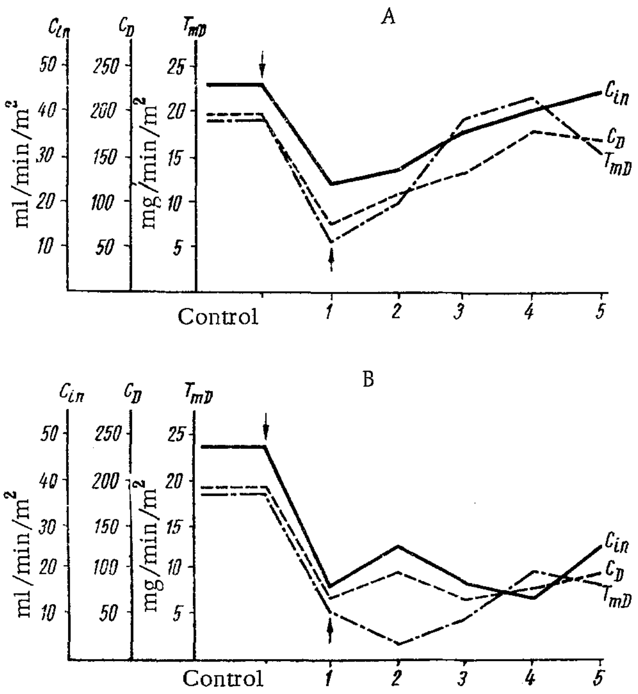

Fig. 2. Function of the right kidney after resection of both poles (↓) and after left nephrectomy (↑) in Laska (A) and Dozer (B). The symbols are the same as in Fig. 1.

In the other dog, the blood flow decreased during the first and second months and it was only towards the end of the observations that it rose a little and reached 98.9 ml/min/m^2, which was 151.2% of the level attained after resection and half that of the original level.

The filtrated fraction from the right kidney in its original condition varied from 24.1-32.6%. It did not alter very much after resection of the kidney, but after removal of the opposite kidney it gradually dropped to 19.8%, which implied a somewhat larger increase in the blood flow than in filtration.

We assessed the state and function of the kidney tubules by observing the changes in the resorption of water and the maximum excretion of the epithelium of the tubules. In the tubules of the right kidney in its original condition, resorption of water amounted to 42.4-45.6 ml/min/m^2. After resection of one pole it fell to 27.3-29.1 ml/min/m^2. Already during the first few days after left nephrectomy, this characteristic increased to 31.3-43.5 ml/min/m^2 and in the course of the first month it reached 33.2-44.1 ml/min/m^2, remaining at this level for the remainder of the observation period. After resection of two poles the resorption of water dropped to 14.6-23 ml/min/m^2. During the first few days following removal of the opposite kidney, it increased to 20.7-22.6 ml/min/m^2. Subsequently, in one of the dogs, resorption rose to 40.5 ml/min/m^2, which was 176% of the level registered after resection. In the other dog, resorption during the first and second months dropped to 11 ml/min/m^2 and it was only towards the end of three months that it reached 18 ml/min/m^2, which was 123.2% of the resorption after resection.

The maximum excretion of the tubules of the right kidney in its original condition varied from 13.6-19.2 mg/min/m^2. After resection of one pole of the kidney it fell to 8-9.6 mg/min/m^2 and following left nephrectomy the maximum excretion of the resected kidney gradually increased; it amounted to 10.5-15.2 mg/min/m^2 during the first few days, to 17-21.1 mg/min/m^2 during the first month and to 18.3-24.5 mg/min/m^2 towards the end of the experiment when the value was 2.2-2.5 times the level of the maximum excretion following resection. After resection of both poles the maximum excretion of the tubules dropped to 6 mg/min/m^2. After removal of the opposite kidney in one of the dogs, the excretion increased over the first few days to 9.8 mg/min/m^2 and after the first month to 18.7 mg/min/m^2, remaining at this level until observations ceased, that is, it was three times the maximum excretion after resection. Following left nephrectomy in the other dog, the excretion from the tubules of the resected kidney fell sharply and it was only after two months that it reached 10.1 mg/min/m^2.

Thus, resection of one pole of the kidney led to a fall of 30-53% in its filtration, resorption of water, blood flow, and tubule excretion (Fig. 1). Resection of two poles reduced these characteristics of renal function by 45-69% (Fig. 2). In the presence of the second kidney the remaining portion of the resected kidney does not compensate for the portion removed; compensation is carried out at the expense of a rise in the function of the opposite, intact kidney.

However, this still does not mean that there is no possible reserve in the resected kidney. The removal of the opposite, intact kidney caused a sharp increase in the function of the resected kidney. Already in the first few days the function of the right kidney, from which one pole had been resected, rose by 14-74%; later, all functional characteristics increased.

The function of the kidney from which two poles had been removed at the same time also increased by 11-64% during the first few days after the removal of the intact kidney. Subsequently, in one of the dogs (Laska) all the functions of the resected kidney increased. In the other dog (Dozer), a drop in the levels of all the functions of the resected kidney was noticed within two months of the removal of the intact kidney. Towards the end of the observation period the functions of the resected kidney had increased a little, but the increase was not enough and the dog died. The greater part of the kidney had been removed, the ratio of the weight of the resected kidney parenchyma to the body weight being 1.32 g/kg. Obviously, the compensatory capacity of the resected kidney in the latter dog was not sufficient. The heavier load created by the removal of the opposite kidney was too great and the function of the resected kidney began to decrease. The residual nitrogen content of the blood, one month after the removal of the intact kidney, went up to 89.6 mg %; after two months it dropped 64.4 mg %, and towards the end of observations it had again risen to 182-205.8 mg %.

Consequently, the portion of kidney left after resection of one pole always possesses an adequate compensatory capacity for maintaining the vital activities of the organism following extirpation of the opposite kidney. The compensatory capacity of the kidney from which two poles have been resected at one time may occasionally prove to be inadequate for preserving life after removal of the opposite kidney.

SUMMARY

The functions of various parts of the kidney, following its resection and the removal of the opposite, intact kidney, were studied on four dogs with exteriorized ureters The glomerular filtration rate and water resorption were estimated by the inulin method, renal blood flow and tubular excretion by the diodrast method. A decrease of 30-53% was noted in all the renal functions after resection of one pole of the kidney and of 45-69% following the simultaneous resection of two poles. The portion of the kidney remaining after the resection of one pole has an adequate compensatory capacity for maintaining the animal's life. The compensatory capacity of the kidney after the simultaneous resection of two poles may sometimes be insufficient for the maintenance of life.

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