COMPARISON OF COMPENSATORY HYPERTROPHY OF THE KIDNEY AFTER UNILATERAL NEPHRECTOMY ON ADULT AND SENILE RATS

V. F. Sidorova and V. D. Gorbunova

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One kidney was removed from rats weighing 35-900 g. The animals were killed 2, 14, 30, and 60 days after the operation. The degree of compensatory hypertrophy of the remaining kidney varied considerably in the animals of different ages, although it was not reduced in old age. The weight of the hypertrophied kidney of the old rats 60 days after the operation was 55-92% of the combined weight of both kidneys in the control. Hypertrophy of the kidney at all ages was accompanied by increased proliferation of cells of the tubules, especially the proximal tubules. An increase in the size of the renal corpuscles during hypertrophy of the kidney was characteristic of rats of both age groups. However, with an increase in age this process developed faster and was more pronounced. At all times of investigation the hypertrophied kidney of rats of both ages contained 1.5-2 times more "open" renal glomeruli than the kidney of the intact animal.

KEY WORDS: *Senile kidney; compensatory hypertrophy of the kidney; glomeruli.*

Experiments to study compensatory hypertrophy of the kidney are carried out as a rule on adult sexually mature animals [4, 6-8]. The age aspect in investigations of this sort is usually disregarded completely, or attention is paid mainly to the character of compensatory hypertrophy of the mammalian kidney in the early stages of postnatal development [1-3, 6]. There have been very few studies of compensatory growth of the kidney in old age [4, 6, 9].

The object of this investigation was to compare compensatory hypertrophy of the kidney after unilateral nephrectomy in juvenile, sexually mature, and old rats.

EXPERIMENTAL METHOD

Unilateral nephrectomy was performed on rats of six age groups. Group 1 consisted of young rats (male and female) weighing 35-50 g, group 2 of males weighing 90-100 g, group 3 of females weighing 150-200 g, and the remaining five groups contained only males: group 4) weighing 150-200 g, 5) 500-600 g, 6) 600-700 g, 7) 700-800 g, and 8) 800-900 g. For each group there were 8-10 experimental and the same number of control rats. The experimental and control animals were killed with ether vapor 2, 14, 30, and 60 days after the operation. The body weight and weight of the kidneys were determined. The kidneys were fixed in Carnoy's fluid. The index of hypertrophy (IH) of the kidney of experimental rats of each age group was expressed in per cent, taking the weight of both kidneys in the control animals as 100%. Paraffin sections 6-8 μ thick were stained with hematoxylin–eosin or by Mallory's method. For the morphometric investigations as a rule one transverse section was taken, viz. the largest central section from the region of the kidney that is continued as the papilla. The total number of renal corpuscles was counted in this section, their large and small diameters were measured by means of an ocular micrometer, and the area of each corpuscle was then calculated by the formula for an ellipse: $\pi \cdot \left(\frac{D_1 \times D_2}{4}\right)$. The degree of func-

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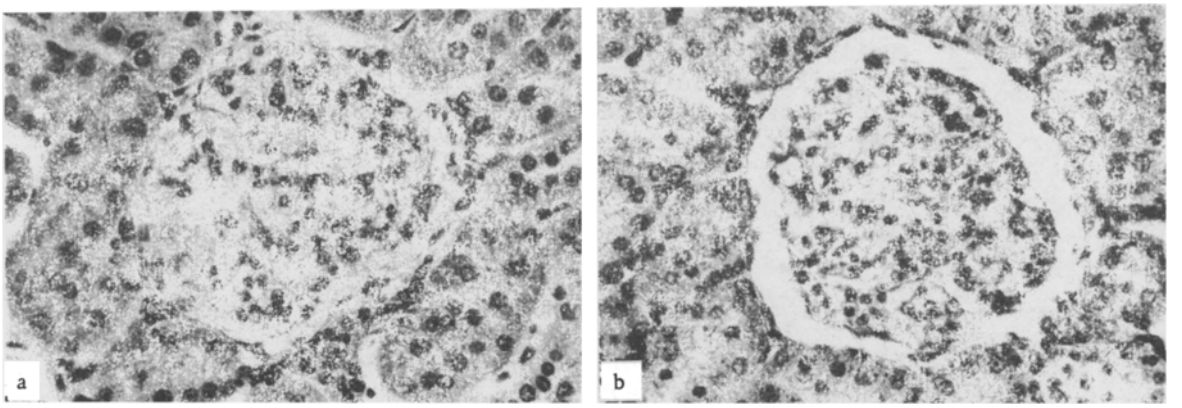

Fig. 1. Renal glomeruli: a) "open"; b) "closed".

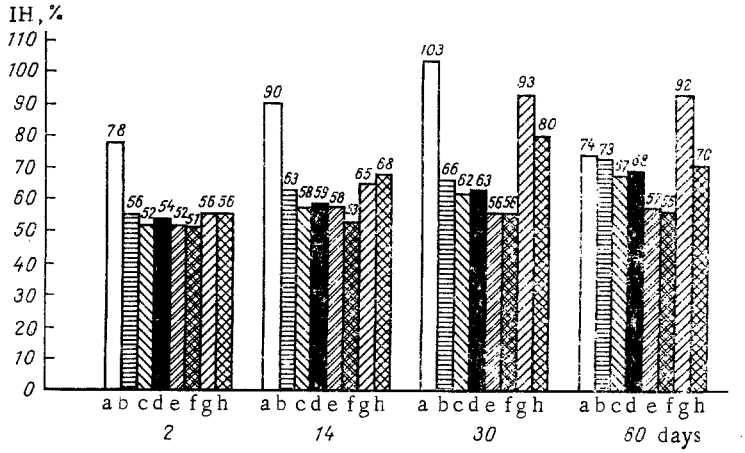

Fig. 2. Degree of compensatory hypertrophy of remaining kidney after unilateral nephrectomy in rats of different ages. Body weight: a) 35-50 g; b) 90-100 g; c) 150-200 g (females); d) 150-200 g (males); e) 500-600 g; f) 600-700 g; g) 700-800 g; h) 800-900 g. Ordinate, IH (in %); abscissa, time after operation (days).

tional loading of the glomeruli was determined in the same section by counting the number of "open" and "closed" glomeruli. Glomeruli were regarded as "open" if the capillary network was strongly dilated and it completely filled the cavity of Bowman's capsule. In the "closed" glomeruli the capillary network appeared more compact and collapsed and the cavity of Bowman's capsule was clearly visible (Fig. 1).

On the second day after unilateral nephrectomy the mitotic activity of the epithelium of the proximal convoluted tubules was determined in the remaining kidney of the animals of all age groups. The mitotic index (MI) was expressed in promille and determined by counting the number of mitoses in 10,000-12,000 epithelial cells.

The numerical data were subjected to statistical analysis by the Fisher—Student method.

EXPERIMENTAL RESULTS

Unilateral nephrectomy had no significant effect on the weight of the experimental animals. Compensatory hypertrophy of the residual kidney was observed in the rats of all age groups; in the first 10-14 days after the operation it was manifested most clearly in the young rats (body weight 35-50 g), in which IH by the second week could reach 90% (Fig. 2). In the remaining rats by the 14th week after unilateral nephrectomy IH did not exceed 68%, irrespective of the age of the animals undergoing the operation (Fig. 2).

TABLE 1. MI (in °/₀₀) in Epithelial Cells of Proximal Portion of Tubules of Right Kidney in Experimental and Control Rats of Different Ages on Second Day after Beginning of Experiment

Animals	Age group 1 (35—50 g)	2 (90 g)	3 (150—200 g)	4 (150—200 g)	5 (500—600 g)	6 (600—700 g)	7 (700—800 g)	8 (800—900 g)
Experimental	3,0	2,8	1,7	1,3	0,6	1,0	1,1	1,2
Control	1,2	0,7	0,2	0,2	0,1	0,09	0,2	0,1

TABLE 2. Number of "Open" and "Closed" Renal Glomeruli in Kidneys of Experimental and Control Animals of Different Ages 60 days after Beginning of Experiment (in % of total number of glomeruli in one central section)

Animals	State of glomerulus	Age group 1 (35—50 g)	2 (90 g)	3 (150—200 g)	4 (150—200 g)	5 (500—600 g)	6 (600—700 g)	7 (700—800 g)	8 (800—900 g)
Experimental	Open	80	78	77	78	58	61	73	72
	Closed	20	22	23	22	42	39	27	28
Control	Open	32	32	39	39	48	41	41	38
	Closed	68	68	61	61	52	59	57	62

In most rats of whatever age group IH reached its highest values on the 30th day after unilateral nephrectomy (62-103%). Old rats weighing 500-600 g, in which IH of the kidney did not rise above 58% at any time of the investigation, were the exception. It is interesting to note that in the even older rats (body weight 700-800 g) IH of the kidney by the 30th day after the operation was considerably higher (80-93%). By the 60th day after unilateral nephrectomy IH of the kidney in these animals still remained just as high.

IH of the rat kidney thus varies considerably depending both on the time elapsing after removal of the contralateral kidney and on the age of the animals.

Determination of MI of the epithelium of the convoluted tubules showed that in rats of all age groups the epithelial cells of the proximal part of the tubules divided most intensively. MI in the hypertrophied kidney showed a considerable increase, but it was relatively lower in the old than in the young animals. Meanwhile, in the old animals undergoing unilateral nephrectomy MI in the hypertrophied kidney could be as much as 5-10 times higher than MI for cells of the proximal tubules of the intact kidney, whereas in the young rats it was 2-3 times higher (Table 1).

During the course of compensatory hypertrophy of the kidney the renal corpuscles increase in size. This increase is due to hyperplasia and hypertrophy of the cells of the outer and inner layers of Bowman's capsule, and also to the considerable functional strain placed on the capillary network of the glomerulus. Measurement of the area of individual glomeruli in the hypertrophied kidney of rats of different ages showed that the area of the glomeruli in the experimental series was always greater than in the control. This was characteristic of rats of all ages and was observed at all times of the investigation. Meanwhile, whereas the glomeruli in the young rats increased in size slowly, from one time of investigation to another, in the adult and, in particular, the old rats, this process took place more rapidly and by a far greater degree (Fig. 3). For example, whereas in the young rats the differences between the area of the glomerulus in the experimental and control

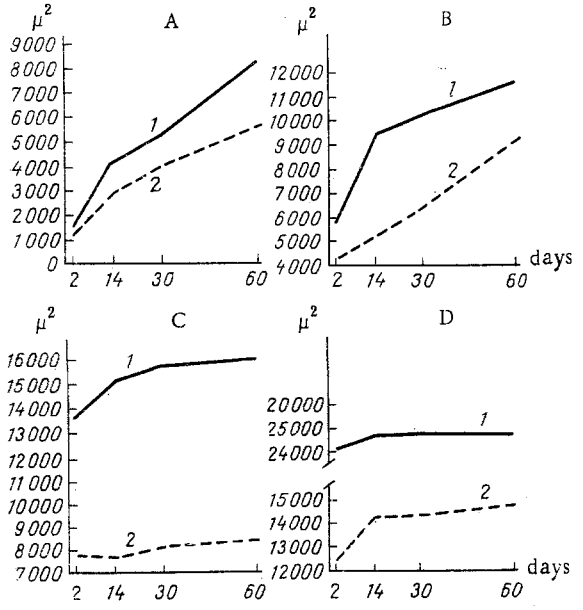

Fig. 3. Area of renal corpuscles in rats of different ages with compensatory hypertrophy of the kidney: A) young rats, body weight 35-50 g; B) sexually mature rats, body weight 150-200 g; C) old rats, body weight 600 g; D) old rats, body weight 900 g. 1) Experiment, 2) control. Ordinate, area of renal corpuscle (in μ^2); abscissa, time after operation (days).

series became statistically significant ($P = 0.001$) only on the 14th day after the beginning of the experiment, in the old rats (body weight 600-900 g) as early as 2 days after the operation the renal glomeruli in the experimental series were 1.5-2 times larger in size than in the control. This indicates the greater reactivity of the old kidney and its considerable powers of compensation and adaptation, a conclusion also confirmed by the results of counting the number of "open" and "closed" renal glomeruli in the hypertrophied kidney of rats of different ages 60 days after the operation. Intensively functioning "open" glomeruli with a maximally dilated capillary network were always more numerous (about 1.5-2 times) in the kidney undergoing hypertrophy than in the intact kidney. In the old animals these ratios between experiment and control remained the same as in the young animals (Table 2). The only exception here was the rats of group 5, in which the number of "open" glomeruli in the experimental series did not differ significantly from their number in the control.

Finally it must be pointed out that the frequency of appearance of various types of pathological changes in the kidney increased both under normal conditions and in hypertrophy (hyalinosis of the capsule of individual renal corpuscles, sclerosis of the walls of the capillary network of the glomerulus, deposition of casts in the tubules). In the hypertrophied kidney these changes were observed more frequently, especially in old animals, but by no means invariably (in 2–4 of 10 experimental rats). Pathological changes accompanying hypertrophy of the kidney in old age have also been described by clinicians [5].

The general conclusion can be drawn from the results as a whole that the rat kidney is capable of compensatory hypertrophy at any age. However, the degree of hypertrophy may vary considerably at different age periods, although no tendency was found for it to diminish in old age. The same rule applies also to mitotic activity of the cells of the tubular epithelium, the degree of hypertrophy of individual renal corpuscles, and the character of functional loading of the capillary glomeruli. An increase in the number of "open" renal glomeruli in the hypertrophied kidney of rats at all ages must be regarded as a distinctive adaptive response of the solitary kidney aimed at increasing the scale of filtration in the organ.

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EFFECT OF SECRETORY ACTIVITY OF THE SALIVARY GLANDS ON MORPHOLOGY AND FUNCTION OF THE PANCREATIC ISLETS

I. V. Sukhodolo, N. M. Tikhonova, and V. D. Sukhodolo

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Chronic experiments on dogs showed that the loss of saliva by the animals through exteriorized ducts of the parotid, submandibular, and sublingual salivary glands causes morphohistochemical changes in the pancreatic islets indicative of reduced functional activity of the β cells.

KEY WORDS: *Salivary glands; islets of Langerhans; β cells of islets.*

The endocrine function of the salivary glands has for a long time attracted the attention of investigators [9, 13, 14]. One aspect of its influence on the body is its role in the regulation of carbohydrate metabolism [1, 2, 10]. It recently became known that not only the endocrine but also the exocrine activity of the salivary glands influences the state of homeostasis [4, 5]. The writers showed previously that loss of saliva by animals through ducts of the salivary glands exteriorized by Glinskii's method and through esophageal fistulas constructed from metal T-tubes is accompanied by lowering of the organism's tolerance to exogenous glucose and by the appearance of a negative Staub–Traugott effect after administration of a second dose of sugar [6].

In the investigation described below the effect of removal of the products of secretory activity of the parotid, submandibular, and sublingual salivary glands on the morphology and functional state of the islet–cell system of the pancreas was studied.

EXPERIMENTAL METHOD

In experiments on 22 male dogs weighing from 8 to 12 kg the ducts of the parotid, submandibular, and sublingual salivary glands were exteriorized by Glinskii's method so that their saliva was lost. The animals were divided into three groups with five dogs in each group: I) dogs losing saliva for 1 month (from the day of operation), II) for 3 months,

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