CHARACTER AND FREQUENCY OF PATHOLOGICAL CHANGES IN THE SOLITARY RAT KIDNEY AFTER REMOVAL OF THE OTHER KIDNEY IN OLD AGE

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One kidney was removed from male rats weighing 500-850 g; the remaining kidney underwent compensatory hypertrophy and, after 1-2 months, it was larger (index of hypertrophy 70-92%) in rats weighing 700-850 g than in animals weighing 500-600 g (56-58%). Histological investigation showed that this marked hypertrophy of the solitary kidney in old rats was not the result of disease of the organ, for pathological changes such as are sometimes found in intact and hypertrophied kidneys were found in only 38 of 223 animals. The results suggest that the ability of the kidneys to undergo compensation and regeneration is not reduced in old age.

KEY WORDS: *solitary kidney; pathological changes; old age.*

The view has long been held that the ability of the internal organs of mammals to regenerate diminishes with age. Recently, however, it has been shown that it is the rate of regeneration that is reduced in old age by a greater degree than ability to recover from disturbances arising in the body [4, 7].

A previous investigation [5] showed that ability of the kidney to undergo compensatory hypertrophy after unilateral nephrectomy in old rats is not only not reduced compared with its ability in younger animals but, on the contrary, it is increased. This has been supported by data in the literature [12]. However, the possibility cannot be ruled out that the increase in weight of the solitary kidney after removal of the opposite organ in old age may be due to pathological changes accompanying hypertrophy of the kidney [2, 12].

In this investigation the frequency and character of the pathological changes in the senile kidney were studied in the course of its hypertrophy following nephrectomy of the contralateral kidney.

EXPERIMENTAL METHOD

Male rats were divided by weight into four age groups. Group 1 contained animals weighing 500-600 g; group 2, 600-700 g; group 3, 700-800 g; and group 4, 800-850 g. One kidney was removed from 8-10 rats of each age group and the remaining 6-10 rats were left intact as the control. The experimental rats and intact rats of the corresponding age were killed 48 h and 14, 30, and 60 days after the beginning of the experiment. The kidneys were removed, weighed, and then fixed in Carnoy's fluid. The index of hypertrophy of the remaining kidney in the unilaterally nephrectomized rats was expressed as a percentage; the weight of both kidneys in the control animal was taken as 100%. The character of the pathological changes in the parenchyma of the kidney was determined in sections and the number of renal corpuscles dying as a result of age or pathological changes was counted.

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TABLE 1. Number of Pathologically Changed Kidneys and Character of Pathology Discovered in Hypertrophied and Intact Kidneys at Various Times after Removal of Contralateral Kidney in Rats

Series	Time of observation	Age group 1: all kidneys	I	II	III	IV	Age group 2: all kidneys	I	II	III	IV	Age group 3: all kidneys	I	II	III	IV	Age group 4: all kidneys	I	II	III	IV
Experimental (hypertrophied kidneys)	48 h	8	—	—	—	2—3	6	—	—	—	5—6	6	1	1	1	8—10	6	1	—	—	18—25
	14 days	6	—	—	—	4—5	7	1	—	—	7—9	6	2	—	—	12—26	6	1	—	—	16—30
	30 »	8	—	—	2	8—10	6	—	1	—	10—15	7	2	—	1	23—35	6	1	1	—	27—40
	60 »	9	—	1	2	8—6	9	—	1	1	17—20	6	1	—	—	16—25	6	1	1	—	20—42
Control (intact kidneys)	48 h	6	—	—	—	5—6	6	—	—	—	5—6	6	—	—	—	13—17	6	3	—	—	17—23
	14 days	6	—	—	—	3—4	6	2	—	—	3—10	6	2	—	—	9—12	6	2	—	—	18—23
	30 »	6	—	—	—	10—12	6	—	—	—	9—12	6	4	—	1	12—19	6	—	—	—	12—18
	60 »	6	—	—	—	4—6	6	—	—	—	16—23	6	2	—	—	10—14	6	—	—	1	13—24

Legend. I) Interstitial nephritis; II) atypical renal corpuscles; III) casts in distal tubules; IV) number of dying glomeruli per transverse midline section (in 130-170 renal corpuscles).

EXPERIMENTAL RESULTS

After removal of one kidney the remaining kidney underwent compensatory hypertrophy, which in the old rats became particularly marked 2-4 weeks after the operation. In the old rats processes of compensation and regeneration in the kidneys develop more slowly than in young rats, although their mechanism is similar [5]. Even within the old age group, the degree and rate of hypertrophy of the kidney could vary. For instance, the graph in Fig. 1 shows that compensatory hypertrophy of the residual kidney in old rats (age groups 3 and 4) was much more marked from the very beginning of the observations than in the animals of the other two age groups (1 and 2).

Histological analysis revealed only a few pathologically changed kidneys in the control and experimental animals. As a rule, of six to nine kidneys studied in each series only one to three showed changes. Most of the pathological changes observed were too mild in character to be reflected in the degree of increase in weight of the kidneys. It could thus be concluded that in every case true hypertrophy of the organ was present. Of the pathological changes and structural abnormalities of the kidney discovered four types could be distinguished, and these types were represented differently in the kidneys of the experimental and control rats of the different age groups (Table 1).

Interstitial nephritis was the most frequent form of kidney disease observed in the old rats of both the experimental and control series. This pathology of the kidneys was particularly characteristic of animals of groups 3 and 4 (weighing 700-850 g). In this form of nephritis small foci of inflammation were located in the stroma of the renal cortex around the glomeruli, tubules, or large vessels. As a rule the number of these foci was small (not more than 14 per section). As Table 1 shows, the number of affected kidneys was similar in the experimental and control groups. For instance (as the total for all periods of investigation) in group 3, of 25 hypertrophied kidneys, this type of nephritis was found in six (24%). Of the 24 control kidneys in this same group eight were affected (33%). In group 4, of the

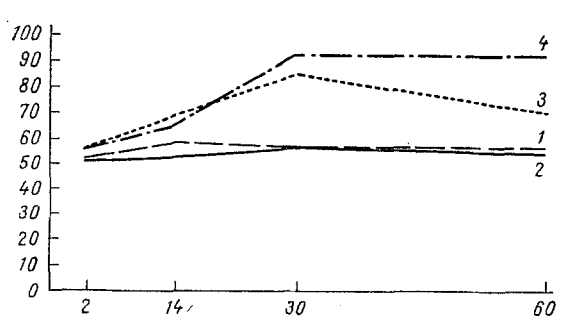

Fig. 1. Degree of hypertrophy of solitary kidney in old rats at different times of observation. 1-4) Group of rats; abscissa, days after unilateral nephrectomy; ordinate, index of hypertrophy, %.

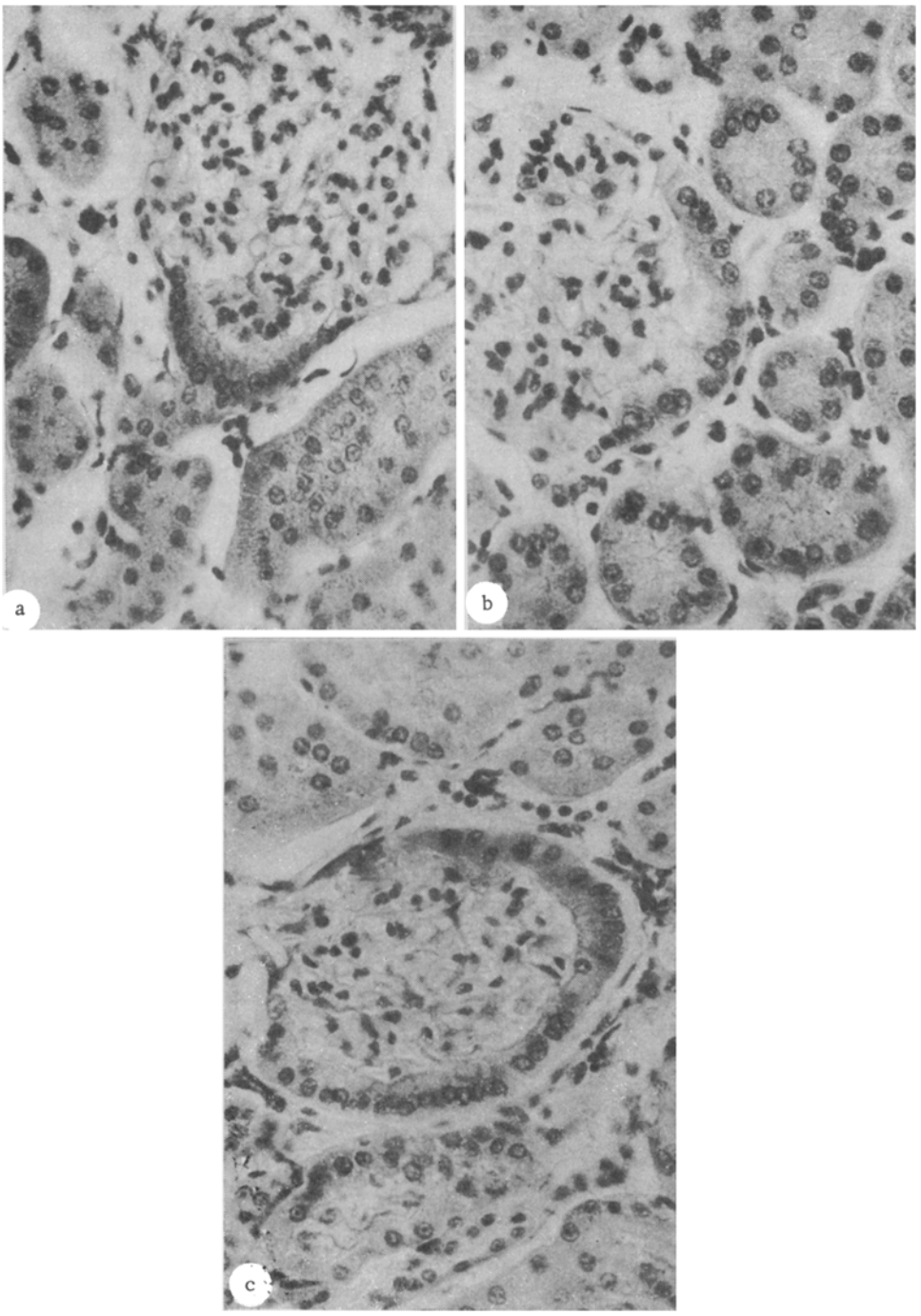

Fig. 2. Atypical renal corpuscles: a-c) successive stages of complete replacement of degenerating squamous epithelium of outer layer of Bowman's capsule by cubical epithelium, similar in structure to tubular epithelium. Hematoxylin–eosin, 500 ×.

24 hypertrophied kidneys studied there were only four (16%) with interstitial nephritis, whereas among the intact kidneys there were five (20%). In the younger rats (groups 1 and 2) interstitial nephritis was observed much less frequently in both the experimental and control animals (in only 2-3% of rats).

Atypical renal corpuscles were found infrequently in the kidneys of the experimental animals of all age groups. For instance, of 110 hypertrophied kidneys studied in all age groups only six (5.4%) showed signs of an abnormal structure of Bowman's capsule. This anomaly was not found in the control kidneys. Details of it are as follows. In the old rats

areas of cubical epithelium, replacing the ordinary squamous epithelium characteristic of the normal kidney, appeared in the renal glomerulus or, more precisely, in the outer layer of Bowman's capsule (on the side of the lumen of the capsule). These bands of epithelium resembled the "half-moons" which sometimes appear in individual glomeruli in productive extracapillary glomerulonephritis [3, 6, 11]. The impression was created by examination of a series of specimens in which in the cases observed the capsule was invaded by cubical epithelium from the proximal portion of the tubules, virtually replacing the degenerating squamous epithelium of the capsule wall. Often all stages of this "overgrowth" of the outer layer of the capsule on the side of the lumen by tubular epithelium until its edges had completely joined could be seen in the same section (Fig. 2a-c). The submicroscopic and histochemical features of the cubical epithelium of the "half-moons" in fact resemble those of the tubular epithelium [9, 10]. It is interesting to note that mitoses were frequently found in the tubules of these modified nephrons, i.e., new cells were formed to replace those departing to "overgrow" the walls of the capsule. The "overgrowth" of the capsule of the glomerulus by tubular epithelium (during hypertrophy of the kidney in old rats) can be interpreted as an example of unique recapitulation [1], for during the development of the secondary kidney in phylogeny the epithelium of the capsule is known to be analogous initially in its morphological features with the epithelium of the proximal portion of the tubule, of which it is a derivative.

Renal casts were found more often in the presence of glomerulonephritis. They were found only in single nephrons. Casts were found most frequently in hypertrophied and normal kidneys of rats weighing 700-850 g. The number of kidneys in the tubules of which casts were found was small, only 10 of 223 (0.4% of the total number of kidneys examined in the experimental and control animals). These changes were found a little more frequently in the experimental group than in the control: in 7 of 118 rats (6%) and in 3 of 96 rats (3%) respectively.

Dying renal corpuscles are always found in the adult, aging mammalian and human kidney [8]. Counting their number per transverse midline section in these experiments showed that, for example, in group 4, 18-42 of the 130-170 normal renal corpuscles in the experimental group were degenerating, compared with 17-24 in the control. The effect of age was seen by the fact that in the hypertrophied kidneys of rats weighing 500 g the proportion of dying corpuscles was 0.1-1.3%, whereas in the same kidneys of animals weighing 800 g the corresponding proportion was 10-20% of the total number of corpuscles per section.

We have emphasized the character of the pathological changes and their frequency in kidneys undergoing compensatory hypertrophy and in the intact kidneys in order to stress that these changes can always be found in old age whether in the normal kidney or after its compensatory growth. However, as the quantitative analysis showed, pathological changes were not found so frequently, nor were they evidently the cause of such a considerable increase in weight of the solitary kidney in old animals after unilateral nephrectomy.

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