

THE EFFECT OF UNILATERAL NEPHRECTOMY ON THE
TOTAL NUMBER OF OPEN GLOMERULI
IN THE RABBIT

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PLATES 10 AND 11

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Karsner, Bunker and Grabfield (1) and others have demonstrated that removal of one-half the kidney substance in the dog results in a transient renal insufficiency with complete recovery in 1 to 2 days. It is apparent that the opposite kidney compensates for the loss. The majority of the published papers summarized by Hinman (2), deal with blood and urine findings and late hypertrophic changes. So far as we are aware, there is no work to explain the immediate compensation occurring after unilateral nephrectomy.

Through the work of Richards and his collaborators (3) the conception of periodic functioning of glomeruli has been placed on a firm foundation. Hayman and Starr (4) have demonstrated that in general, kidney volume, renal blood flow and urine elimination vary in direct proportion to the total number of open glomeruli.

Method

The technique of Hayman and Starr (4) with some modifications was followed. Rabbits were used throughout. As indicated in the protocols ether anesthesia was employed in some, and in others section of the lumbar spine by the technique of Ecker (5).

In control animals the lower abdomen was opened, the intestines wrapped in a warm towel, the aorta isolated and clamped at the bifurcation and just below the renal vessels, a long slender glass cannula introduced into the aorta between the clamps, the upper clamp removed and the cannula inserted so its tip was at the level of the diaphragm. The outside diameter of the cannula was approximately

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one half of the internal diameter of the aorta. With the cannula in position, the superior mesenteric artery and coeliac axis were clamped and 0.75 cc. of 3 per cent solution of Janus Green B (Coleman and Bell) in 0.9 per cent NaCl solution injected under moderate pressure. The time elapsed during the injection averaged 5 seconds. Within 10 seconds the left renal artery was ligated and the animal killed by a blow on the head or by ether. In some cases the left renal circulation was irrigated with saline and filled with 5 per cent ammonium molybdate. In others the left kidney was removed, cut in thin slices and placed in the molybdate solution. After death of the animal the right kidney was injected by the method of Nelson (6).

In experimental animals, the right kidney with as long a pedicle as possible was removed through a lumbar incision. It was then injected supravitaly with Janus Green for a determination of the total number of glomeruli. After a variable period, the left kidney was stained intravitaly by the procedure outlined above for control animals.

In the animals on which a sham operation was performed, the kidney region was exposed by lumbar incision, the kidney freed from its bed, the pedicle exposed, the whole replaced and in some cases a suspension suture placed in the capsule. After variable periods these animals were subjected to the same procedure of intravital staining as the control and experimental group.

The whole procedure may be summed up as follows: One kidney is injected supravitaly to determine the total number of glomeruli in one kidney of this animal; the opposite kidney is injected intravitaly for a determination of the number of glomeruli which are in active circulation during a period of 5 seconds under certain experimental conditions: and division of the latter by the former gives the percentage of open g.-----

The counts were made after the general technique of Vimtrup (7). The cortex and medulla are separated and the weight of the entire cortex secured. From the cortex, 6 to 10 small samples are removed, pooled and accurately weighed. The total weight of these samples varied from one-tenth to one-sixth of the entire cortex. From the number of glomeruli in these samples of known weight, the total is secured by estimation. In some cases, microscopic sections were also prepared to determine the completeness of injection in supravital injections and to check the percentage injected by the intravital method.

Results

As shown in Table I, in seven adult rabbits, the percentage of open glomeruli varied from 44 per cent to 78 per cent with an average of 63 per cent. In general those in which ether was used as an anesthetic have slightly more than those with fractured spine anesthesia.

After unilateral nephrectomy the percentage was increased to 91 to 99 per cent with an average of 95 per cent (Table II). This

increase appeared in less than 24 hours and continued until at least 10 days after nephrectomy.

TABLE I
Normal Controls

Rabbit No.	Supravital		Intravital		Per cent open	Anesthetic
	Kidney No.	Count	Kidney No.	Count		
1	45	179,767	46	79,640	44	Section spine
2	51	185,769	50	101,193	54	Section spine
3	69	158,400	70	124,410	78	Ether
4	71	147,734	72	110,670	74	Section spine
5	76	152,238	75	100,702	67	Section spine
6	78	138,406	77	92,386	67	Section spine
7	80	149,134	79	98,210	66	Section spine
Average.....					63.5	

TABLE II
Experimental

Rabbit No.	Supravital		Interval in days after nephrectomy	Intravital		Per cent open
	Kidney No.	Count		Kidney No.	Count	
8	93	102,300	1	98	99,700	97
9	94	132,750	2	99	130,111	98
10	95	170,930	3	100	165,453	92
11	96	135,670	5	101	122,500	90
12	97	181,000	10	102	178,420	98
13*	54	87,350	1	56	80,222	92
14*	55	111,508	2	58	101,538	91
15	61	172,331	3	63	169,210	98
16*	57	68,620	5	60	67,752	98
17*	62	96,250	10	64	95,499	99
18	126	150,364	1	106	156,217	100
19	127	154,782	2	107	149,167	97

* Young animals, 5 to 7 months of age; remainder over 1 year of age.

The animals subjected to a sham operation (Table III) do not differ markedly from the normal controls. The open glomeruli vary from 51 per cent to 75 per cent with an average of 64 per cent.

DISCUSSION

There are certain points in the technique which need further comment, in order to validate the results.

Janus Green B is known to be a powerful vaso-constrictor and it is possible that it might cause such constriction that the results are not those present in life. Hayman and Starr (4) used India ink and obtained the same figures. Further, their results with salt and with caffeine, as well as the results here described following unilateral nephrectomy, prove that 90 to 100 per cent may be open with the same experimental technique.

TABLE III
Sham Operation

Rabbit No.	Supravital		Interval in days after operation	Intravital		Per cent open
	Kidney No.	Count		Kidney No.	Count	
23	118	161,208	1	119	82,344	51
24	104	150,100	1	103	102,614	68
25	120	158,316	2	121	93,562	59
26	122	122,488	5	123	86,920	71
27	124	135,728	10	125	100,786	75
Average.....						64

The percentage figures depend on the assumption that the two kidneys of any one animal each contain approximately the same number of glomeruli. In addition to the proof offered by Haymann and Starr we add the results in two rabbits.

<i>Rabbit No.</i>	<i>Left</i>	<i>Right</i>
30	145,200	152,328
31	165,160	160,209

We also have unpublished observations that this is true in man and rats. The variation is rarely over 5 per cent. Further proof is adduced by the agreement between the counting method and the study of sections with determination of the relative number stained.

The accuracy of the weight estimation method for determination of the total number of glomeruli may be open to some doubt. We be-

lieve it to be accurate to within 10 per cent. Vimtrup (7) has offered evidence to support this view. Work soon to be published from this laboratory on the total number of glomeruli in the kidney of man and animals will further support the accuracy of the method.

The distribution of the dye in intravitaly stained normal kidneys is peculiar. Never are the stained glomeruli distributed evenly throughout the cortex. As noted by Hayman and Starr, often the peripheral glomeruli are not stained while the more central are all stained. In other cases there are small to large areas corresponding to the distribution of an interlobular or interlobar artery in which very few glomeruli are stained. In selecting the specimens for counting, such areas must be taken into consideration and a proportionate amount of them contributed to the pooled specimen.

Richards and Schmidt (3) have noted that an increase in the number of open glomeruli is associated with an increase in the number of open loops of any one glomerulus. In general, we have found this to be true (compare Fig. 3 and Fig. 4). In the active kidney, more glomerular loops are stained and those that are stained are more definite and larger.

The results themselves are unequivocal and need little discussion. The results on the sham operation animals prove that the operation itself is not the cause of the increase. Experiments are under way to contribute evidence on the cause of the increase.

SUMMARY

1. Under the experimental conditions employed, from 44 to 78 per cent of the glomeruli of the normal rabbit kidney contain circulating blood at any one moment.
2. After unilateral nephrectomy the number of glomeruli in the remaining kidney, which contain circulating blood, is increased to 91 to 99 per cent.
3. Compensation for the removal of one kidney is accomplished during the first 10 days at least, by an increase of the number of open glomeruli in the opposite kidney.

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EXPLANATION OF PLATES

PLATE 10

FIG. 1. A teased preparation of cortex injected by Janus Green B, to show the definition of the glomeruli. Such preparations are used in counting. $\times 8.5$.

FIG. 2. Section of kidney supravivally stained. $\times 110$.

PLATE 11

FIG. 3. Section of normal kidney intravivally stained with Janus Green B. Note the unstained and partially stained glomeruli. Compare with Fig. 4. $\times 90$.

FIG. 4. Section of kidney from animal after unilateral nephrectomy intravivally stained with Janus Green B. Note the absence of unstained glomeruli and the more complete staining of the glomerular loops. Compare with Fig. 3. $\times 90$.

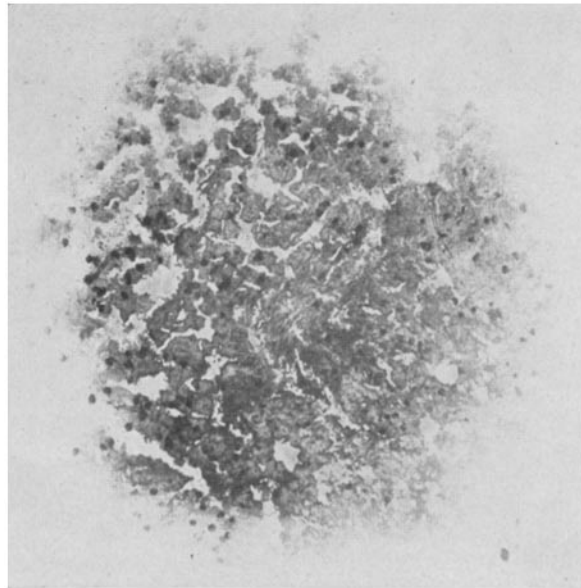


FIG. 1

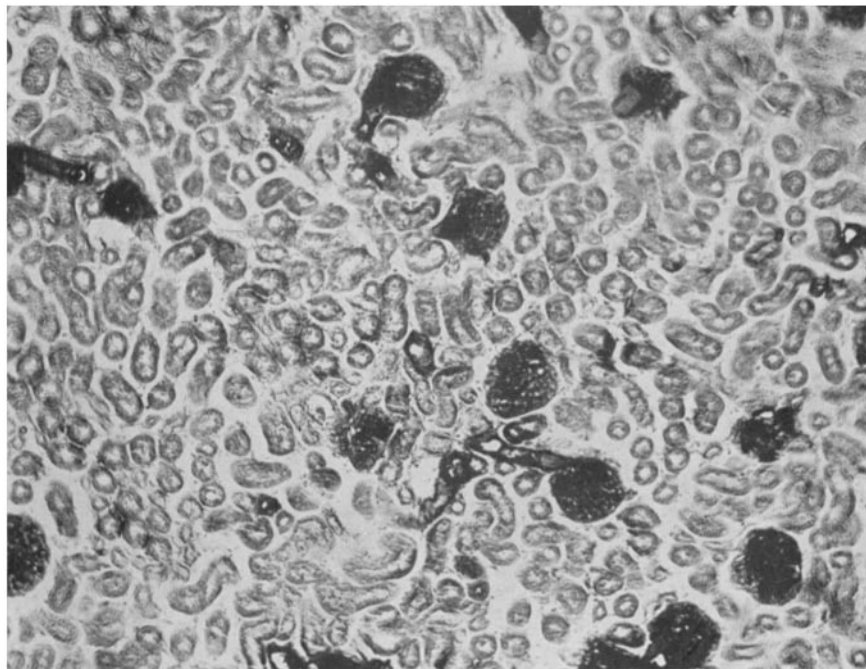


FIG. 2

(Moore and Lukianoff: Unilateral nephrectomy in the rabbit)

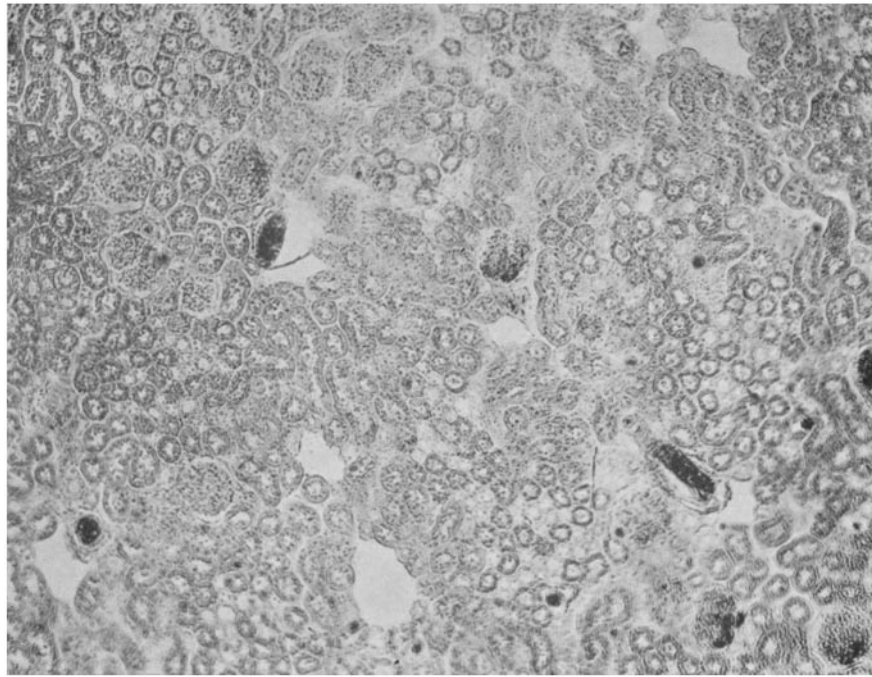


FIG. 3

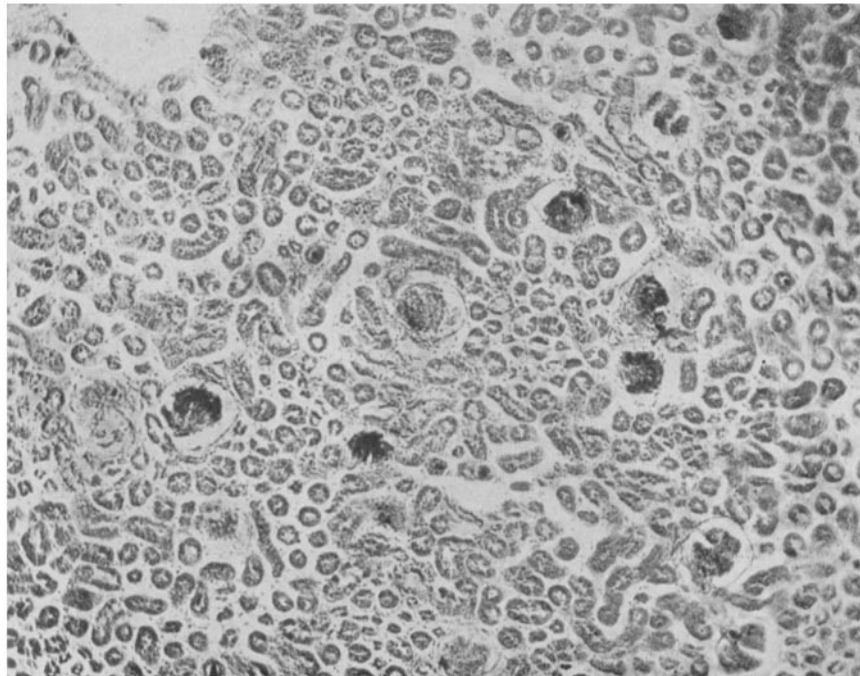


FIG. 4

(Moore and Lukianoff: Unilateral nephrectomy in the rabbit)