FACTORS WHICH DETERMINE RENAL WEIGHT*

**XI. RENAL FUNCTION

By EATON M. MacKAY, M.D., AND BURRELL O. RAULSTON, M.D.

(From the Department of Medicine, Stanford University Medical School,
San Francisco)

(Received for publication, October 3, 1930)

There are certain special conditions under which the rate of urea excretion is primarily controlled only by the concentration of urea in the blood (1) and the amount of functioning renal tissue (2). Under these conditions the rate of urea excretion is directly proportional to the blood urea concentration so that the ratio:

$$\frac{\text{urine urea rate}}{\text{blood urea concentration}}$$

in a given subject remains approximately constant (3). The order of magnitude of this ratio is regulated directly by the size of the kidneys and hence becomes a measure of the amount of functioning renal tissue (4). In the rabbit it has been demonstrated (2) that the ratio is directly proportional to the weight of renal tissue. It is probable that there is a similar relationship in man for in normal individuals the ratio is directly proportional to body surface (5, 6) and in so far as one may judge from the figures given by Vierordt (7) the weight of the kidneys seems to be dependent on the body surface. In the present series of studies of the factors which determine the weight of the kidneys in the albino rat the constant use of the gross anatomical weight of these organs made it desirable to determine what relation this measure of size bears to function in the normal animal.

The small size of the experimental subject precluded the repetition

* This investigation was made possible by the Edward N. Gibbs Prize Fund of the New York Academy of Medicine.

** Earlier papers of this series have appeared in *The American Journal of Physiology* and *The Journal of Nutrition*.

of ratio measurements upon a single individual and gave reason to expect highly variable results. It was therefore desirable to use a

TABLE I

No.	Age	Body weight	Body surface	*Kidney weight	Dry kidney weight	Urine urea rate	Blood urea conc.	Ratio: urine rate blood conc.	Ratio per 1000 mg. kidney
	<i>days</i>	<i>gm.</i>	<i>sq. cm.</i>	<i>mg.</i>	<i>mg.</i>	<i>mg./hr.</i>	<i>mg. %</i>		
1	390	380	600	2601	504	57	123	0.465	0.179
2	390	370	590	1966	449	33	129	0.255	0.130
3	390	330	545	2132	512	40	97	0.409	0.192
4	350	322	535	1757	405	43	115	0.370	0.210
5	350	360	575	1900	444	40	120	0.337	0.178
6	350	380	600	2300	501	55	113	0.488	0.212
7	300	380	600	2086	500	45	113	0.393	0.189
8	300	350	565	1919	458	45	122	0.365	0.190
9	300	340	555	1808	415	45	125	0.359	0.198
10	253	340	555	2200	555	55	144	0.384	0.175
11	253	325	537	1911	474	38	132	0.289	0.151
12	253	340	555	1710	442	35	135	0.259	0.152
13	174	300	510	1714	461	42	114	0.368	0.214
14	174	270	475	1788	422	41	142	0.290	0.162
15	174	320	530	2440	500	49	81	0.606	0.248
16	135	290	500	1787	446	40	121	0.328	0.184
17	135	260	463	1507	391	38	114	0.333	0.221
18	135	300	510	1739	460	48	129	0.373	0.214
19	106	200	390	1221	323	41	117	0.350	0.286
20	106	210	400	1263	328	44	199	0.223	0.177
21	106	190	380	1250	309	38	144	0.264	0.211
22	74	150	320	1035	270	39	149	0.263	0.254
23	74	160	335	1173	293	17	112	0.152	0.129
24	74	160	335	1177	294	22	71	0.312	0.264
25	56	140	310	1191	299	31	142	0.222	0.185
26	56	140	310	1122	287	38	128	0.299	0.266
27	56	150	320	1124	298	23	100	0.232	0.207
28	42	106	255	942	196	27	180	0.152	0.162
29	42	112	265	893	195	33	128	0.258	0.288
30	42	112	265	902	195	21	81	0.253	0.281
31	32	66	190	632	134	15	152	0.099	0.157
32	32	64	188	601	120	12	208	0.059	0.098
33	32	56	170	542	234	20	220	0.090	0.166

* Weight of both kidneys.

considerable number of rats of widely varying size. Thirty-three male albino rats varying in weight from 56 to 380 gm. were used.

The special conditions under which the rate of urea excretion is directly proportional to the blood urea concentration are essentially abstinence from food (8), an increased blood urea concentration and a copious diuresis. In man the latter are easily attained by having the subject drink urea solutions and water and in the rabbit these

FIG. 1

fluids may be administered by stomach tube. This is practical only with very large rats and so the same conditions were brought about by the intraperitoneal injection of urea solutions.

A single ratio measurement was made on each rat. The body surface was calculated by the formula derived by Carman and Mitchell (Carman, G. G., and Mitchell, H. H., *Am. Jour. Physiol.*, 1926, **76**, 380). After abstinence from

food for 18 hours 30 cc. per 1000 sq. cm. of body surface of an aqueous solution containing 2.5 per cent urea and 0.7 per cent sodium chloride were injected intraperitoneally. 3 hours later the bladder was emptied by pressure over the abdomen and the administration of a few whiffs of ether (9) and 15 cc. per 1000 sq. cm. body surface of an 0.8 per cent sodium chloride solution given intraperitoneally. 90 minutes later, at the middle of a 3 hour period of urine collection, a specimen of blood was taken by heart puncture with a very small hypodermic needle. The blood specimens which were drawn were from 0.5 to 2.0 cc. depending on the size of the animal. 3 hours after the urine collection was commenced the bladder was emptied again and this specimen added to the urine and washings from the collection cage. The urea in the urine and blood was determined by the urease and aeration method and the ratio:

$$\frac{\text{urea excretion per hour}}{\text{urea in 100 cc. of blood}}$$

was calculated. Some hours later the animals were killed and the kidneys at once removed and weighed (10). They were then dried at 120°C. to constant weight. We hesitate to attach much importance to these dry weights because of the inherent difficulties in completely drying any tissue without loss.

The weights of the kidneys are compared with the ratios in Table I and all of the observations are charted in Fig. 1. These results indicate that in the albino rat as in the rabbit there is an approximately direct relation between the magnitude of the ratio:

$$\frac{\text{urine urea rate}}{\text{blood urea concentration}}$$

and the weight of the kidneys. It is very probable that a better agreement would have been found had it been possible to make repeated measurements upon each individual and had the blood specimens been more adequate in volume. However, considering these unavoidable circumstances there is a remarkable constancy in the kidney weight:ratio relationship. As might be expected the variability is higher than in the case of the rabbit. The mean ratio for each gram of renal tissue is 0.198 while the average found for the rabbit was 0.176, an agreement which is as good as might be expected. That the ratio would bear a more constant relation to body surface than to other measures of body size in the rat as in the rabbit (2) and man (5, 6) would follow from the constant relation which renal weight has been shown (11) to bear to body surface in the rat.

SUMMARY

The amount of functioning renal tissue as measured by the weight of the kidneys in the albino rat is directly proportional to the renal function as measured by the ratio:

$$\frac{\text{urine urea rate}}{\text{blood urea concentration}}$$

under certain special conditions.

REFERENCES

1. Addis, T., and Watanabe, C. K., *Jour. Biol. Chem.*, 1917, 29, 391.
2. Taylor, F. B., Drury, D. R., and Addis, T., *Am. Jour. Physiol.*, 1923, 65, 55.
3. Addis, T., and Drury, D. R., *Jour. Biol. Chem.*, 1923, 55, 105.
4. Addis, T., *Arch. Int. Med.*, 1922, 30, 378.
5. Addis, T., *Am. Jour. Med. Sci.*, 1923, 176, 617.
6. McIntosh, J. F., Möller, E., and Van Slyke, D. D., *Jour. Clin. Invest.*, 1928, 6, 467.
7. Vierordt, H., *Anatomische Physiologische und Physikalische Daten und Tabellen*, Jena, 1906, 3rd Aufl., 36.
8. Addis, T., and Drury, D. R., *Jour. Biol. Chem.*, 1923, 55, 629.
9. Addis, T., MacKay, E. M., and MacKay, L. L., *Jour. Biol. Chem.*, 1926, 71, 139.
10. MacKay, L. L., and MacKay, E. M., *Am. Jour. Physiol.*, 1927, 83, 179.
11. MacKay, L. L., and MacKay, E. M., *Am. Jour. Physiol.*, 1927, 83, 191.