DISTRIBUTION OF BLOOD IN THE FUNCTIONAL KIDNEY*

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Plates 1 and 2

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It has long been known that the kidney, in its functioning state, is distended with blood (1–4). Rose-Bradford (1) stressed the "passive" character of this distension, for he noted that the kidney swelled when the blood pressure rose and shrank when it fell. Text-fig. 1 shows how the organ collapses when its circulation is abruptly cut off; in this instance, although drainage was obviously incomplete, it shrank from a volume of 49 cc. to a volume of 39 cc., showing that at least 20 per cent of its normal functioning volume was distending fluid. This fluid drains from the renal vein when the renal artery is occluded; in quantity, when drainage is complete, it averages 26 per cent of the functionally distended kidney (5, 6).

This aspect of renal behavior has, however, been overlooked by those investigating the functional vascular morphology of the organ. Led recently by Trueta *et al.* (7), many studies of blood distribution have been attempted, using particularly the technic of injecting India ink into the vascular system and then, at necropsy, examining the distribution of ink. In such studies, the distribution of ink at necropsy should reflect the distribution while the organ is functioning. But if the kidney's blood were to drain out after removal, the subsequent localization of the dye would give only very rough information about the distribution of blood in the functioning organ. The latter is not thoroughly known and hence the present study was undertaken.

Actually, the fluid naturally distending the kidney is not blood alone; rather, it is a fluid containing less red cells and less plasma protein than simultaneously drawn blood, the same amount of Na and Ca, and increased quantities of K, Cl, urea, and PO_4 (6). Because kidney interstitial fluid (or lymph) has approximately this same composition, we have concluded that the distending fluid is very probably a mixture of blood and interstitial fluid. Furthermore, since the distending fluid contains only about half the red cells that blood contains (6), the volume of its two components, in terms of percentage of the functionally distended kidney, is 13 per cent blood and 13 per cent interstitial fluid.

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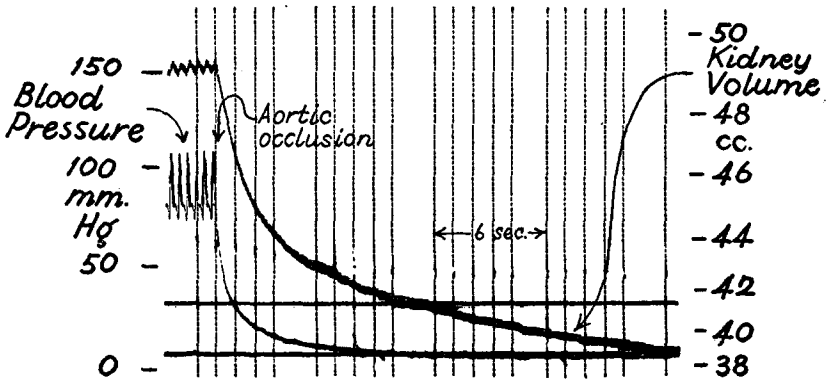
The problem of functional blood distribution also has some bearing on the measurement of "intrarenal pressure." In taking it, a syringe needle is thrust into the renal parenchyma and then, with special precautions, the pressure at its tip ascertained (8). It was known that the needle lacerates many tissues and so it was suggested that the pressure at its tip is the pressure in a pool of fluid from the torn tissues. Hence it was of interest to visualize the morphology of the renal vasculature in its functional state, in order to find out what blood vessels might be lacerated by the insertion of the needle while taking the measurement.

In this paper, a new technic will be described for measuring the volume of functional blood vessels. The only available description of normal renal blood



TEXT-FIG. 1. Decline in kidney's volume when circulation is arrested. Femoral arterial blood pressure and kidney volume, measured with an oncometer, are shown. Where indicated, the aorta was occluded with a tourniquet above the renal arteries. The kidney shrank rapidly in volume at first, then more slowly.

distribution is that of Heggie (9). He states that in the rabbit, the total renal blood is 0.6–0.7 ml. per 6 to 7 gm. kidney, or approximately 10 to 13 per cent of its weight. He thinks that 70 to 80 per cent of this blood is in the venous system, 6.7 per cent in the glomerular tufts, and the balance evenly divided between arterial system and peritubular rete. Heggie did not present details about his methods or measurements in his summarizing report.

Methods

To measure the quantity and distribution of blood in the renal vascular bed, casts were made of the separate parts of the bed and then the volumes of the casts were measured. Following Lieb (10), the casts were made of latex rubber;[1] the fluid rubber was run into the

[1] The latex rubber was obtained from the Polson Rubber Co., Garrettsville, Ohio. Its specific gravity is 0.950; its dry rubber content is about 60 per cent. Its viscosity at 37° is 32

kidneys at physiologic pressures. Then the kidney was fixed in dilute acid to harden the rubber. After this, all the renal tissue was dissolved away in hot HCl, leaving the casts intact for measurement.

In the course of this study, we have been constantly troubled with the difficulty of obtaining physiologic conditions under which to make the casts. In previous work with preparations like these, even the most elementary precautions have not been taken to maintain the organ normal. Thus, Duff and More (11) perfused kidneys with tap water for 12 to 15 hours before injecting the liquid latex, and Trueta and his colleagues (7) injected liquid latex into the renal veins at pressures of 50 to 250 mm. Hg. Perfusing a vascular system with tap water can hardly leave it in a normal condition, and pressures of, say, 100 mm. Hg on a venous system would probably distend it grossly. We have attempted to avoid such obvious distortions of the organ's natural state. But even so, as will be brought out in the discussion, our methods are by no means free of manifest faults.

The injections were made into dog kidneys just removed from the living body. Under pentobarbital anesthesia, the kidney was exposed by a flank approach, the dog having been suspended in the standing position to permit good visualization of the organ. All collateral circulation to and from the renal capsule was prevented by tying off all vessels except the main renal artery and vein. In all animals, the ureter was cannulated to make sure that the kidney was functional. Then the artery and vein were clamped simultaneously; the renal vessels cut distal to the clamp, and the organ removed and allowed to bleed freely from its vein. The volume of fluid draining naturally was measured. This volume plus the volume of the dissected, injected kidney (see below), less the volume of latex injected, gave the measurement of the "distended kidney", which will be employed in the tables. The phrase applies to the kidney in its natural, functioning state, *in situ*. In this paper, all measurements will be expressed as percentages of the functionally distended kidney.

After letting the kidney drain for a few minutes, a cannula was tied into the renal artery or vein and the injection of latex started. Both the liquid latex and the kidney were kept at 37° by immersing them in a warm saline bath. The latex was delivered from a buret through flexible tubing; by raising or lowering the buret, its latex meniscus could be kept at a fixed level, thus controlling the pressure of delivery. The latex runs into the kidney rapidly at first and then slowly. In all cases, flow was permitted to continue until, by inspection of the buret, it stopped. This required 10 to 20 minutes.

The cannulated vessel was tied at the hilus and the kidney fixed for 24 hours in a solution of 4 per cent acetic acid in 4 per cent formaldehyde. Then the kidney was dissected free of fat and its volume (or weight, kidney densities are about 1.04) measured. (The process of fixation does not change its volume.) It was next cut into 3 mm. slices; then with a sharp knife, the cortical portions were separated from the medulla and the volumes of the two measured. Finally, they were corroded separately in concentrated HCl at 55° for 24 hours. The rubber casts remaining were washed free of acid and debris, a Buchner funnel, with a fritted glass disk of coarse porosity, being found useful in the washing. The volume of the casts was measured by fluid displacement: the rubber pieces were blotted dry with absorbent paper and placed in a specific gravity bottle (Hubbard-Carmick). The flask was then filled from a measuring buret with 1 per cent formaldehyde, the solution being introduced into the stoppered bottle through a fine polythene tube. The volume of the solution introduced into the empty bottle less the volume of solution needed to fill the bottle containing rubber casts gave the required measure of the volume of the rubber casts. It was found that the latex shrinks during the several manipulations; the shrinkage amounts to 20 per cent. To allow for it, all ob-

times that of water. By adding NH_4OH, its relative viscosity was reduced to 21 just before introducing into the kidneys; 1 to 2 ml. of 30 per cent NH_4OH in 100 ml. of latex effects this change.

served volumes of the set rubber were multiplied by the factor 1.25 and are so reported in this paper.

RESULTS

1. Volume of Arterial Tree.—It was found empirically that when liquid latex was run into the renal artery, a pressure equivalent to 100 mm. Hg caused the filling of only very few glomerular tufts, this being readily ascertainable by examining the casts with a magnifying lens. (To get thorough filling of the glomeruli under our conditions of viscosity, *etc.*, a pressure of 300 mm. Hg is necessary.) The pressure of 100 mm. Hg was therefore used for all arterial injections. The volume of the renal arterial tree herein reported represents all the arterial system up to the glomerular capillary. Table I shows that it aver-

TABLE I

Volume of Latex in Arterial Tree

No.	Weight of distended kidney	Latex in cortex arteries		Latex in arteries below cortex	
		Amount	Per cent of distended kidney	Amount	Per cent of distended kidney
	gm.	*ml.*		*ml.*	
1	31.4	0.64	2.0	0.83	2.6
2	27.5	0.51	1.9	0.60	2.2
3	21.5	0.43	2.0	0.61	2.8
4	27.5	0.90	3.3	0.62	2.3
5	26.4	0.51	1.9	0.59	2.2
6	55.8	0.91	1.6	1.15	2.2
Averages			2.1		2.4

ages 4.5 per cent of the functionally distended volume of the kidney, 2.1 per cent being in the arteries of the cortex and 2.4 per cent being in the arteries below the cortex.

2. Volume of the Venous Tree.—We were interested in measuring the volume of both the veins of the cortex (interlobular, stellate, and capsular) and of those below the cortex (arcuate, interlobar, and main branches up to the hilus). The two regions are known to be under different pressures: 25 mm. Hg or above for the former and 7 mm. or less for the latter (12). If we injected the whole venous system with a pressure of 7 mm. Hg, some latex would probably run into the interlobulars, whereas if we injected the whole system with a pressure of 25 mm. Hg, we might distend unnaturally the larger veins. Thus, in either case, the preparation would be unphysiological. The difficulty was resolved by using both pressures in different kidneys and then dissecting away the compartment which had been unphysiologically injected.

(*a*) *The Larger Veins.*—The latex was run into the cannulated renal vein

at 7 mm. Hg pressure. After fixation, the kidney was cut into 3 mm. slices. Next, with a sharp knife the cortical portions were separated from the subcortical portions and then the two parts were corroded separately. Finally, with sharp scissors any fraction of the subcortical moiety which belonged with the cortical moiety was cut away and added to its rightful compartment, and *vice versa*. (With a little practice, one can tell at a glance whether a given piece of cast is out of place: the subcortical portions are large in bore or characteristically branched.) Where the interlobulars drain into arcuates or interlobars,

TABLE II

Volume of Latex in Venous Tree

No.	Pressure of injection	Weight of distended kideny	Latex in Cortex veins		Latex in veins below cortex	
			Amount	Per cent of distended kidney	Amount	Per cent of distended kidney
	mm. Hg	*gm.*	*ml.*		*ml.*	
7	7	26.8	0.39	1.5	1.19	4.5
8	7	57.5	1.25	2.2	1.72	3.0
9	7	35.0	0.50	1.4	0.87	2.5
10	7	30.6	0.75	2.4	0.56	1.8
11	7	37.4	1.13	3.0	0.80	2.1
12	7	50.0	0.81	1.6	0.89	1.8
Averages				2.0		2.6
13	20	26.8	0.88	3.3	1.00	3.7
14	20	24.0	0.94	3.9	0.63	2.6
15	20	32.8	1.12	3.4	1.48	4.8
16	20	50.2	2.33	4.7	2.00	4.0
17	20	35.5	1.68	4.7	0.82	2.3
18	20	46.5	2.25	4.8	1.12	2.4
Averages				4.1		3.3

they appear somewhat like the teeth of a comb joined to the perpendicular back. They were separated just at this point; if several interlobulars formed a confluent bulb which then drained into the gently arching interlobars, they were cut just where they entered the bulb. The volumes of the two portions are shown in Table II: that of the "subcortical portion" (*i.e.* arcuate veins, interlobar veins, main branches, and renal vein to the hilus) is 2.6 per cent of the functionally distended kidney. In the table we have also included the volume of latex found in the cortex: 2.0 per cent of the functionally distended kidney. This shows that a considerable quantity of latex did run into the cortical veins, in spite of the low pressure of the injection.

(*b*) *The Cortical Veins.*—Exactly the same technics of injection and dissection were used to measure this compartment, except that a pressure of 20 mm. Hg was used. It would have been more physiological to use an injection pressure of 25 mm. Hg, since this is known to be the pressure within this compartment. But it was found that the higher pressure caused the filling of numerous peritubular capillaries. With the lower pressure, virtually none was filled. Hence the lower pressure was used: it was felt that the error introduced was less than it would have been with the higher pressure.

The volume of this compartment was found to be 4.1 per cent of the functionally distended kidney, as shown in Table II. This represents the blood in the interlobular, stellate and capsular veins. The table also shows that this pressure did distend the larger veins in a somewhat unphysiological way.

3. Incidental Observations.—

(*a*) *Relative Volume of Cortex.*—The volume of the cortex was measured in 10 instances after the initial dissection of the renal parenchyma described above. It comprised, in per cent of the total kidney, respectively, 66, 67, 69, 69, 69, 70, 70, 71, 72, and 73 per cent. The average is 70 per cent.

(*b*) *Medullary Veins.*—At the pressures employed, very little latex entered the veins of the medulla (see Fig. 1). The reason for this is unknown. To get rubber into these veins in any quantity, given our conditions, pressures of 30 to 100 mm. Hg are required.

(*c*) *Interlobular Venous Morphology.*—If cut in coronal section and then corroded, the venous cast's appearance is like that shown in Fig. 1: the interlobars and arcuates appear somewhat like the ribs of an umbrella, with the interlobulars branching off perpendicularly. This whole vascular bed has profuse interconnections (13): if one cannulates only one branch or the renal vein or even one interlobular vein, one can readily inject rubber into it to fill most of the venous bed of the kidney.

The distribution of latex in the interlobular veins was of interest: it formed a dense palisade, as illustrated in Figs. 1 and 2. An histologic section of the latex-injected veins is shown in Fig. 3: the numerous interlobular veins are apparent. Their diameters range from 40 to 300 μ. Their walls are of endothelium only (14), their thinness being apparent in Fig. 3; at times their walls cannot even be percenved. This portion of the renal vascular bed obviously loses its blood at death or when the organ is removed, and its thin walls then collapse against each other. For this reason this part of the renal vascular bed is poorly visualized in most histologic preparations.

The palisade of interlobular veins first becomes very profuse some 1 to 2 mm. below the cortical surface; then it thins out and runs straight toward the arcuates. The term "palisade" suggests that the interlobular veins are constant in diameter, that is, that the stakes of the palisade do not change greatly in bore from capsule to corticomedullary junction. This is not strictly

true, but the term is so apt that it is used deliberately. The volume of the interlobular veins at various levels was measured thus: a kidney was injected with latex at 25 mm. Hg pressure. After fixation in acid-formaldehyde, a 1 cm. cube of cortex was cut out, embedded in gelatin, frozen, and sections made at each successive 1 mm. of depth below the cortical surface. The sections were lightly stained with hematoxylin and mounted in glycerin jelly (see Fig. 3). The latex in each section (excluding capillary latex) was then traced with the aid of a magnifying projector, and finally the area of latex was measured with a planimeter. Expressing this as per cent of the cortical volume at the same level, the latex volumes at each successive millimeter of depth were: 0.1, 22, 13, 9, 10, 8, 9, and 15. The figures reflect the profuseness of the veins at the 2 mm. level, *i.e.* 22 per cent of the cortical volume. From the 4 mm. depth through the 7 mm. depth the palisade is uniform at about 10[2] per cent of the cortical volume; at 8 mm. the venous vascular volume rises again to 15 per cent where the veins at the corticomedullary junction become profuse.

(*d*) *Completeness of Blood Drainage.*—The questions arose: how complete is the drainage of blood from the kidneys under the conditions of the experiment? does enough stay behind so that the analyses of functional distension are incomplete? The questions were answered by measuring the blood remaining behind after routine drainage. The kidneys of 6 dogs were removed and allowed to drain as usual. Then they were washed free of blood as follows: the artery was cannulated, and the organ perfused with Tyrode's solution, to which 6 per cent dextran[3] was added. The perfusing fluid was gassed with 5 per cent CO_2 in O_2; the perfusion pressure was 100 mm. Hg; the temperature was maintained at 37°. Under such circumstances, flow was profuse for 10 to 20 minutes, *i.e.* at about 4 ml. per gm. of kidney per minute. The perfusate was collected and its total hemoglobin content ascertained colorimetrically. By comparing this with the hemoglobin content of systemic blood, the amount of blood washed out of the kidney was calculated. The perfusate very quickly became red cell-free; also, when examined in the gross after the perfusion, the organ appeared to be free of blood. For these reasons, it appeared that all the kidney's contained blood had been washed out by the technic.

The quantity of hemoglobin found in the effluent washings was small, amounting to less than 0.1 gm. In the six experiments, the individual estimations for blood remaining in the kidney were calculated to be respectively: 0.2, 0.3, 0.3, 0.5, 0.6, and 0.7 ml. The average is 0.4 ml. It is apparent that the

[2] This volume is 1.7 times the volume for cortical veins obtained when latex is injected at the unphysiologically low pressure of 20 mm. Hg, as previously described. The discrepancy is considerable. However, as brought out in the discussion, the strict accuracy of all of these methods may be impugned, and the present difference appears not excessive.

[3] We are indebted to Commercial Solvents Corporation, Terre Haute, Ind., for the dextran used in these experiments.

kidneys drain almost completely of blood under these conditions: taking averages, the kidney's weight after drainage is 28½ gm. 10 ml. of fluid drained out of it, or 26 per cent of its functionally distended volume. Of the 10 ml., 5 ml. is blood and 5 interstitial fluid, amounting, in each case to about 13 per cent of the functionally distended volume. 0.4 ml. of blood remained behind, which is 8 per cent of the original blood in the kidney or 1 per cent of the kidney's functional volume.

DISCUSSION

Perhaps the worst error in this method of attempting to measure the functional vascular volume lies in the composition of the injection compound: the fluid latex is certainly an unphysiologic material; it contains much ammonia, and its pH is about 9. It undoubtedly affects the tissues with which it comes into contact, how adversely we do not know. Another error is implicit within the method: if the arterial system has collapsed before the injection, then more latex would run into the venous system under a given pressure than if the arterial system were naturally distended with blood. The same considerations hold for a collapsed tubular system or pelvis. A third error perhaps lies within the latex itself: it is very viscous and so perhaps it does not penetrate a given region thoroughly before hardening. Furthermore, as previously described, under our conditions, none enters the medullary parenchyma.

But in spite of these drawbacks, it is felt that the method gives fairly good information concerning the distribution of blood in the naturally distended organ. The functional organ contains 13 per cent blood, as discussed in the introduction. With our present technic, we have put into the vascular bed, at approximately physiologic pressures, almost this same volume, that is, 11.2 per cent. The two figures agree fairly well, in our opinion, and consequently, in spite of the obvious faults in the method, we feel that we have obtained a good first approximation to the functional distribution of blood in the organ. Furthermore, no latex penetrated either the glomerular capillaries, the efferent arterioles, the medullary parenchyma, or the peritubular capillaries. Perhaps the blood in these portions would make up the difference between the 11 per cent found and the 13 per cent of blood that drains. In summary, our method is thought to have given us a fair approximation to the distribution of blood in the functionally distended organ: 4.5 ml. per cent (*i.e.* per 100 gm. kidney) in the arteries, 4.1 ml. per cent in the cortical veins, and 2.6 ml. per cent in the subcortical veins, with about 2 ml. per cent undetermined, distributed somehow between glomerular capillaries, efferent arterioles, peritubular capillaries and medullary vasculature.

The magnitude of the distention becomes apparent when all available figures are summarized. The volumes of fluid in the several cavities and spaces of the kidney, expressed as ml. per 100 gm. of distended kidney, are estimated to be as follows:—

1. Subcortical arteries	2.4
2. Cortical arteries	2.1
3. Glomerular capillaries	0.9
4. Peritubular capillary rete	0.9
5. Cortical veins	4.1
6. Subcortical veins	2.6
7. Tubular urine	1.0
8. Interstitial fluid	13.0
Total	27.0

The bases for these estimates are as follows: for the first, second, fifth, and sixth compartment, the data of Tables I and II are used. For glomerular capillary blood, the estimate of Heggie (9) is taken that it is 6.7 per cent of the renal blood: 6.7 per cent of 13 ml. is 0.9 ml. The volume in the peritubular capillaries is also probably small: in most capillary beds it is thought to be 5 to 10 per cent of the vascular volume (15). Since the vascular volume of the kidney is 13 ml., we have estimated the capillary volume as 7 per cent of this amount. The grand total for blood is 14 ml. per cent, of which 13 ml. per cent drains readily. These estimates for blood distribution agree reasonably well with those previously made by Heggie (9). The volume of tubular urine is small: from the estimate of Brodie and Mackenzie (16) for the nondiuretic kidney, it is probably 1.0 ml. or less. Finally, as described in the introduction, the volume of the (?) interstitial compartment is about 13 ml.

Thus the operational distension of the kidney appears to be considerable: the organ in its functioning state is about a quarter fluid, distributed in special compartments around the cells. The existence of all of these compartments depends upon the blood pressure. It is this which inflates them like balloons, and in its absence they shrink down almost to nothing: when their contained volume was originally 28 ml., they collapse down to a volume of about one-twentieth of this quantity. Because of this change, any attempt to ascertain the distribution of blood in postmortem kidneys, by means of dyes injected before death, appears to us of dubious and limited value.

With this information, we may also appraise the meaning of the measurement designated as "IRP", or intrarenal pressure. In taking it, a syringe needle, often with lateral holes, is thrust into the renal parenchyma and then the pressure at its end ascertained (8). The 20-gauge needles employed are 890 μ in diameter—very large in comparison with the interlobular veins (40 to 300 μ) or peritubular capillaries (10–15 μ) or tubules (15–60 μ) or interstitial spaces, all of which are functionally distended with fluid. Fig. 3 shows the syringe needle outlined to scale upon these structures: the appropriateness of our dictum that the needle is like a "crowbar" is apparent (17). As such, when it is thrust into the tissue, it lacerates many of these delicate, fluid-filled structures (8). The pressure, then, around the needle is undoubtedly that of a pool of fluid in the lacerated tissue. Contributing to the pool,

as originally postulated, are all the torn tubes: arteries, capillaries, veins lymphatics, interstitial spaces, and tubules. The pressure in such a pool would be determined by the rates of flow into the pool from the ruptured channels and the rates of flow out of it through any available effluent. In the present instance, it appears to us far the most likely that the governing channel is that of the interlobular veins. We have already described them as a thick palisade: their profusion all through the cortex, undoubtedly all engorged with blood, is remarkable. The inserted needle, it is felt, must easily tear their ultrathin walls and hence lacerate scores, or even hundreds, of them. Blood flow also through the interlobular veins must be copious and hence they would furnish the most free-flowing influent, as well as effluent, around the needle's shaft. Hence they are probably the dominant structure in determining the pressure around the needle. For example, if a few score arterioles were torn, their high pressure contribution would be dissipated in the "swamp" of the interlobular venous contribution. Considering another aspect, suppose that the tubular pressure is less than interlobular venous pressure: then, if hundreds of tubules were lacerated by the inserted needle, one might expect the needle's pressure to be less than interlobular venous pressure. However, tubular filling and drainage are so slow in comparison with interlobular venous flow and drainage that the postulated low pressure in the tubules would be quickly raised to venous pressure by flow from torn veins. Hence the pressure observed would be that of the venous system.

It will be seen that the pressure around the needle is in part a matter of chance: it depends on the quantity and quality of the laceration. It is for this reason, in our opinion, that the measurement of IRP shows such considerable intrinsic variation (17, 18). In our hands, the range in normal animals is 10 to 58 mm. Hg, with a standard deviation of 11 mm. By contrast, the range of interlobular venous pressures is narrower: 18 to 30 mm. Hg. Particularly when the higher IRP's were observed, presumably enough arterioles (or arteries?) were lacerated so that the reading obtained was a reflection of considerable effective participation of arteriolar pressure in the pool around the shaft of the needle. Such considerations also readily account for the differences in IRP observed in different sites of the same kidney, in a contralateral kidney, etc. (8, 18).

The conclusion that the pressure measured by the IRP technic is that in a vascular compartment, perhaps that in venous capillaries, is also held by Miles and de Wardener (18) and de Wardener (19): they support it on the grounds that IRP may fluctuate so rapidly (it also shows pressure pulses). We now consider, in using the IRP technic for the kidney, that it gives an approximate measure of the pressure within the interlobular venous compartment. The coefficient of correlation between the two measures, over a wide range, is 0.85 (12); failure to give a perfect correlation is due, in our

opinion, to the crudeness of the IRP technic. Direct measure of the interlobular venous pressure is undoubtedly superior to the IRP technic, but this is difficult and also often technically impossible (*e.g.* in chronic preparations). In such conditions, the IRP technic, cautiously employed, is indispensable.

The measurement of "tissue pressure" by the technic of inserting syringe needles into a tissue—this method, or variations of it, has been widely used (see reference 20)—must, in our opinion be guided by considerations of the vascular system of the organ investigated: if it is scanty, as in resting skeletal muscle, then the measurement probably does give a fair estimate of interstitial pressure; but if the vascular bed is profuse or sinusoidal, as in kidney or spleen or liver, then the technic probably gives an estimate of the pressure within a lacerated vascular compartment. Probably the only true measurement of "tissue pressures" is to be found with the micropuncture technic of McMaster *et al.* and even this, in the final analysis, is thought to be an approximation, although certainly a very good one (21).

SUMMARY

An attempt to measure the distribution of blood in the functional kidney of dogs was made. The method involved the injection of liquid latex rubber into the vascular system at physiologic pressures, fixation of the rubber *in situ*, and then, after corroding away all tissue, measurement of the volume of the rubber casts. The kidney contains, in its functionally distended state, 14 per cent blood. Of this, 4.5 per cent is apparently in the arteries and some 7 per cent in the veins. The functional engorgement of the cortical interlobular veins (about 4 per cent) is particularly striking, for they form a dense palisade of 40 to 300 μ vessels. These are not seen at the usual autopsy since they have drained out and collapsed.

It is pointed out that attempts to describe the blood distribution in the kidney after it has been drained of blood are of dubious value. In the light of these data, also, the nature of the measurement of "intrarenal pressure," accomplished by inserting a needle into the renal parenchyma, may be better understood: it is suggested to be primarily a measure of interlobular venous pressure.

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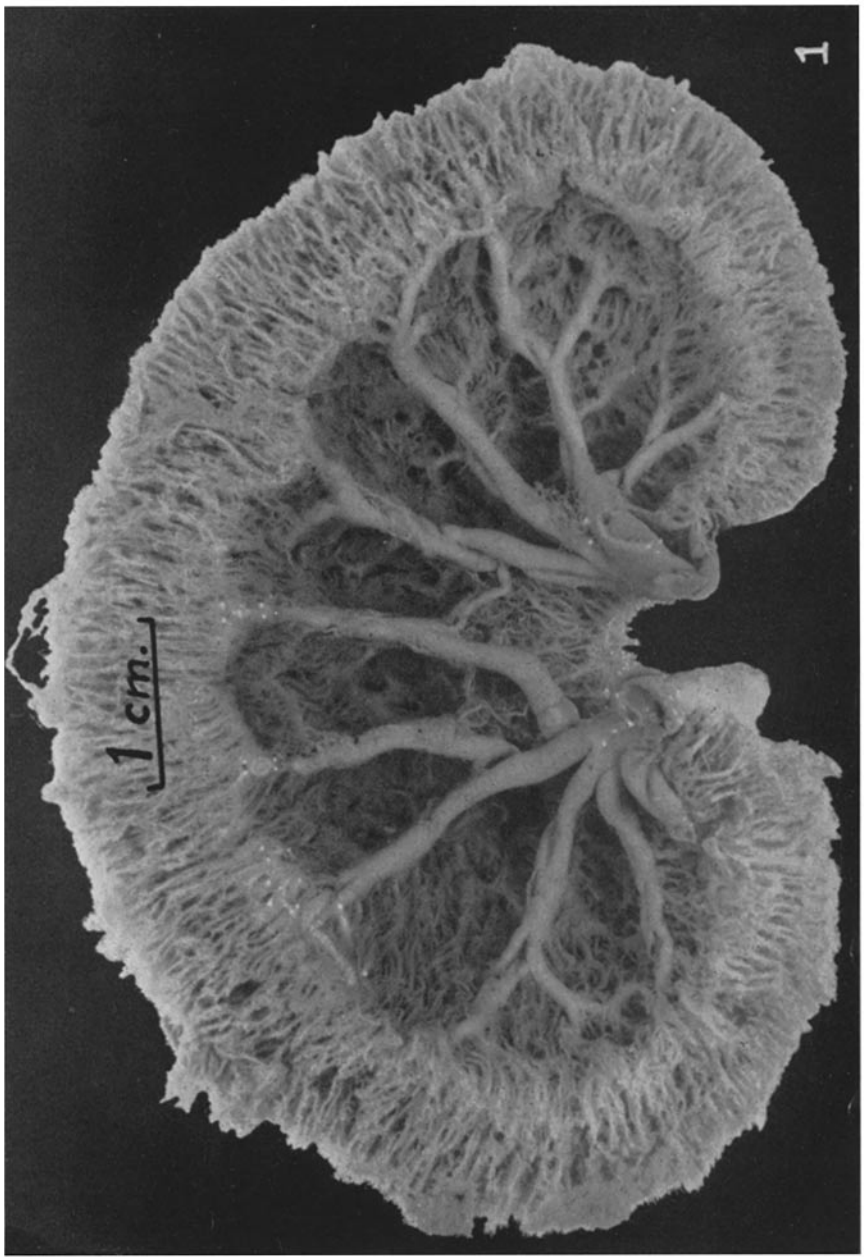
EXPLANATION OF PLATES

PLATE 1

FIG. 1. Latex rubber cast of veins of kidney. The rubber was injected into the renal vein at a pressure of 25 mm. Hg. Filling of the medullary veins is minimal. The profuse "palisade" of interlobular veins is evident. × 2.2.

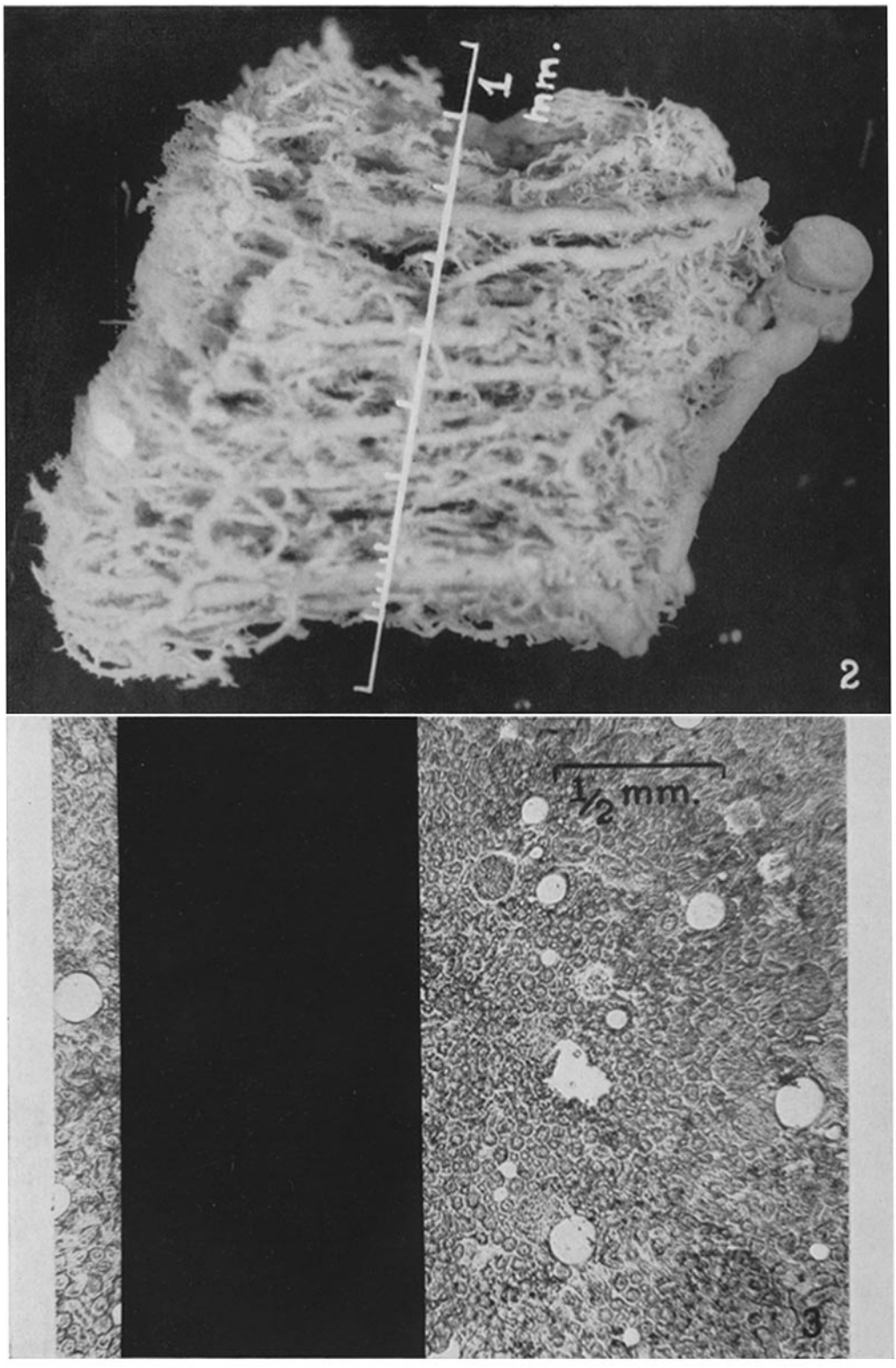


(Weaver *et al.*: Distribution of blood in the functional kidney)

PLATE 2

FIG. 2. Magnification of cast of interlobular venous palisade. Same kidney as in Fig. 1. × 11.

FIG. 3. Section of cortex 4 mm. below and parallel to the capsule. The interlobular veins appear round and white; they were filled with latex at a pressure of 20 mm. Hg. Specimen fixed in acid-formaldehyde and frozen; sections cut at 15 μ stained with hematoxylin, and mounted in glycerin jelly. The bar across the figure shows the diameter of the needle used in measuring "intrarenal pressure." × 71.



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