THE VEINS OF THE ADRENAL.

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WITH 3 TEXT FIGURES.

Within the past decade our knowledge of the functions of the adrenal glands, and of their relations to the rest of the economy, has been greatly enhanced by many careful chemical and physiological researches. The recent studies of Aichel (1), Wiesel (2, 3), Soulie (4), and others have placed the early development of the organ upon a fairly certain basis. These advances in the physiology and embryology of the organ have not as yet been accompanied by corresponding advances in our appreciation of its minute anatomy. Hence this branch of the subject is, at the present time, one of unusual interest.

The intimate relation of the parenchyma of the adrenal to its blood-vessels, as shown by the general tendency to regard the organ as a true gland whose secretion enters its blood-vessels and leaves the organ through its efferent veins, makes it specially important that these vessels should be carefully studied and their structure and distribution accurately recorded.

The exhaustive study of Flint (5), on the course of the adrenal vessels, based as it was upon carefully prepared reconstructions, leaves little to be desired along this line. The writer is, however, unable to find in the literature any reference to the minute structure of the veins of the adrenal, with the notable exception of Minot's (6) article on sinusoids.

To be sure Pfaundler (7) mentioned the occurrence, in the medulla of the adrenal, of venous vessels whose only wall consisted of endothelium. Gottschau (8) also, though omitting their description, has figured similar vessels in his Plate XVIII, Fig. 1. But as to the structure of the larger blood-vessels of the adrenal glands the literature seems to be entirely barren.

The architecture of the arterial walls does not appear to offer any distinctive peculiarities, the tissues of which they consist being arranged in a manner precisely similar to that which characterizes the arteries of

similar size occurring in other organs. The veins, however, present distinct and remarkable peculiarities which it is the purpose of the present paper to describe.

Methods and Material.—The tissue used for this study has included specimens of the adrenal from twenty-one human adults, together with the casual examination of fetal adrenals of the pig and of man. The adrenals of other mammals, e. g., monkey, dog, cat, rabbit, and guinea-pig, have also been more or less carefully studied.

These tissues have been fixed and hardened with many reagents, among which are Zenker's solution, formol, Müller-formol, alcohol, corrosive acetic mixture, Tellyesniczky's fluid, and Flemming's solution. The stains used were hematein by various methods, acid hematein, iron hematein, etc., and for counter stains eosin, orange, Van Gieson's picro-fuchsin, Weigert's elastic tissue stain, Mann's methyl blue-eosin mixture, Congo-red, and Ehrlich's triacid mixture. A combination of Mann's hematein, Weigert's elastic tissue stain and Van Gieson's picro-fuchsin, gave the best results for the differentiation of the muscular and connective tissues. This method was applied as follows, and may be used after any of the above fixatives.

1. Stain 10-12 minutes in Mann's hematein or in Böhmer's hematoxylin, until somewhat overstained.
2. Wash well in water.
3. Stain 10-20 minutes in recently prepared resorcin-fuchsin solution after the method of Weigert (9).
4. Wash in water.
5. Stain 1-3 minutes in the freshly prepared picric acid-acid fuchsin solution of Van Gieson (10).
6. Wash and dehydrate in 95 per cent, or in absolute alcohol.
7. Clear, and mount.

Types of Adrenal Veins.—The efferent veins of the adrenals arise in the medulla of the organ by the union of the broad capillaries of the medulla and the adjacent zone of the cortex. These capillaries form broad thin-walled vessels which have been described by Minot (6) as *sinusoids*. They converge toward the middle of the medulla, where they pass into somewhat larger vessels, which, for convenience, may be termed *small central veins*. These veins tend toward the hilum, are relatively short, and by union with one another soon form thicker-walled vessels which may be described as *large central veins*. These large veins pass toward the hilum, near which they unite to form a large efferent vessel, the *suprarenal vein*. This last vein makes its exit from the hilum of the organ and enters either the vena cava inferior, as is the rule on the right side, or the renal vein, as frequently occurs on the left.

From this brief review of the course of these vessels it will be seen that four distinct venous types have been enumerated, and it is the purpose

of the writer to show that these types exhibit well-defined structural peculiarities.

Observations.—The *sinusoids*, after the careful description by Minot (6), will require but brief mention. These vessels possess the wall of a capillary and the lumen of a venule. A number of such vessels may be seen in Fig. 1, in the central portion of the medulla, on either side of the group of central veins. Their wall consists of nucleated endothelial plates which rest directly upon the parenchymal cells. Their lumen is several times the diameter of the medullary capillaries. They are dis-

FIG. 1. A group of vessels from the central portion of the medulla of the human suprarenal gland. *a*, sinusoids; *b*, small central veins. Fixation, 5 per cent formalin; stain, Mayer's hematein; thickness, 8μ ; photomicrograph, $\times 100$.

tinguished from the small central veins by the absence of connective tissue from the wall of the sinusoids.

The *small central veins* are of the type shown in Fig. 1. The wall of these vessels consists of two coats, endothelial and connective tissue. The latter is always relatively thin, though the vessels possess a very considerable lumen. Venules of this type of structure, Fig. 1, collect the blood from the sinusoids of the medulla. Frequently, however, the sinusoids open directly into the small central veins and venules, the connective tissue of the venous wall being occasionally continued for a very short distance upon the endothelium of the sinusoid.

The connective tissue of the small central veins is richly supplied with elastic fibers, which are disposed in oblique and circular directions,

FIG. 2. The medulla of a suprarenal gland of man, showing a group of large central veins. The middle and lowermost veins are in transection, the uppermost vessel in longitudinal section. The series of sections shows that this last vessel is a branch of that in the middle of the figure. Fixation, Zenker's fluid; stain, hematein and methyl-blue, Mann's method; thickness, $10\ \mu$; photomicrograph, $\times 60$.

occasional elastic fibers are also longitudinal. The typical small central veins contain no muscle. As they approach their termination in the

large central veins a few smooth muscle fibers are found, but these are always disposed in a longitudinal direction. As soon as longitudinal muscle fibers appear in appreciable numbers the venous wall acquires the type of the succeeding variety, the large central vein.

In the *large central veins*, as in the small, but two coats can be readily distinguished. The inner coat, or intima, in these vessels consists of a lining endothelium, which rests upon a very thin membrane of delicate connective tissue, containing many elastic fibers.

The outer coat, or adventitia, is also a very thin membrane of fibro-elastic tissue, but its fibrous bundles are coarser than those of the intima, and its elastic fibers form a very close network. The outer portion of this coat contains a few longitudinal smooth muscle fibers. The great majority of these fibers, however, are arranged in the form of longitudinal ridges which project into the adjacent medullary tissue. From one to five of these muscular ridges occur in the circumference of the vein (Fig. 2 and 3). Except at those points at which the muscle occurs, the venous wall is extremely thin (Fig. 3). The muscular ridges are frequently so large as to materially obstruct the lumen of the vessel (e. g., the middle vessel in Fig. 2, also the uppermost vessel, which is cut in very nearly longitudinal section), and they form so noticeable a peculiarity that their presence may be considered characteristic of this type of vessel. The writer has never failed to find these peculiar muscular ridges more or less highly developed in each of the human adrenals which he has examined: he believes them to be constantly present. They are less highly developed in the suprarenal vessels of the lower mammals, but even there they may frequently be demonstrated.

The muscle fibers of the larger ridges are arranged in bundles which are enveloped in fibro-elastic septa of connective tissue. All of the muscle fibers in these bundles are longitudinally disposed. This arrangement is well shown in Fig. 3, in which a large central vein is seen in transection at a point near the entrance of a large branch. Examination of sections somewhat higher in the series shows the union of these two vessels.

In the section photographed, the branch has been longitudinally cut. The fine dark lines shown in the figure are bands of elastic fibers which are enveloped in delicate white fibrous tissue inclosing the cut ends of the bundles of smooth muscle. The tendency to form longitudinal ridges is shown in this figure by the irregular distribution of the muscle, one side of the vessel, in both the parent stem and the branch, being almost devoid of muscle fibers. The muscular character of these ridges is beyond doubt.

FIG. 3. Large central veins from the medulla of the human suprarenal gland. The figure shows the distribution of the elastic tissue and the bundles of smooth muscle which are seen in transection in the larger vein and in longitudinal section in the smaller ones below. The series shows these latter vessels to be branches of the former, the section being selected to show a plane near the point of division. The smaller vessels are very obliquely cut and the muscle is distinctly longitudinal. Fixation, Zanker's fluid; stain, Mann's hematein, Weigert's elastic tissue, and Van Gieson's picro-fuchsin; thickness, $10\ \mu$; photomicrograph, $\times 37$.

The writer has observed that the formation of such heavy ridges as those shown in Fig. 3, nearly always occurs at those points where the vessel branches. It is possible that, as in the case of the somewhat similar ridges in the veins of the erectile tissues (see Kölliker's *Handbuch der Gewebelehre*, 6te Aufl., 1902, pages 486 and 487), these muscular protuberances may to some extent serve the purpose of valves.

As the large central veins approach the hilum of the organ they form still larger vessels which partake of the structure of the suprarenal vein. The point of transition from the one type to the other is variable, occasionally the type of the large central veins is continued to the exit of the suprarenal vein at the hilum of the organ. More frequently the primary branches of the suprarenal vein may be traced for a considerable distance into the medulla of the organ, still retaining the type of structure found in the larger vessel.

The *suprarenal vein* presents three coats, intima, media, and adventitia. The tunica intima, in addition to its endothelial lining, possesses a thin membrane of very delicate connective tissue in which occasional branched connective tissue cells may be distinguished; such cells are, however, very scanty. This coat also contains a delicate network of elastic fibers.

The tunica media of the suprarenal vein is extremely thin, rarely ever does it exceed in thickness the tunica intima. It consists chiefly of fibro-elastic tissue, the elastic fibers forming quite a dense network. Few muscle fibers occur in this coat, nowhere are they found in sufficient numbers to form a definite layer, as in veins of similar size in other organs. Some of the muscle fibers are circularly disposed, but many of them are longitudinal.

The tunica adventitia is by far the thickest of the three coats and forms two-thirds to five-sixths of the entire vascular wall. It consists chiefly of smooth muscle fibers, all of which are longitudinally disposed. These smooth muscle fibers form characteristic coarse bundles which are distributed around the entire circumference of the vessel. The largest of these bundles may occasionally form projecting ridges as in the smaller veins, but as a rule the muscular tissue is more evenly distributed than in the central veins. Each of the muscle bundles is enveloped in a perimysial sheath of connective tissue, which blends with that of the tunica media. These adventitial sheaths possess a dense network of elastic fibers, in fact the greater part of the elastic tissue in the vascular wall is frequently found in the adventitia. On its outer surface the tunica adventitia is continuous with the capsule of the adrenal or with the adjacent connective tissue.

This peculiar type of vessel is not strictly confined to the suprarenal

gland, but occurs, more or less typically developed, in many of the large abdominal veins, notably in the renal veins and vena cava, into which the suprarenal veins empty. But nowhere is this peculiar venous type more strikingly developed, nowhere is the adventitia relatively so much thicker than the media, nowhere is a greater proportion of the smooth muscle of the venous wall longitudinally disposed, nowhere is there relatively less circular muscle, than in the suprarenal vein. Realizing the intimate relation of the parenchyma of the organ to its blood-vessels, and adopting, if we may, the accepted physiological function of the adrenal—the formation of an internal secretion, a powerful vaso-constrictor which is poured into the blood within the capillaries and veins of the organ—the peculiar longitudinal arrangement of the muscular tissue, the valve-like protuberances at the junctions of the venous vessels, the absence of circular muscle from the walls of the veins of all sizes, and the general appearance of these vessels which are so remarkably different from the veins of most other organs, become, to say the least, extremely significant of a close structural relation, physiologically speaking, to the presence of an astringent secretion in the outflowing blood current.

In this connection, one further observation is of importance. In the periadrenal connective tissue are numbers of small veins which return the abundant blood supply of the tissues of this region, most of them emptying into the phrenic veins. Many of these veins do not differ from the similar veins of other parts, but in many others the writer has observed that the muscle tissue is almost entirely disposed in a longitudinal direction, a condition which is quite the reverse of that found in the adipose and areolar tissues of other portions of the body.

The writer also finds that many of the small veins of the adrenal, instead of opening into the central veins as is usually the case, pursue a less frequent course, penetrating the cortex and capsule of the organ, and emptying into the small veins of the surrounding connective tissue. The frequency with which this condition was associated with the occurrence of longitudinal muscle fibers in the periadrenal veins, suggests a more than casual relationship between the two conditions.

SUMMARY.

In conclusion, the above facts may be summarized as follows:

1. The efferent blood-vessels of the adrenals form four successive vascular types, the sinusoids, the small central vein, the large central vein, and the suprarenal vein.
2. Each of these types presents distinctive characteristics.

3. In all four types circular muscle is either absent or noticeably deficient.

4. In the large central veins prominent and characteristic muscular ridges are constantly present, and are frequently in relation with those points at which the branches of these vessels enter.

5. These peculiarities of structure may possibly bear a close physiological relation to the function of the adrenal as a gland that forms an internal secretion which has been shown to be a powerful vaso-constrictor and stimulant of smooth or involuntary muscle.

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