

Surgical Anatomy of the Adrenal Glands

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OPERATIVE approaches to the adrenal glands are becoming standardized, and the indications for operation more clearly defined. Current text-book accounts of adrenal anatomy, however, do not always provide an accurate picture of the variations which may be encountered at operation. For this reason the anatomical findings in a series of 225 dissections carried out at the autopsy table are presented. In addition, the incidence of accessory adrenal cortical nodules located away from the main glands is presented from a series of 50 complete retroperitoneal dissections. These findings are compared with representative figures in the literature.

Embryology of the Adrenals

A study of the embryological development of the adrenals provides an explanation for the formation of accessory or *aberrant* glands. The widespread distribution of chromaffin tissue in sites away from the adrenal medulla, so important in the consideration of pheochromocytoma, is also to be explained on an embryological basis.

Both medullary and cortical elements appear between the fifth and sixth weeks of fetal growth.¹⁶ The cortical portions are derived from mesothelial cells lying in the dorsal wall of the primitive coelom just mesial to the mesonephric tubules and gonadal ridges. The medullary elements, the sympathogonia, migrate forward from both sides of the neurogenic crest to take up their position ventral to the developing vertebral column between the cortical anlage.

The sympathogonia differentiate into sympathoblasts and pheochromoblasts. These remain closely associated during the growth of the organism, and as the sympathoblasts develop into mature sympathetic ganglion cells along the length of the sympathetic chain, pheochromoblasts become the pheochromocytes of the chromaffin tissue, which remains in close association with all of the sympathetic ganglia. The most prominent portions of chromaffin tissue are those associated with the adrenal medulla, and that group of cells anterior to the lower aorta which is designated as the *Organ of Zuckerkandl*.

Adrenal cortical cells grow mesialward during succeeding weeks to enclose the medullary elements and to complete the formation of the adrenal glands. During this process small buds of cortical cells are evidently trapped within the meshes of the coeliac and renal plexuses, and pursue a separate development as *accessory adrenals*. In addition, the caudal migration of the gonads, with which the cortical anlage are closely associated, may cause a further dislocation of adrenal tissue, and so it is not rare to find accessory glands along the course of the spermatic or ovarian vessels. Curiously, the association of macroscopic accessory adrenal glands with the gonads themselves is much more infrequent.

Normal Anatomy

Though the right kidney is almost always lower than the left, because of the firm mass of the liver above it, the right adrenal is usually *higher* than the left. It lies above

the upper pole of the right kidney, between the liver and the diaphragm, and forms the *impressio suprarenalis* on the liver surface, just to the right of the inferior vena cava (Fig. 1). It is in close contact with the liver capsule on the bare area of the liver, and is commonly fixed to it by loose areolar tissue.

In some cases, the right adrenal is firmly adherent to the liver by fibrous union of the capsules of each organ (Fig. 2A, B). In 225 unselected autopsies union of all or a part of the right adrenal to the liver was found in 17 (7.6%) of the specimens. Much more infrequently one or both adrenals may be adherent to the kidney, usually at its upper pole.¹⁸ In such cases, there is usually not a complete capsule, the renal and adrenal cells mingling irregularly.

The left adrenal lies within the perirenal fat along the medial or superomedial border of the left kidney. It is more closely related to the kidney than is the right adrenal, and it is more easily drawn down with the kidney because its central vein drains into the midpoint of the left renal vein, while on the right the central vein fixes the gland high on the inferior vena cava. The left adrenal is semilunar in shape, and is usually somewhat broader than the right, which is compressed firmly between the liver and the diaphragm.

Because of these differences in shape and position, it is best to seek the left

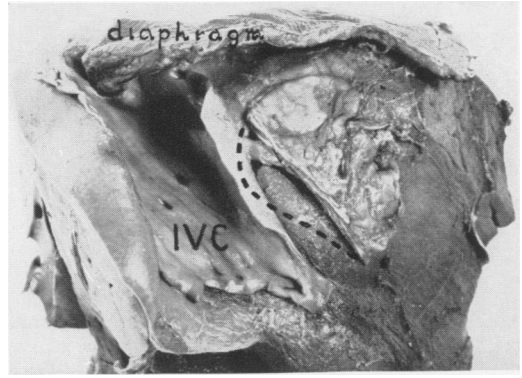


FIG. 1. Posterior view of right adrenal lying on bare area of liver, in *impressio suprarenalis*. Medial one-third (dotted line) removed to show central vein. Vena cava has been opened. Note hepatic vein entering vena cava below entrance of central vein.

adrenal in the perirenal fat between the upper medial border of the left kidney and the contiguous border of the aorta, while the right is most easily found by palpating the extreme superomedial border of the subdiaphragmatic space posteriorly. The upper border of the right adrenal gland is never surrounded by fat, and the firm rolled upper edge of the gland may be felt in this area by drawing the palpating fingers laterally and inferiorly against the liver (Fig. 1).

Exposure of the adrenals requires incision into two fascial compartments. The *transversalis fascia*, which lines the entire abdomino-pelvic cavity, fuses with the anterior and posterior layers of the thoraco-

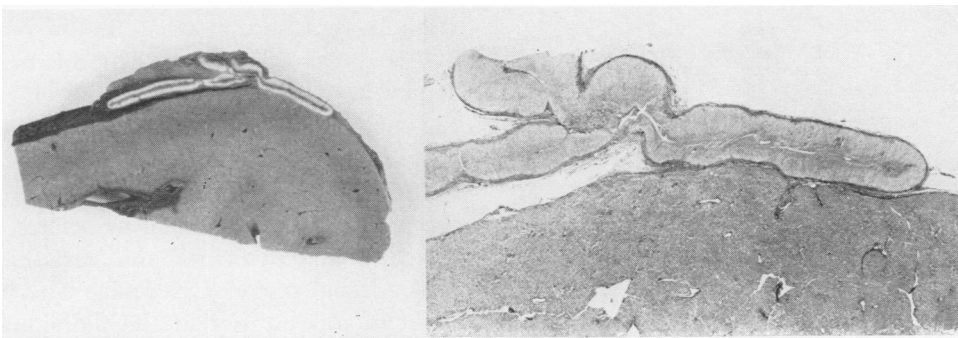


FIG. 2A. Same adrenal as in Figure 1, cross-section to show fusion to liver. B. Fused area of adrenal and liver capsules to show intimate union, $\times 10$.

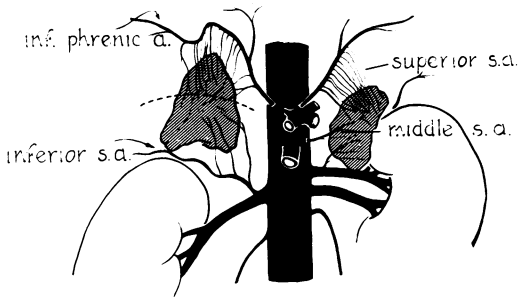


FIG. 3. Arterial supply of adrenals. Note small caliber of the feeding arteries, designated as superior, middle and inferior suprarenal arteries (s.a.).

lumbar fascia at the lateral border of the quadratus lumborum muscle. It continues over the quadratus lumborum and psoas muscles as their limiting fascia, and over the upper parts of these muscles it is thickened to form the medial and lateral lumbocostal arches, which give rise to portions of the diaphragm (Fig. 6). Since these arches lie well below the medial portion of the twelfth rib, the pleural reflection and pleural space also lie below and anterior to the medial portion of this rib. The pleura, therefore, may quite easily be opened accidentally in the posterior approach to the adrenal glands. The transversalis fascia is continued under the diaphragm as the inferior diaphragmatic fascia. At the tip of the twelfth rib the fused aponeurotic layer of thoraco-lumbar and transversalis fasciae may conveniently be opened to enter the retro-peritoneal space.

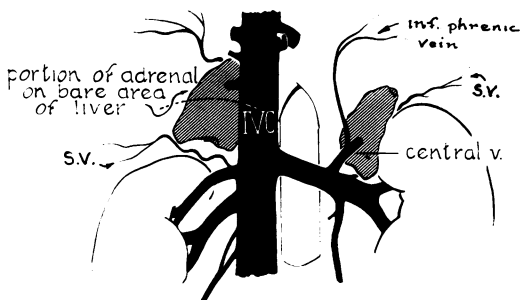


FIG. 4. Adrenal central veins. Small caliber veins also run with the arteries to suprarenal veins (s.v.) and inferior phrenic veins.

Immediately under the fascia is a variable layer of retro-peritoneal fat, usually not copious, which covers the *renal fascia* (Gerota's fascia).

The renal fascia encloses the kidney and adrenal in their covering of perirenal fat. It tends to be thicker posteriorly over the kidney, and to thin out superiorly over the adrenal. It is very variable, however, and when well-developed it passes superiorly to fuse with the inferior diaphragmatic fascia (Fig. 5). It ends to follow the upper border of the kidney as a firm fibrous-fatty pad lying between the kidney and adrenal, and it is usually deficient below the kidney, where the perirenal fat tends to mingle with the retro-peritoneal fat.¹⁵

In seeking the adrenals, the renal fascia must be opened. It is best to incise it as high as possible, for extensive dissection between the kidney and adrenal makes inferior mobilization of the gland more difficult. On the right, where traction on the kidney does not produce much dislocation of the adrenal because of its high fixation to the inferior vena cava, the gland is to be sought very high in the infradiaphragmatic space. It is of advantage to have opened the fascia near the upper border of the gland in order to avoid extensive tunnelling through the thicker fat at its lower border.

Arterial Supply

The *arteries* of the adrenals are copious, and run to the glands as multiple fine straight vessels, somewhat in the manner of the spokes of a wheel. There is no constancy in their origin, which may be from the inferior phrenic artery, the aorta, the renal artery of the corresponding side, or even from the spermatic or mesenteric arteries (Fig. 3). Anson and associates,² and Busch⁴ have described the variations of the adrenal arterial supply. The main point of interest is that the individual arteries are always very small. Because of their small caliber and great length, they

thrombose quickly when cut, and usually do not require ligation during removal of the gland.

Adrenal Veins

In contrast to the arteries, the adrenal veins are much more constant (Fig. 4). The main venous drainage of the adrenal gland is through the *central vein*. The left central vein is much longer than the right. It drains into the left renal vein just at the left margin of the aorta, usually in conjunction with the left inferior phrenic vein. It leaves the anterior surface of the gland in its lower one-third. On the right, the central vein also takes origin from the anterior surface of the gland, but it does so in the upper one-third, frequently from the apex (Fig. 1). It is very short and stout, and enters the lateral border of the inferior vena cava at once. It very frequently drains into the vena cava *above* the entrance of the lowest hepatic veins, a point not often emphasized in anatomical texts.

In addition to the central veins a second series of small-caliber veins runs parallel to the adrenal arteries and drains into suprarenal veins lying within the upper perirenal fat and also into the phrenic veins. On the left side communication with branches of the portal system through veins about the tail of the pancreas has been observed.¹¹

Variations of the adrenal central veins are not common. They are discussed by Franksson and Hellstrom⁶ and by Johnstone.¹⁰ The variations consist usually of a doubling of one or other central vein, and do not present a great problem during dissection. In 50 studies of this problem, we observed only two minor variations. In one, the right central vein arose from the right hepatic vein at its junction with the inferior vena cava, and in the other, also on the right, two parallel veins entered the vena cava in the usual place.

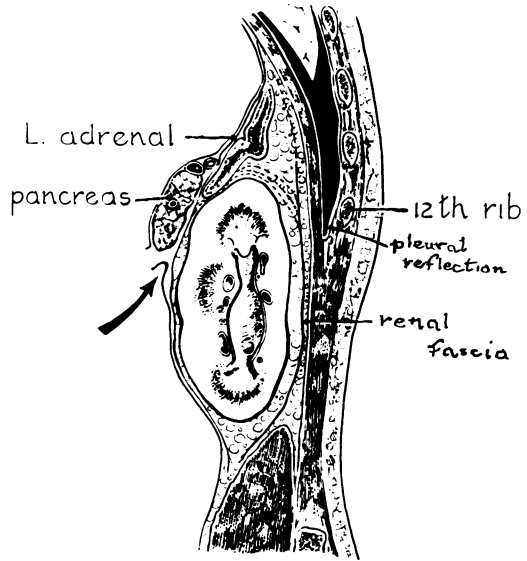


FIG. 5. Sagittal section through left kidney and adrenal. Arrow indicates route of access to adrenal under pancreas. Note thinning of renal fascia over adrenal, and fibrous extensions between kidney and adrenal.

Adrenal Lymphatics

The lymphatics of the adrenals drain into the upper lumbar chain by way of small channels accompanying the adrenal arteries. Other minor channels may run with the splanchnic nerves to nodes located in the posterior mediastinum. The cisterna chyli and the origins of the thoracic duct, lying on the bodies of the first and second lumbar vertebrae, are generally well-protected from injury by the aorta and right crus of the diaphragm behind

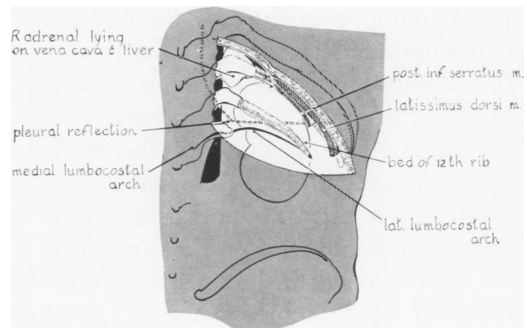


FIG. 6. Surgical anatomy of posterior approach to right adrenal.

which they are concealed, but they conceivably could be damaged during an extensive dissection of the adrenal area. Section of the adrenal lymphatics is often a cause for fairly profuse serous drainage from the wound for a few days after adrenalectomy.

Adrenal Nerves

The adrenals are served mainly by pre-ganglionic sympathetic nerve fibers which end about the medullary ganglion cells. They stream to the gland from the celiac plexus and the greater splanchnic nerves. A few fibers may come from the phrenic nerves. The greater part of the nerves supply to the adrenal glands ends in the medulla; the few fibers destined for the cortex appear to serve only the cortical blood vessels.¹⁹

Adrenal Ectopia and Adherent Adrenals

The adrenal sometimes may be located away from its usual position, or it may be so united to surrounding structures even when occupying its normal position that difficulties are experienced in its removal. True renal ectopia is rare. Weller¹⁸ reviewed 12 reports of adrenal-renal heterotopia, and added one of his own. In 11 of the 13 cases the condition was bilateral. In our series of 225 autopsies, unilateral inclusion of the left adrenal at the upper pole of the kidney was found in one specimen. Absence of one adrenal due to aplasia or extreme hypoplasia is an even more infrequent finding. In such cases, there is usually a considerable hyperplasia of the remaining gland. Fusion of the adrenals with surrounding structures is much more frequent. For all practical purposes it is fusion of the right adrenal with the liver which presents a difficulty of this sort at adrenalectomy. As noted above, adherence of all or a part of the right adrenal to the liver was found in 17 of 225 autopsy specimens, an incidence of 7.6 per cent. The union was such that very careful sharp dissection was required

to remove the gland without injury to the liver (Fig. 2B). Conditions for such sharp dissection do not usually exist during the usual operative exposure of the adrenal, and in most such cases the operator is forced to remove the gland piece-meal, or to incise the liver, with consequent risk of prolonged oozing from the cut surface.

Aberrant Adrenals

The frequency of occurrence of aberrant adrenal tissue has now been fairly well established by careful regional dissections of the various areas where it is known to occur. Graham⁹ found 32 of 100 autopsy specimens to have accessory adrenals in the area of the coeliac plexus. In a study of adult testicles, Nelson¹⁴ was able to report ten cases of aberrancy occurring in or near the epididymis. In only one was the nodule of greater than microscopic size. The number of testicles examined was not specified. Marchetti¹³ found only two microscopic rests of adrenal tissue in the ovaries of 1,200 postmortem cases. The occurrence of macroscopic gonadal aberrancy of adrenal tissue must therefore be relatively rare.

In the present study 50 complete retroperitoneal dissections were carried out to verify in a general way these findings. The dissection included the area of the adrenals and the celiac plexus, the tissues about the gonadal vessels and ureters, and a careful examination of the testicles or ovaries. The findings are as follows:

In strands of celiac plexus	21	42%
In periadrenal fat	7	14
In spermatic cord	3	6
In or near testis or ovary	0	—
Multiple accessories	13	26

Accessory adrenal nodules were found in 29 of the 50 cases, an incidence of 58 per cent. (In two cases multiple nodules were found and included at least one accessory gland in the spermatic cord.) These accessory adrenals are almost invariably of a similar color to the cortex of the main

glands, and are much easier to find when the main adrenals are hyperplastic and rich in lipoid. They are small round or oval structures varying in size from 2.0 to 8.0 mm. or more, and appear usually as brownish nodules irregularly flecked with lighter yellow areas. They do not usually contain medulla: we were able to identify medullary elements in only four of the 53 accessory glands which were found.

The importance of accessory adrenals at present is in their capacity for tumor development. This is not frequent, considering the frequency of aberrant adrenal tissue. Rapaport lists six adrenal cortical tumors arising away from the main glands in his excellent review of 277 cases reported in the literature.¹⁷ All of these were found in the upper retroperitoneal space, either above the kidneys or within the base of the mesentery, apparently arising in the area of the celiac ganglia. Others have reported isolated instances of adrenal tumors found at the lower pole of a kidney, within the retroperitoneal fat, or occurring as nodules palpable within the inguinal canal, but these appear to be rare. Adrenal medullary tumors, on the other hand, are well-known to arise frequently outside the adrenal glands. In his review of pheochromocytoma, Graham⁸ found tumors outside the adrenals in 23 of 207 cases, or about 10 per cent. The majority of these were found in the lumbar paravertebral space or anterior to the lower aorta.

Certain authors have stated that aberrant tissue may be searched for during adrenalectomy by one or another route. We do not believe that a complete survey is possible by any of the usual routes, for the crura of the diaphragm are firmly adherent to the upper surface of the celiac axis and to the aorta for a considerable distance inferiorly. Accessory glands occur most often within the meshes of the celiac plexus, and usually posteriorly. By any route, therefore, an extensive dissection is required to expose them, either by mobilization of the dia-

phragmatic crura and aorta from the posterior route, or by dissection of the celiac plexus within the root of the mesentery by the anterior approach.

Operative Considerations

The adrenals are relatively difficult to explore by any route. Experienced surgeons have developed preferences of approach to the glands, and have published their methods, to which the reader is referred. The following anatomical considerations, based on operative experience and dissections at the postmortem table, may be found to be of value.

In the translumbar approach^{6, 12, 20} it is important to avoid entering the pleural space during incision of the thoracolumbar fascia. This may be done by recalling that the pleural reflection descends below the medial portion of the bed of the twelfth rib (Fig. 6), and that a horizontal incision from the tip of the rib, or one following the lateral lumbocostal arch, will avoid injury to the pleura. Once inside the retroperitoneal space, it is easiest to find the right adrenal by palpation as high as possible against the liver in the posterior subdiaphragmatic space, in order to take advantage of the lack of fat which occurs at the upper border of the adrenal. Since the central vein arises near the upper medial border of the right adrenal (Fig. 1), it is of advantage to have located this border before beginning dissection of the gland. On the other hand, it is easiest to locate the left adrenal by seeking the medial-superior border of the left kidney, and carrying out the preliminary dissection between the kidney and the left border of the pulsating aorta. Injury to the inferior vena cava or to the left renal vein is not infrequent by this approach,¹⁰ and can only be avoided by careful exposure of the adrenal central vein prior to putting great traction upon the adrenal during its mobilization.

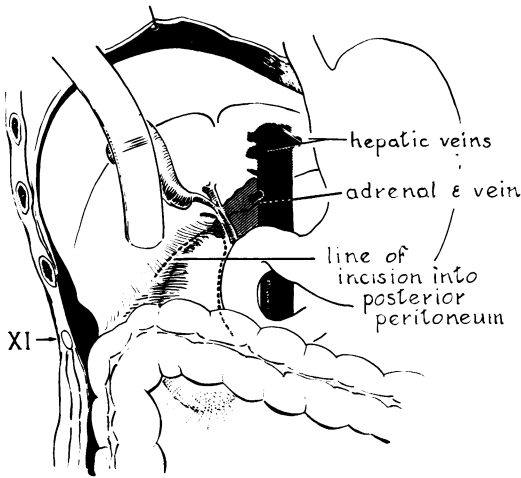


FIG. 7. Anterior operative approach to right adrenal, showing incision of posterior peritoneum at margin of bare area of liver.

The transabdominal route has been presented as more convenient, and with fewer complications.^{1, 3, 7} On the right, the dissection must take into account that the adrenal lies partly or wholly on the bare area of the liver, and that mobilization of the bulk of the liver superiorly must be effected (Fig. 7). In addition, the right adrenal lies partly behind the inferior vena cava, and careful dissection is required to free it from this structure. It is dangerous to attempt traction to bring the gland into better

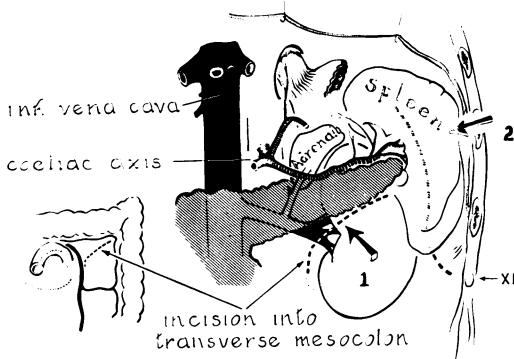


FIG. 8. Anterior operative approach to left adrenal. (1) Approach under pancreas. (2) Less desirable route, with mobilization of spleen and tail of pancreas medially. (3) Through gastrocolic omentum, not illustrated. Difficulty is here encountered in handling of adrenal vein.

view before ligation and section of the central vein, which should be carried out as early as possible in the procedure. On the left, three approaches are possible by the transabdominal route (Fig. 8). In each of them the tail of the pancreas must be mobilized to expose the left adrenal central vein. At the autopsy table it has always proved to be easier to gain a good view of the left adrenal by incision into the transverse mesocolon just below the lower border of the pancreas (Fig. 5), as recommended by Brady,³ than by mobilization of the spleen and tail of pancreas by lateral incision,¹ or by entry through the gastrocolic ligament and posterior peritoneum above the pancreas.

The transthoracic route has been recommended for removal of large adrenal tumors or of adrenal carcinoma. The excellent article of Chute and his associates⁵ should be consulted for operative details.

Summary

1. The surgical anatomy of the adrenal glands is presented from a survey of 225 specimens at the postmortem table.
2. The right adrenal is adherent to the bare area of the liver in 7.6 per cent of cases.
3. Accessory adrenal cortical tissue was found in 58 per cent of 50 specimens. Comparative figures are presented from the literature.
4. The three main surgical approaches to the adrenal glands are illustrated.

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