REPRINTED FROM THE PROCEEDINGS
OF THE ASSOCIATION OF AMERICAN
ANATOMISTS, 1900.

THE INTRINSIC BLOOD-VESSELS OF THE KIDNEY AND THEIR SIGNIFICANCE IN NEPHROTOMY.

By Max Brödel.

[PRELIMINARY COMMUNICATION.[1]]

In view of the enormous number of investigations of the different structures of the kidney recorded in the literature it seems strange that only scanty information exists on the actual course of the larger blood-vessels and their relation to the pelvis of the kidney. The normal and abnormal arrangement of the vessels at the hilum are well known and the microscopical pictures of the vessels in the cortex and pyramids are likewise thoroughly familiar to every student. But as to the actual form of the pelvis and the course and distribution of the larger vessels around its walls very vague ideas still prevail. It is evident that exact knowledge of the anatomy of this region would prove of the utmost importance to the surgeon in enabling him to open the pelvis of the kidney without running the risk of cutting large branches of the renal artery.

In order to study this region I made a large number (40) of celloidin injections of human kidneys. The injected

[1] Since this article was sent to press, I learned that Dr. William Keiller, of Galveston, Texas, has been following a similar line of research. His findings were embodied in a report to the Texas State Med. Soc., in whose Transactions for 1900 they appear. I have just received through the kindness of Dr. Keiller some of his specimens which substantiate many of the points brought forth in this paper, although the methods he employed differed essentially from mine. This being merely a preliminary communication precludes the possibility of discussing in detail Dr. Keiller's excellent work.

specimens were then digested [2] and the casts thus obtained, examined. Nearly thirty additional injected kidneys were not digested, but were cut into sections in various planes in order to control the results obtained by the method of digestion. Some of these sections were rendered translucent by the usual methods.

I made separate injections of the arteries, of the venous system and of the pelvis, combinations of any two out of three and finally triple injections. The great majority were of the last class. At first I confined my injections to kidneys which seemed normal so far as regarded form and size; later, after I had, in this way, determined the law according to which the vessels were grouped, I concentrated my attention upon abnormally shaped kidneys. The present paper will contain a short abstract of the main results of these studies. I shall confine myself to the description of the normal form and mention briefly only a few variations. A more elaborate communication will appear later.

The Pelvis of the Kidney.—From a surgical standpoint all forms of pelves may be classified under two main groups.

(1) True pelves with major and minor calices.

(2) Divided pelves, where there is no free communication possible between all of the calices inside of the kidney.

(1) *True Pelves.*—Fig. 1 shows the ideal form of a true pelvis. There are eight calices; the uppermost (1) and lowest (8) of which many have double papillæ. The remain-

---

[2] I employed Schieferdecker's corrosion-method, slightly modified by Mixter and Mall. The procedure was as follows: The vessels and pelvis of the kidney were thoroughly washed out and then dehydrated with alcohol and ether. The arteries, veins and pelvis were then injected with cinnabar, Prussian blue and arsenic preparations of an alcohol and ether solution of celloidin, respectively. The kidney was then placed in a digesting fluid consisting of varying amounts of 1:3000 pepsin (Sharp & Dohme) dissolved in 0.3 per cent to 0.5 per cent of HCl. The process of digestion was completed in from three to four days to two weeks. When the substantia propria and the connective tissue of the kidney were completely dissolved, they were washed out with a gentle stream of water, leaving only the casts of the injected vessels and pelvis. The casts were preserved in glycerin to which a few drops of carbolic acid were added.

ing six calices stand upon the pelvis in a double row; an anterior, irregularly arranged (2, 4, 6) and a posterior, more regular, row (3, 5, 7).

The horizontal axis of the pelvis (Fig. 1 D, *a*, *a'*) runs from the posterior surface of the kidney obliquely through the organ to the outer third of its anterior surface and the two rows of calices leave this axis at almost equal angles. The posterior calices, therefore, point to a line just a little posterior to the lateral convex border of the kidney (*b*), while the anterior calices are directed straight forward into the convex anterior region of the organ (*c*). This form of the pelvis is, next to the distended pelvis, the most favorable for a surgical incision.

The great majority of pelves have well defined major calices, with a very narrow lumen, and owing to this condition it is often impossible to gain access to the minor calices and remote pockets through a surgical incision into the pelvis at the site of the hilum. Furthermore, this incision must be short, as there is a constant branch of the renal artery running downward over the posterior surface of the pelvis at the hilum.

The varieties of the ideal form are very numerous and will be described in detail in the fuller communication above referred to. All kidneys with a true pelvis have a smooth surface or moderate degree of lobulation, regular outline and, as a rule, a normal blood-supply.

(2) *Divided Pelves.*—Fig. 2 shows the typical form of a divided pelvis. Comparing it with Fig. 1 one finds that between calices 2, 3 and 4, 5 there is a zone of cortical substance (*a*), which extends to the hilum. It divides the upper part of the pelvis from the lower, and in the majority of cases the lower portion receives the greater number of calices. Although the number of calices in divided pelves may be eight, they are generally more numerous. In other respects the topography of these pelves is similar to that of the true pelves. A kidney with a divided pelvis, as a rule, preserves its fœtal lobulations and has an abnormal arterial circulation; the division between the individual sections of the pelvis is generally marked on the surface by an especially

deep groove, thus causing the appearance as though there were two separate kidneys, one on top of the other. Frequently they are indeed separate organs as far as their secretory function and their arterial circulation are concerned. The veins, however, collect, as a rule, in one single trunk. These conditions are readily understood by one who is familiar with the different stages of the development of the kidney, with its origin, its ascent from the pelvis to the lumbar region and finally the wandering in of the vessels.

The Renal Artery.—The renal artery divides at the hilum, as a rule, into four to five branches, the distribution of which, in relation to the pelvis, is such that three-fourths of the blood-supply is carried anteriorly, while one-fourth runs posteriorly. The relative size of the two systems may occasionally be $\frac{4}{5} : \frac{1}{5}$, $\frac{2}{3} : \frac{1}{3}$, but rarely $\frac{1}{2} : \frac{1}{2}$. The arteries are end-arteries in the strictest sense of the word and the branches of the anterior division never cross over to the posterior side, or *vice versa*. They do not anastomose with each other.[3] The plane of division between the two arterial trees is indicated by the axes of the posterior row of calices (see Fig. 1 D *b* and Fig. 3 B arrow).

Fig. 3 B demonstrates this in a schematic way. The section is imagined as passing transversely through the middle of the kidney, as in the lower diagram in Fig. 1. The artery (*a*) sends a large branch (*a′*) anteriorly and a small branch (*a″*) posteriorly. Both branches are seen running close to the pelvis and the calices up to the region of the papillæ, whence they send off fan-like branches (*b*) around the pyramids. The anterior branch (*a′*) supplies the whole of the anterior pyramid (P) and the anterior portion of the pos-

---

[3] To Hyrtl apparently is due the credit of having first mentioned the "natürliche Theilbarkeit der Niere," by which he means that in a corrosion specimen the two arterial systems are completely separated by the pelvis. He also affirms that this arrangement of the renal arteries is found "without exception in all mammalia from the whale to man." [Hyrtl, Topographische Anatomie. Wien, 1882. Bd. I, pg. 834.] Hyrtl's statement has unfortunately been overlooked and up to this date the text-books on anatomy and surgery make no mention of this anatomical fact, so important to the surgeon.

terior pyramid (P′), while the posterior branch (*a″*) supplies only the remaining portion of the posterior pyramid (P′). The arrow indicates the division between the two vascular trees. *c* represents a section of the long lateral column of cortical substance, which is situated between the anterior and posterior rows of pyramids P and P′.

The greater part of the arterial circulation of the kidney follows this system. The entire region from calices 2 to 7 has this arrangement. Around the uppermost (1) and lowest (8) calyx, however, the arteries have a somewhat different arrangement (Fig. 4). They are derived from the anterior group of vessels and run either as a single trunk, having a diameter of 2-3 mm., to the base of the major calyx, or divide before they reach the calyx into three branches, I, II, III. Branch I and branch III run courses similar to those of branches *a′* and *a″* in Fig. 3 B, *i. e.* anteriorly and posteriorly to the calyx. It is obvious that their arrangement must prolong the arterial division, existing in the central portion of the kidney, upward and downward. Branch II may be short, as in Fig 3 A (upper pole), and vessels coming from branches I and III partially may take its place. Or it may be of considerable length, as in Fig. 5, where it makes a long sweep around the inner border of the pole. Branch II is the one that generally plays the rôle of the supernumerary artery; it may arise from the renal artery near its aortic origin (Fig. 5 *a* and *b*) or even from the aorta (Fig. 5 *c*); in the latter case it must be considered a supernumerary artery.

Although separate arteries are found in kidneys with smooth surfaces, they are much more frequently met with in those that have preserved their fœtal lobulation. This abnormal arrangement of the arteries is, perhaps, the cause of the persistence of the lobulated form. When he meets with a kidney having a distinctly lobulated form, the operator may expect to find a long hilum with separate arteries and an abnormal renal pelvis.

The further course of the arteries, the irregularities that may occur and to what extent they affect the above described schema, will be dealt with in a fuller communication.

The Renal Vein.—Concerning the veins, I shall here record only a few notes dealing with their more important characteristics.

While there is a complete arterial division in the plane connecting the posterior calices and terminating in the lateral half of the upper and lower calices, the veins follow quite a different arrangement. Around the bases of the pyramids they anastomose and form the familiar venous arches. They unite in large branches that run between the sides of the pyramids and the columns of Bertini to the necks of the calices, where they lie between the pyramid and the arterial branches. The thickness of these collecting veins accounts for the peculiar lobulated appearance of the base and sides of the pyramids (Fig. 6 B). Around the necks of the calices, both anteriorly and posteriorly, these veins form a second system of anastomoses (Fig. 6 B *b*) much shorter and thicker than that at the base of the pyramids (*a*). This appears as a number of thick loops or rings which fit like a collar around the necks of the calices. Nearly all the collected blood of the posterior region is carried anteriorly through these short thick stems, to join that of the anterior portion at the point indicated by *c*.

In comparing Figs. 3 and 6 one finds that an incision through the posterior row of calices would avoid all the arteries but would sever six of these collecting veins. As there remain, however, sufficient anastomoses at the upper and lower pole of the kidney, no serious consequence should follow an injury to these veins. The large veins at the hilum are generally described as being in front of the artery. This is, however, only the case in the neighborhood of the vena cava, while at the hilum and throughout the entire kidney the veins are usually situated between the arteries and the pelvis.

The Surface of the Kidney and its Relation to the Underlying Structures.—If one is thoroughly familiar with the kidney's surface it is a comparatively easy matter to determine the arrangement of the underlying structures; one can map out fairly accurately the position of the pyramids, of the columns of Bertini and of the calices; and as a consequence the position of the plane of arterial division can also be determined. Let us consider briefly the principal landmarks.

The anterior surface (Fig. 7 B) of a normally shaped kidney is convex and has its greatest prominence at the lower portion at the point indicated by *a*. The posterior surface (A) is somewhat flattened. A lateral view of the organ (C) shows this very clearly; there is also rendered visible a depression (*b b′*), which indicates the position of the lateral column above referred to, or the line of division between the anterior and posterior rows of pyramids. This depression, however, by no means indicates the division between the arterial systems, as below it is situated the greatest number of large vessels contained in the kidney. This line (*b b′*) is therefore a most important landmark and in every nephrotomy should be thoroughly mapped out. The other depressions on the surface indicate the positions of the margins of the individual pyramids or subdivisions of such.

Fig. 8 shows the same kidney as Fig. 7, with its pyramids and calices schematically drawn. The posterior pyramids (A 3, 5, 7) are long and slender, while the anterior ones (B 2, 4, 6) are more rounded at their base, thicker and do not extend so far laterally as the posterior pyramids. Consequently, the line of division (D *b* and *b′*) between the pyramids leans more towards the anterior surface of the kidney, so that the anterior surface of the organ bulges, while the posterior is flat.

Between the pyramids are the columns of Bertini which carry the larger vessels. Fig. 8 C shows that these columns join in a longitudinal column (*b b′*), in which all of the largest vessels of the kidney (three-fourths of the arteries and all of the veins) are found (see also Figs. 3 and 6).

As was said before, in lobulated kidneys this column is indicated as a distinct depression on the surface. The capsule seems thickened along this line and frequently forms a whitish band, to which the perirenal fat appears to be more intimately attached than elsewhere.

Lobulation of varying degrees of distinctness is found in the great majority of cases. The trained eye can detect this lobulation in kidneys which a novice would pronounce perfectly smooth. Should, however, the kidney present not the slightest depression or lobulation, the arrangement of the large stellate veins of the capsule will still serve to sufficiently locate the limits of the pyramids and the position of the important lateral longitudinal column (*b b'*, Figs. 7 and 8). These veins are found to be more conspicuous and are arranged in rows along the lines where the fœtal lobulation has been. (See Fig. 7.)

The Incision and Subsequent Suture.—The above described landmarks should suffice to guide the surgeon in making his incision so that the kidney can be readily opened between its anterior and posterior arterial branches.

Fig. 9 A shows the lateral view of the kidney; *a a'* represents a line showing the lateral convex border; *b b'* indicates the position of the lateral longitudinal column bearing the large vessels; *c c'* is the line along which an incision should be made. Diagram B shows the direction in which the knife should pass. An incision through the middle of the kidney (*d e*), would be inadvisable, inasmuch as it would cut through large vessels in region *f* and would fail to open the posterior calices. The proper direction is indicated by *c x*, the knife remaining in the posterior half of the kidney. The cut should be made anteriorly to the posterior papillæ (*p*) in order to avoid severing the collecting tubules of the posterior pyramids. It is advisable to palpate if possible the vessels and the pelvis at the hilum before making the incision, and if their arrangement is found to be normal, *i. e.* the pelvis at the posterior region of the hilum and the great majority of vessels anterior to the pelvis, then the above described procedure is applicable.

I wish to add a few suggestions as to the incision itself and also as to the subsequent suture.

A short incision is made into the lowermost posterior calyx if possible by means of blunt dissection (Fig. 1 A 7), and through this incision the pelvis is explored. In a collapsed state of the renal pelvis it may be difficult to enter one calyx. In such cases a moderate distention of the pelvis with sterile water or boric solution will facilitate the procedure considerably. If this short incision does not prove satisfactory, the three calices (3, 5, 7) should be carefully opened by means of an incision from within to the surface (Fig. 10). A curved knife will best answer this purpose. A glance at Fig. 3 A shows that short transverse incisions through the anterior or posterior parenchyma may produce little hemorrhage, provided they do not come too near the hilum. However, such incisions never open the pelvis satisfactorily.

The arrangement of the vessels in the kidney suggests the mattress suture as best adapted for approximating the two cut surfaces. Simple interrupted sutures almost always tear the tissues and produce an insufficient union. The mattress sutures are placed at right angles, or nearly so, to the large vessels and thus effectively prevent any tearing of the kidney substance. If the bight of the suture be 1½ to 2 cm., no strangulation of kidney substance should result. The sutures should be applied in the manner represented in Fig. 11.

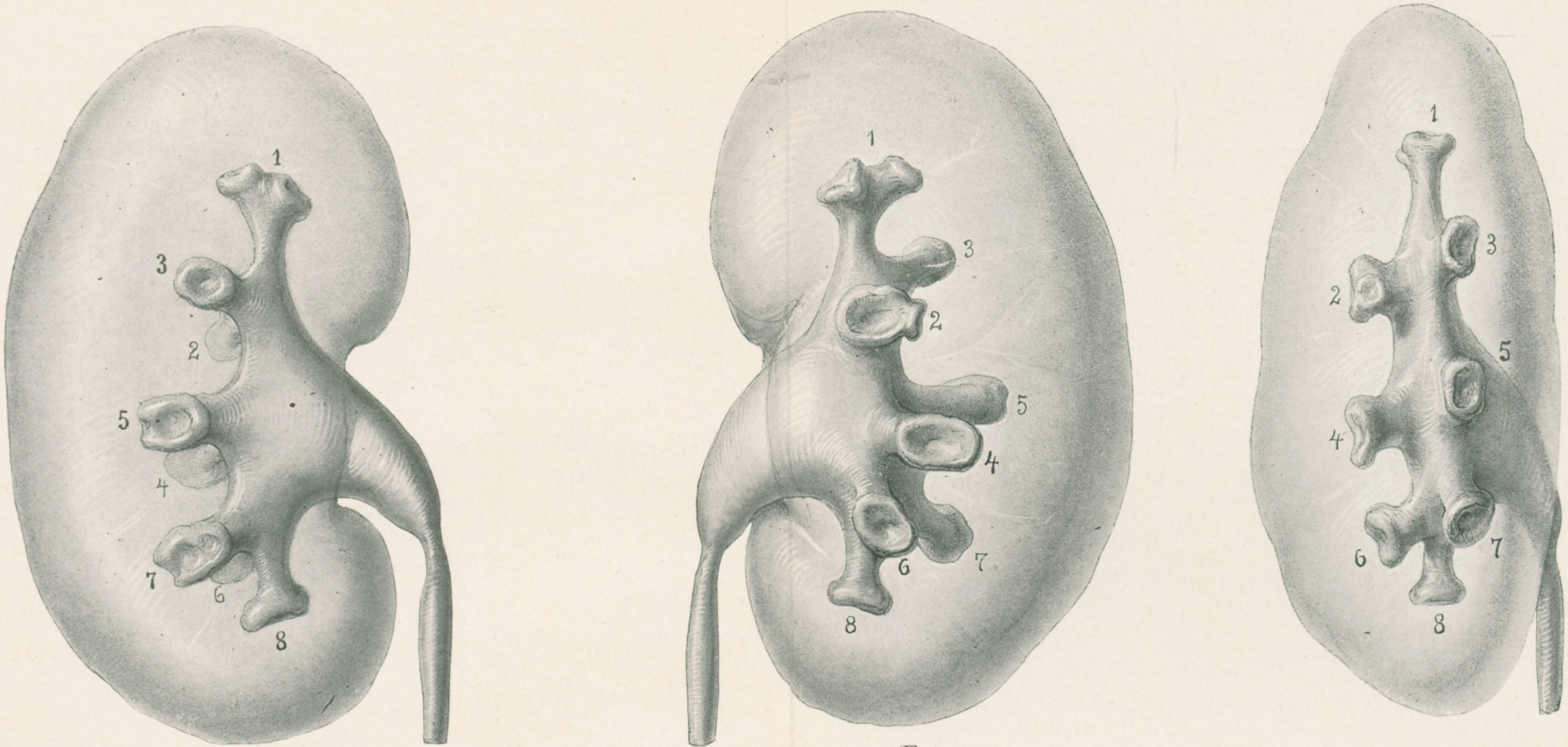
I. The pelvis is approximated with fine catgut sutures (*a*). These ought to be placed between the calices and take in only the fat, the outer fibrous coat and the muscular layers. The mucous membrane should not be included.

II. The second system of sutures should also be of catgut and should unite the region of the papillæ. They should be mattress sutures (Fig. 11 *b*) and are best placed by means of a long straight three-cornered needle with a blunt point, so that no injury to the large vessels results. A possible oozing would only serve to tighten the grip of these sutures and thus render them more effective.

III. The third system of catgut sutures should also be mattress sutures and be placed parallel to the second through the cortex near the bases of the pyramids (Fig. 11 *c*). Occasionally the third system of sutures is superfluous.

IV. The capsule is then closed in the usual manner (Fig. 11 *d*).

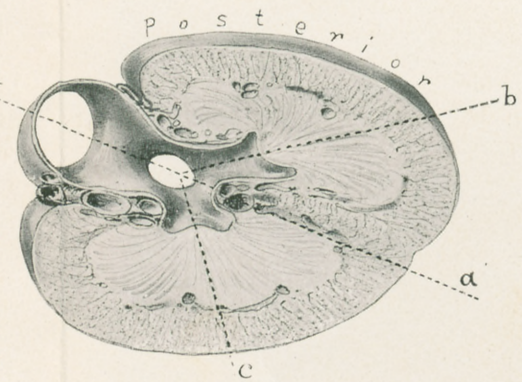
Dr. Holmes asked if Mr. Brödel had met with the anomalous distributions of renal blood-supply in which the vessels go to the poles of the kidney directly from the aorta, in addition to those to the hilum; and whether both sets anastomose. It may be considered a law that arteries which usually come from a common stem may spring directly from the parent trunk. Thus the three diverging branches of the external circumflex are often formed directly from the profunda or common femoral; or the inferior thyroid and transversalis colli from the subclavian; or gastric and hepatic from the aorta, the cœliac axis being absent. Conversely arteries closely associated may at times spring from a common trunk, as the superior and inferior profunda in the arm, or the facial and lingual in the neck. In the kidney the four or five branches which usually arise from the renal artery may come separately from the aorta and may be distributed to the poles as well as the hilum. This is of great importance to the surgeon, 1st because the amount of hemorrhage depends not only upon the size of the artery cut, but upon the size of the trunk from which it springs, and 2nd, because after ligating the mass at the hilum, he is apt to cut ruthlessly, ignorant of the possibility of large branches running to the extremities. Doubtless some of the profuse hemorrhages after nephrectomies are due to this.



A

B

C



D

FIG. 1.—Left kidney drawn as though transparent, showing form and divisions of a true pelvis. The major calices are not very marked, the minor calices being situated directly upon the pelvis.

A. Posterior view.

B. Anterior view.

C. Lateral view.

D. Transverse section through B viewed from above.

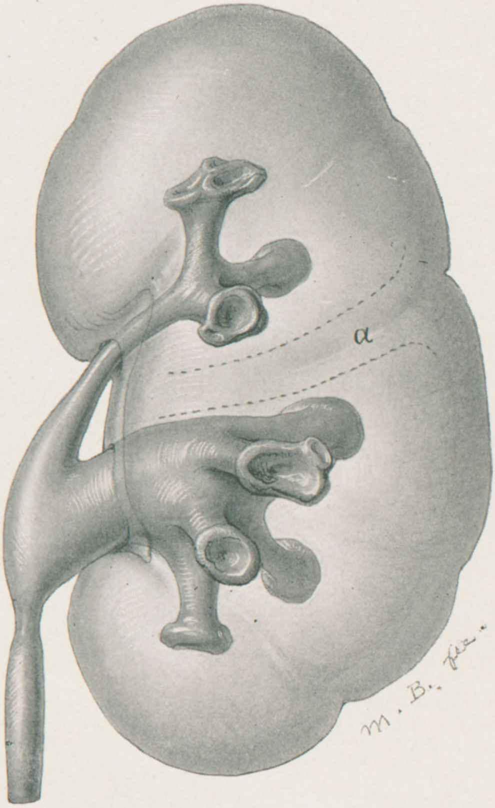


Fig. 2.—Left kidney with typical form of a divided pelvis. The two divisions of the pelvis are separated by an area of corticle substance (*a*) extending almost to the hilum. As a rule the upper division is narrow and has fewer calices than the lower. The division between the two branches of the pelvis is generally marked on the surface of the kidney by a deep depression.

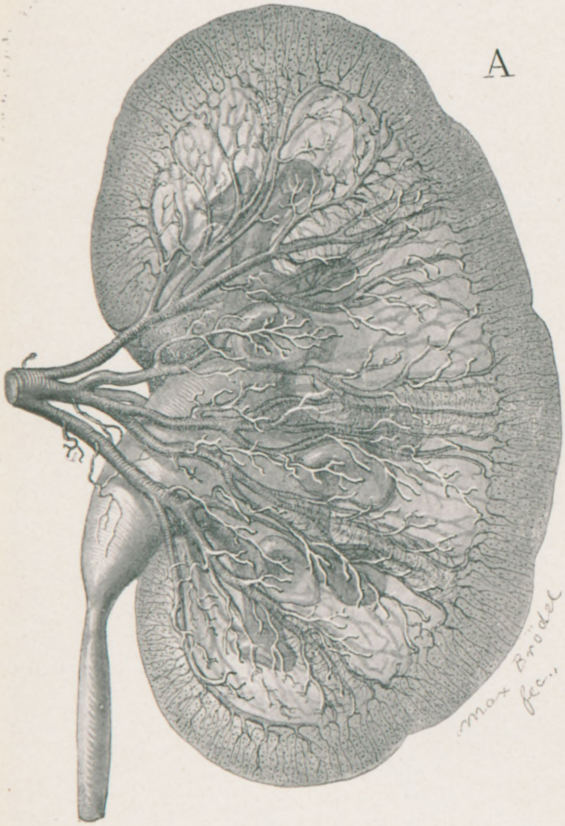
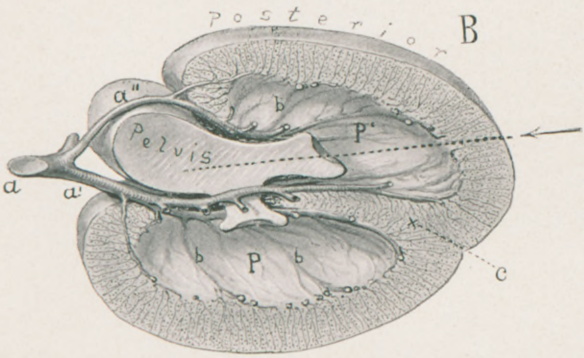


FIG. 3.—The renal artery and the distribution of its branches in relation to the pelvis.

A. Anterior view of a left kidney. There are 6 main branches seen entering the kidney substance. Only one of these (the third) passes posterior to the pelvis at the hilum, also small arteries coming from the upper and lower main branches are seen to pass posterior to the upper and lower calices. All the rest of the arteries pass anterior to the pelvis and its calices. The small branches to the cortex of the anterior portion of the kidney have not been drawn in order that the large branches and the pelvis might appear more distinctly.



B. Transverse section through the middle of the same kidney seen from above. The anterior branch of the artery supplies about ¾ of the kidney substance while the posterior branch supplies only ¼. The dotted line and arrow indicate the plane of arterial division.

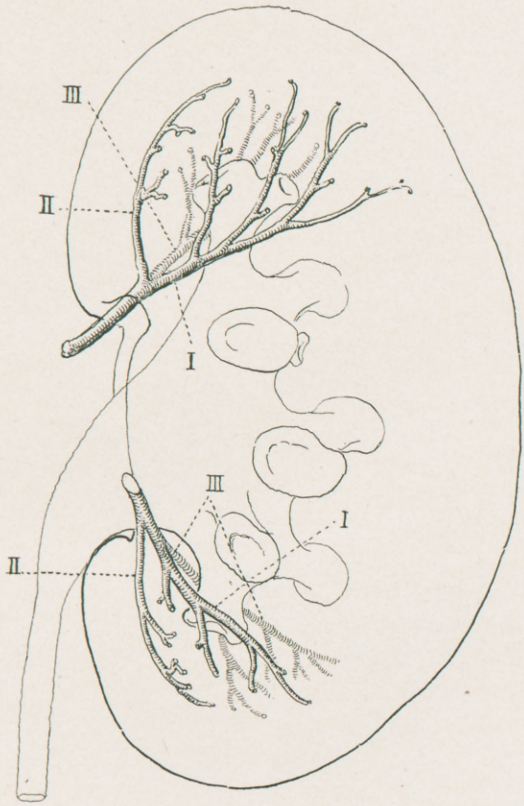


FIG. 4.—Arrangement of the arteries at the upper and lower pole. They come as single trunks from the main artery and run at an angle of 45° or more upward and downward to the vicinity of the major calices, where they divide into three branches.

I. Anterior branch.

II. Median branch.

III. Posterior branch.

The anterior and posterior branches are as a rule much larger than the median.

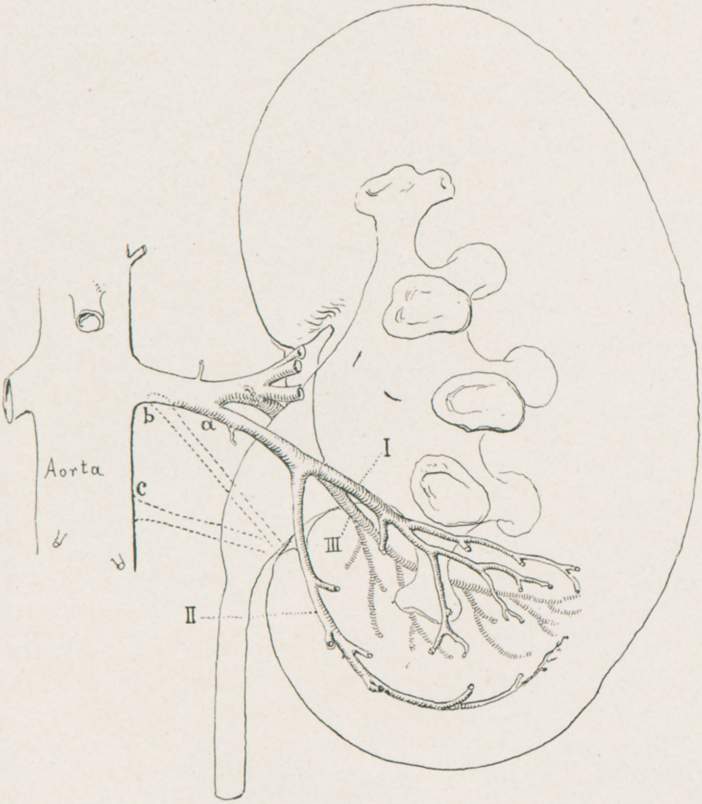


Fig. 5.—Variation of the median branch. This branch may be larger than usual and arise separately from the main artery at points *a* and *b*, or from aorta direct (*c*). It may be as large as the renal artery itself, in which case it gives off branches I and III or more. Such an arrangement of the arteries is as a rule associated with an abnormal form and position of the renal pelvis.

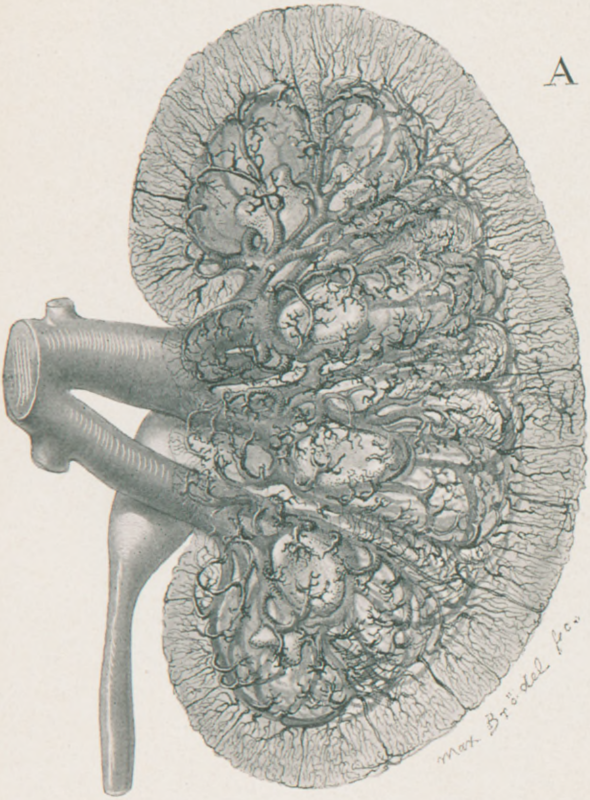
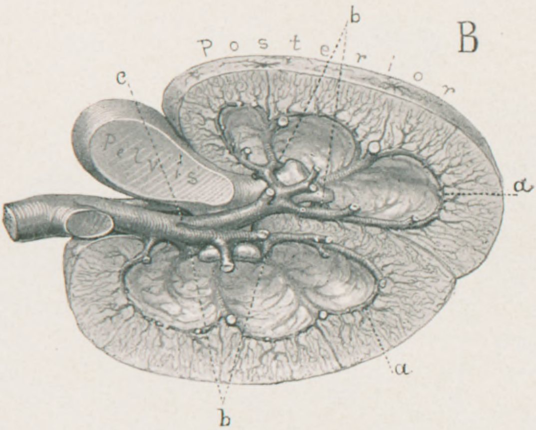


FIG. 6.—The renal vein and the relation of its branches to the pelvis of the kidney.

A. Anterior view of the left kidney. For the sake of clearness the small veins of the cortex of the anterior portion of the kidney have been omitted.



B. Transverse section seen from above. There is no collecting vein posterior to the pelvis; all the veins of the posterior region cross over to the anterior portion between the necks of the minor calices (*b*) to join the veins of the anterior region at a point indicated by *c*.

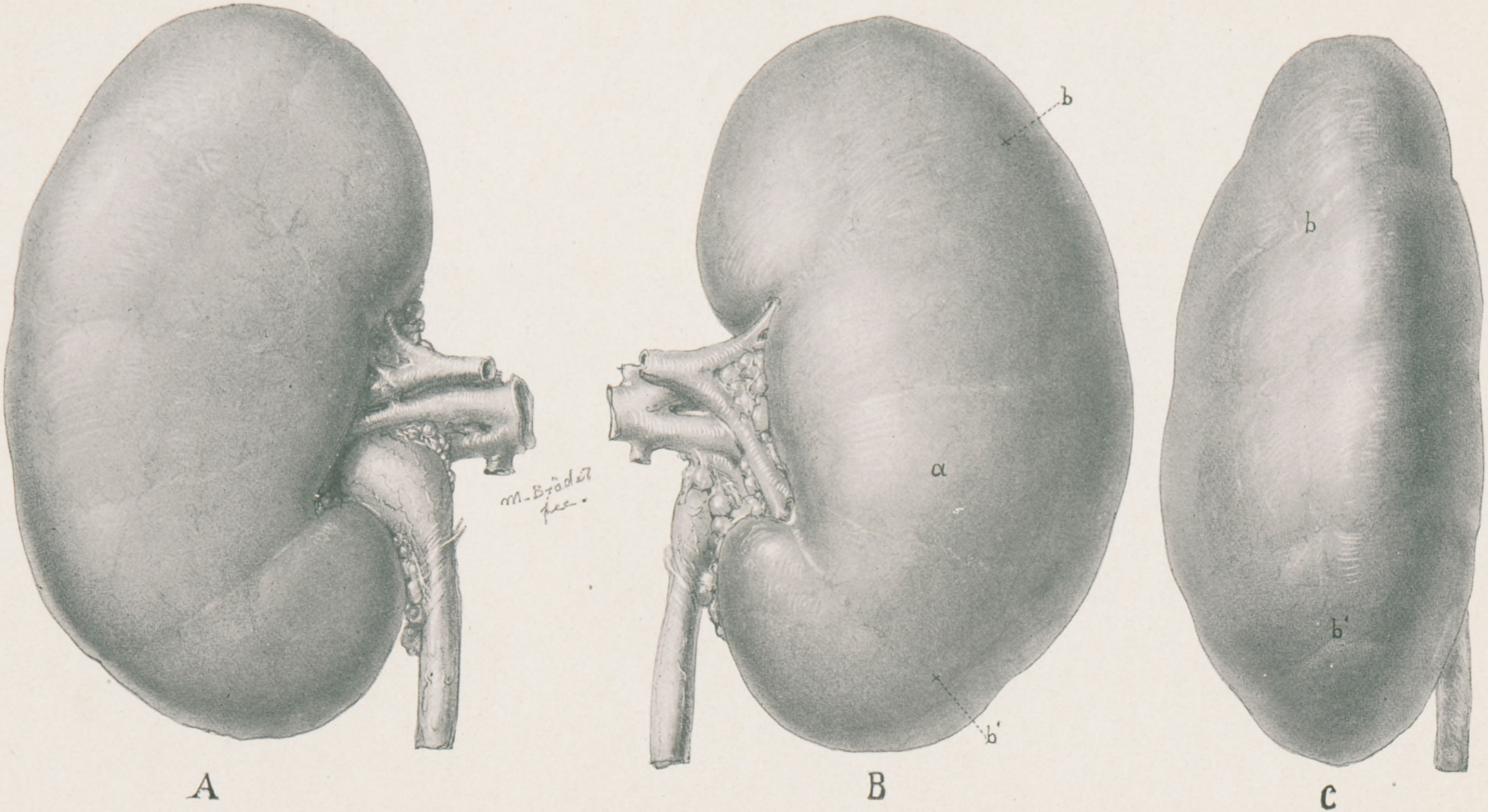
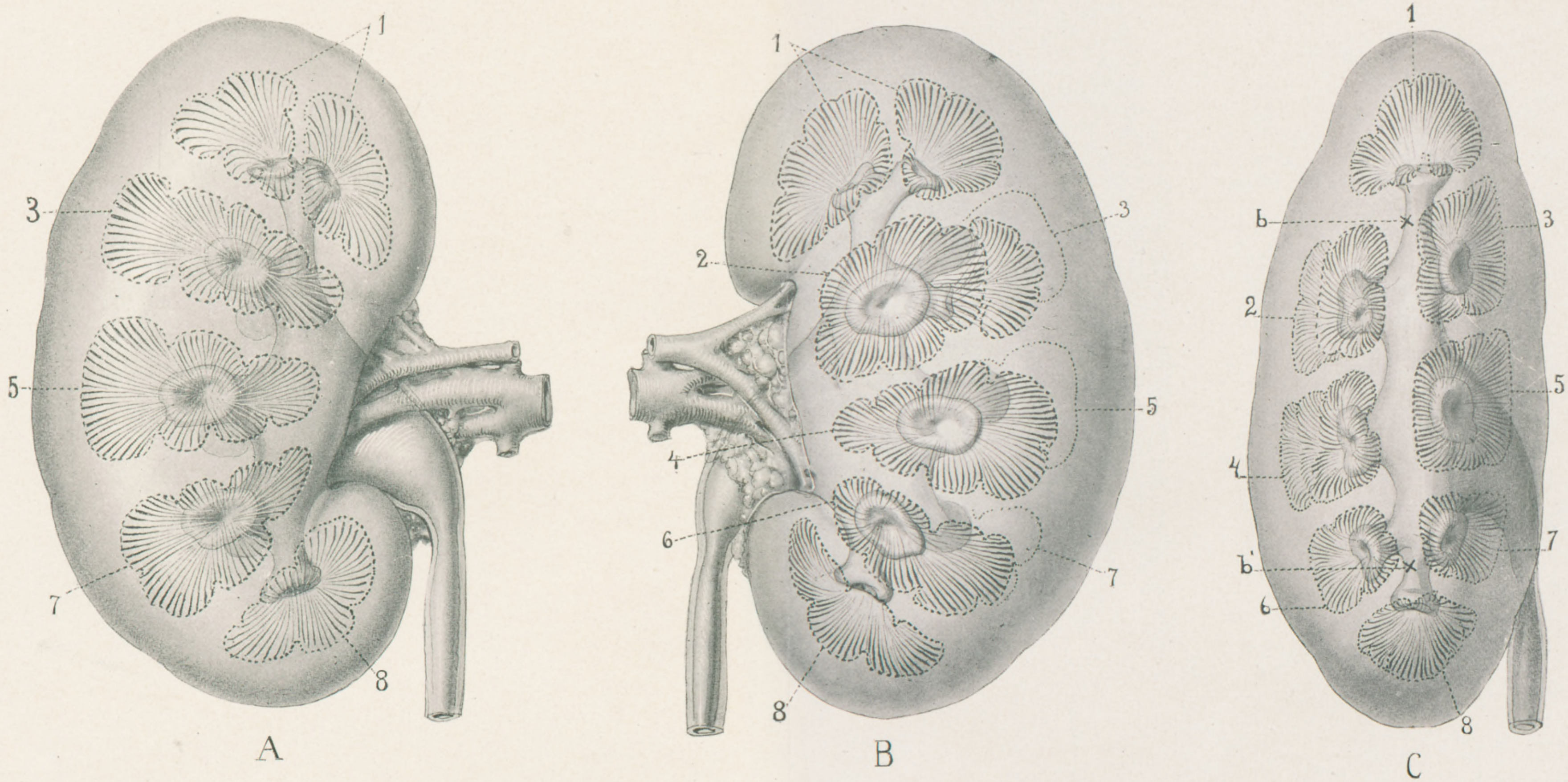


FIG. 7.—A normal left kidney. A. Posterior view. B. Anterior view. C. Lateral view.



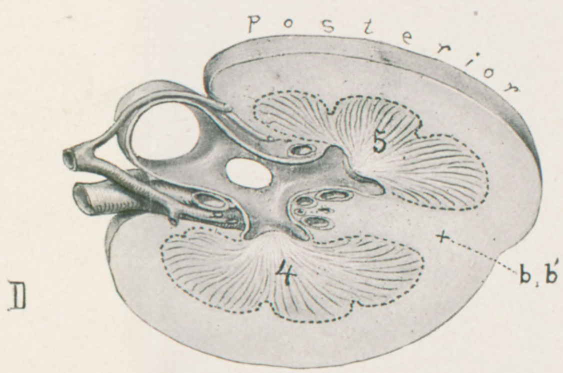


FIG. 8.—Same kidney as seen in Fig. 7 with a semi-schematic representation of the pyramids. The converging lines indicate the direction of the uriniferous tubules.

A. Posterior region.

B. Anterior region.

C. Lateral view.

D. Transverse section through B seen from above.

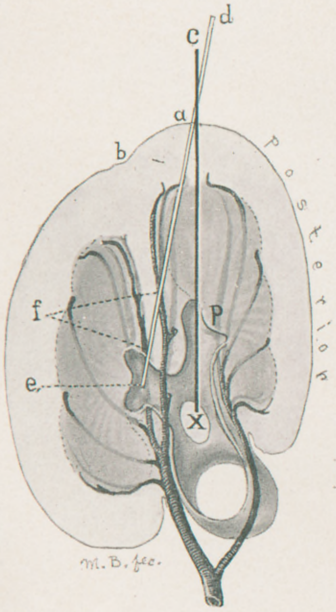
A

FIG. 9.—A. Lateral view of left kidney, showing the location of the most advantageous incision through the parenchyma in kidneys which have a normal arterial arrangement.

aa′ Lateral convex border of kidney.

bb′ Position of lateral column of cortical substance containing the vessels.

cc′ Best incision.



B

B. *de* Incorrect direction of incision

cx Correct direction of incision.

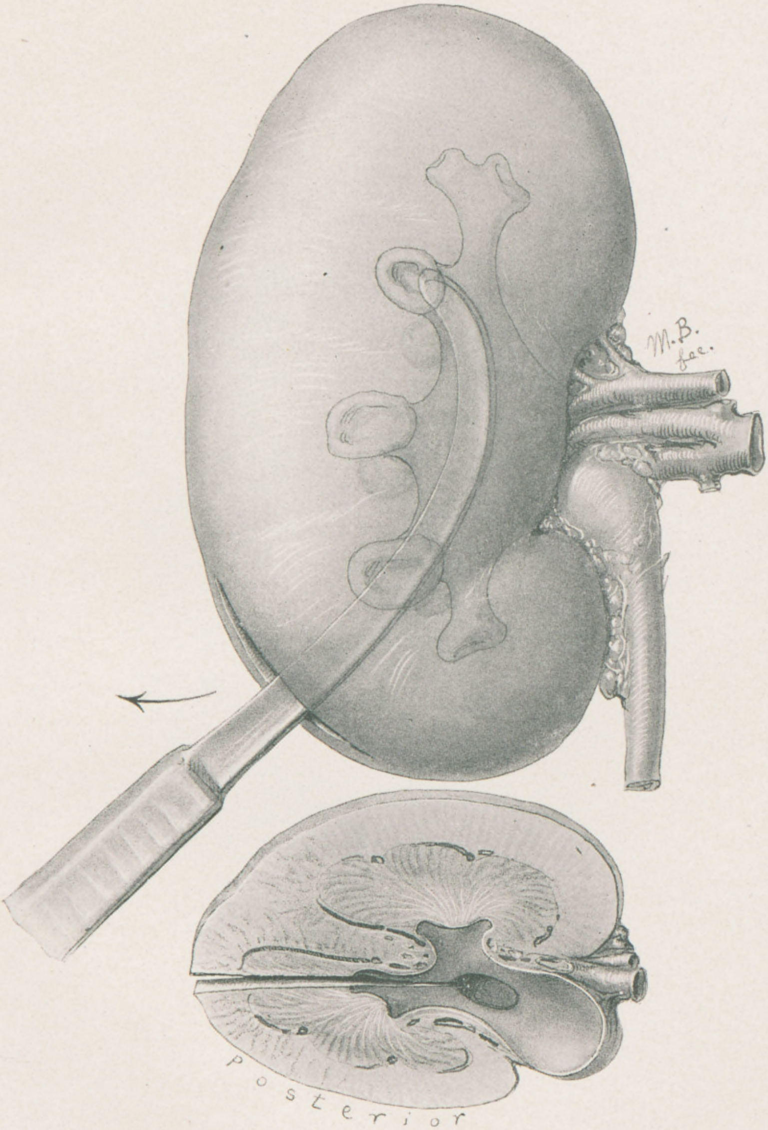


FIG. 10.—Posterior view of left kidney, showing method of exploring and opening the pelvis. The lower diagram indicates the direction of the incision in relation to the papillae of the posterior pyramids.

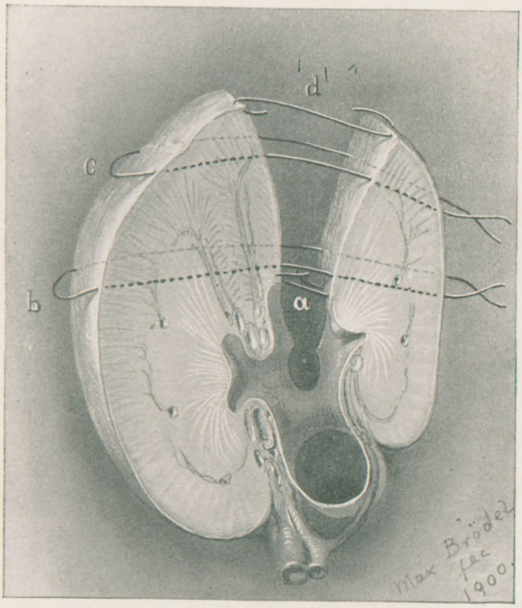


Fig. 11.—Imaginary transverse section through a kidney similar to Fig. 9 B, showing manner of placing the mattress sutures.