THE RADIOLOGICAL ANATOMY OF THE PARENCHYMAL DISTRIBUTION OF THE RENAL ARTERY—A REVISED APPROACH*

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In a previous study, Fine and Keen[1] described the arteries of the human kidney. This article describes the radiological confirmation of the modified anatomical concept, and also some aspects of its application in practice.

ANATOMY OF THE RENAL ARTERY

In a recent account of the distribution of the renal artery, Fine and Keen[1] analysed casts of the arteries, pelves and calyces of 107 normal kidneys. They introduced a concept of 3 primary branches of the renal artery (excluding the common but relatively small suprahilar artery or arteries, formerly called apical), and 2 secondary branches. The primary branches are the posterior, lower and upper arteries (Figs. 1 - 4). Large multiple (supernumerary, aberrant, accessory) renal aortic branches, which were seen in 25% of all casts, are readily recognized as one or other of the primary branches with unusually precocious origin; most often all or part of the lower artery, least often the upper artery. When the renal artery is single the first primary branch of the renal artery is the posterior artery in 60% and the lower artery in 30%; the rare occurrence of an early upper artery, or triple branching of the renal artery make up the rest. The secondary branches are (*i*) the intermediate artery (not described by previous authors) and (*ii*) the middle artery (Figs. 1 - 3).

The intermediate artery was present in 75% of the casts, and was a branch of the upper artery twice as often as it was a branch of the lower artery. This artery supplies the intermediate cortex between the upper and lower calyceal groups of a bifid pelvis, or between the upper and middle calyceal groups where the pelvis is divided into 3 major calyces (as it was in 25% of the casts). It also frequently sends a strong branch vertically down between anterior and posterior calyces (Fig. 1).

The middle artery was present in 75% of the casts and was a branch of the lower artery 3 times as often as it was of the upper artery. It supplies the parenchyma in front of the upper minor calyces of the lower major calyx (Figs. 2 and 3).

The posterior artery (a separate aortic branch in 8, and consisting of 2 separate branches in only 2 of 107 casts) normally crosses the back of the upper major calyx, or otherwise the upper part of the pelvis. It had a curved 'magistral' shape in only half of the casts; in other cases it bifurcated, or divided into ascending, transverse and descending branches. The posterior segment was of variable size, and included the lateral renal border and part of the anterior parenchyma in half of the casts. It included the posterior half of the upper end of the kidney in half the casts, and in a few casts also supplied anterior paren-

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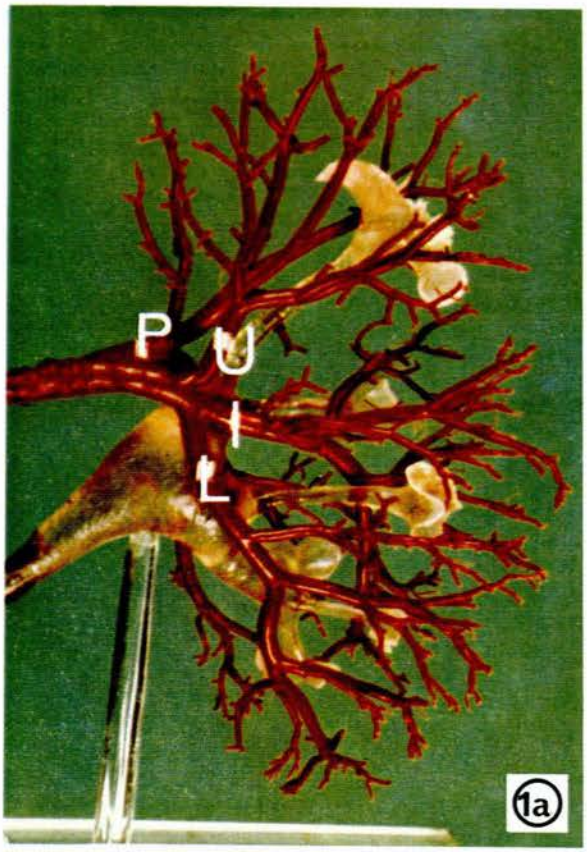
Abbreviations used in labelling the illustrations:

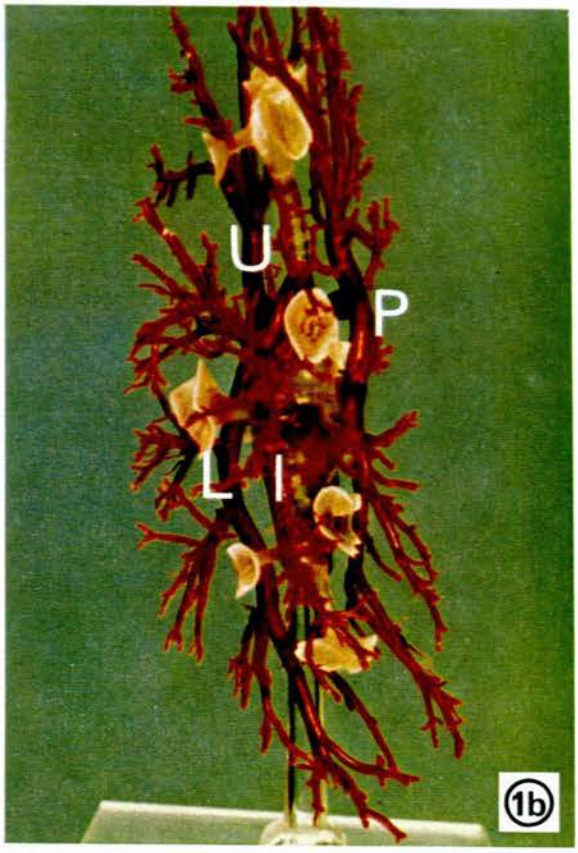
RA = renal artery.
U = upper artery.
P = posterior artery.
L = lower artery.
aL = anterior branch of the lower artery.
pL = posterior branch of the lower artery.
I = intermediate artery.
M = middle artery.
SH = suprahilar artery.

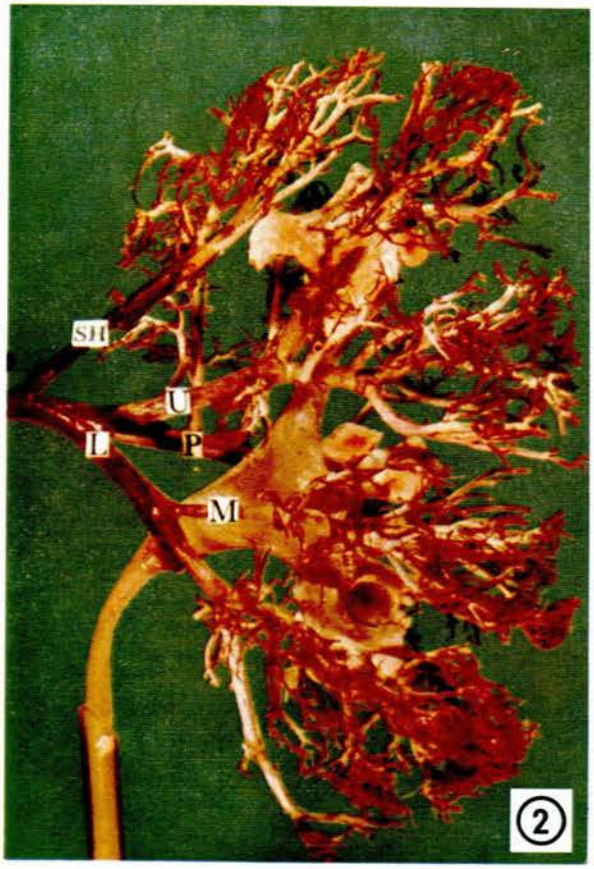
Fig. 1. Anterior and lateral views of a cast of the arteries and pelvicalyceal system of a left kidney. The intermediate artery is strongly developed. The posterior artery supplies an unusually large part of the lower end of the kidney, and its lowest branch is in an unusually medial position.

Fig. 2. Anterior aspect of a left cast. Note the large suprahilar artery. The lower artery is the first primary branch of the renal artery, and has a large middle branch. The intermediate artery is a branch of the upper artery, and is limited to an area above the middle artery.

Fig. 3. Anterior aspect of a right cast. The intermediate and middle arteries are well developed and the lower artery has a strong posterior branch. The posterior artery is coloured blue.







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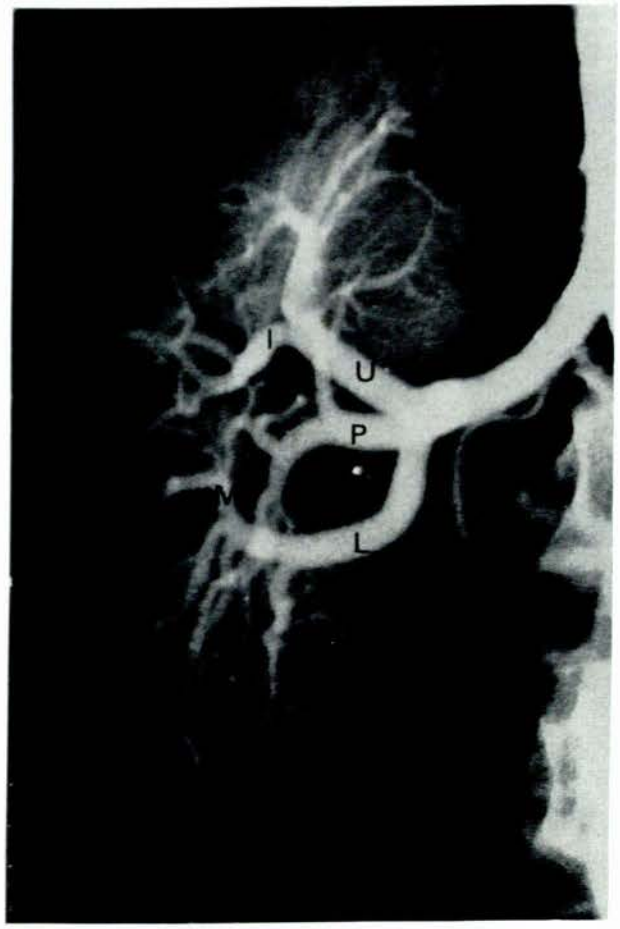


Fig. 4. Right renal angiogram demonstrating a common pattern of distribution into upper, posterior and lower arteries. The upper artery gives an intermediate branch. The lower artery is of an unusual shape. Note that ascending branches of the posterior artery cross the upper artery.

chyma at the upper end. It rarely reached the lower end of the kidney, as this is almost always supplied by the lower artery.

The lower artery (all or part of which was a separate aortic branch in 15, and consisted of 2 separate branches in 6 of 107 casts) runs down the front of the pelvis. After crossing its lower border, it normally divides into anterior and posterior branches with a variable relationship to the lowest calyx. In more than half the casts the lower artery was the origin of a middle artery, and in about a quarter gave off an intermediate artery. The lower segment usually incorporates both front and back of the lower end of the kidney, and is normally more extensive anteriorly.

The upper artery (an aortic branch in 3 and consisting of 2 separate branches in 11 of 107 casts) was usually situated medial to the pelvis and upper major calyx (Figs. 2 and 3). The upper artery often consisted of a main stem clearly ending as the intermediate artery; the upper anterior part of the kidney was then supplied by one or more branches of the main stem. In all, the upper artery gave rise to an intermediate artery in nearly half the casts. In one-fifth of the casts the upper artery was the origin of a middle artery. The upper segment was variable in size, and shared the upper end of the kidney with the posterior artery in half the casts; branches of the upper artery passed backwards to supply parenchyma on the back of the upper end in a further 40%.

Subsequent Study

The casts were again studied at the stage of radiological correlation, to determine further details of the relationship between the main stems and more peripheral distributions of the branches of the renal artery. Damage to casts slightly reduced the number available for study. The casts were placed in anatomical obliquity, and viewed from the front.

In 103 casts, we first examined the upper, intermediate, middle and lower arteries to determine whether any of these crossed each other. We also studied the posterior artery and its branches to determine whether these branches crossed each other, and to see where they crossed anterior branches.

The following observations were made (excluding the fine terminal branches which often overlap and cross in marginal areas).

Except for the intermediate artery in some instances, the arteries in front of the pelvis and calyces did not cross each other. They supplied regions serially from above downwards, and these arrangements may be borne in mind in angiographic analysis.

In 22 out of 103 casts the intermediate artery crossed a middle artery from above downwards (Fig. 1); it crossed branches of the lower artery in only 2 casts.

In 92 casts where the lower artery could be examined in detail it divided into anterior and posterior branches in 86 (Fig. 6b). The relationship between these two was variable, but it was more common to find the posterior branch below or medial to the anterior branch. In the remaining 6 the lower artery was confined to its anterior distribution, because the posterior artery supplied the whole of the back of the kidney including its lower end.

As observed in the arrangement of arteries in front of the pelvis, the branches of the posterior artery on the back of the pelvis and calyces did not cross each other (Figs. 4 and 7b).

The main stem of the posterior artery bore no constant relationship to the upper artery, but in 25% of the casts these arteries crossed each other. In such cases the ascending artery was usually the upper.

In 96 casts the relation of the main stem of the posterior artery to the main stem of the lower artery could be observed. In all but 7 the posterior artery lay above and lateral to the lower artery (Figs. 2 - 4); in all 7 exceptions it crossed from a medial or lower position to its normal situation.

In more than half the casts upper branches of the posterior artery were seen to cross the upper or intermediate arteries. The upper branches of the posterior artery regularly crossed from a position below and lateral, to a position above and medial to the upper or intermediate arteries; there was only one exception to this in the whole series.

In nearly half the casts crossings of the intermediate and/or the middle artery with branches of the posterior artery in the middle zone of the kidney were seen. No consistent pattern of crossing was observed.

The lower branches of the posterior artery were frequently seen to cross branches of the lower artery. No consistent pattern of such crossings was found, but as the identification of the lower artery in arteriograms is usually easily made from the position of its main stem (see above), the branches crossing the branches of the lower artery identify themselves as branches of the posterior artery.

Circumferential Position of the Origin of the Renal Arteries

During the course of the present work the question of inserting aortic catheters into the orifices of the renal arteries gave rise to the following observations on the circumferential position of origin of these arteries. Segments of aorta including the origins of coeliac, superior mesenteric and renal arteries were removed and opened from the back. Measurements were then made of the aortic circumference and the distance from the middle (arbitrarily taken as the centre of the superior mesenteric origin) of each renal artery. Assuming a circular cross-section of the aorta, these figures can be transformed into angles at which the renal artery origin occurs. These angles are read from the mid-line anteriorly, so that the figure of 90° means a perfect lateral origin, lesser angles anteriorly inclined origins, and larger figures posteriorly inclined origins. Table I gives the angles of origin in 55 cases with single renal arteries on both sides.

TABLE I. ANGLES OF ORIGIN OF 55 RENAL ARTERIES

Angle	*Right*	*Left*
74° or less	33	15
75° — 84°	12	14
85° — 95°	6	15
96° — 105°	3	6
106° or more	1	5
Total	55	55

Taking each aorta and comparing the distance in mm. round the circumference of the 55 pairs of right and left renal arteries, in 26 cases the left artery was 2 mm. or more further round the aorta, in 25 cases they were not different by more than 1 mm., and in 4 only was the right artery found to be further away from the middle by 2 mm. or more.

These two approaches lead to the same conclusion. The origin of the right renal artery is most often anterolateral in position, whereas the left renal artery branches off from the lateral or anterolateral aspects of the aorta. Only in rare cases do the renal artery origins approach a posterolateral position.

It is therefore interesting to read in Barr Stirling's book on aortography, published in 1957,[2] that 'The renal arteries arise . . . from the posterolateral aspect of the aorta . . .'. This statement must, in our opinion, be rejected. The truth of the anatomy described above has been confirmed in this study by the radiologist performing aortography. He has stated that his chances of successful selective catheterization of a renal artery have much increased since he started turning his catheter point forwards rather than backwards. It is also apparent that when it is desired to obtain a clearer view of the origin of the right renal artery in aortographic studies, then it is advisable to rotate a supine patient to the right.

ANALYSIS OF RENAL ARTERIOGRAMS

Ninety-four aortograms were examined with the possibility of analysing the renal arteriograms in mind. From the 188 possible renal arteriograms it was found that we could analyse 126. In many cases pyelograms were also available. The following observations were made.

Pelvic Outline

In 39, either there was no intravenous pyelogram available, or the pyelogram was unreadable. In the others, we observed what appeared to be a bifid pelvis in 77, a pelvis with 3 major calyces in 9, and a 'rosette' formation in 1 case. Considering the bifid pelves, we found that middle calyces were seen in all but 8 of the 77. They were derived from both major calyces in 29 cases, from the lower major calyx alone in 29 cases, and from the upper major calyx in 11 cases.

Method of Renal Artery Division

In 106 of the 126 arteriograms, the renal artery was a single artery. The first branch of the renal artery was the

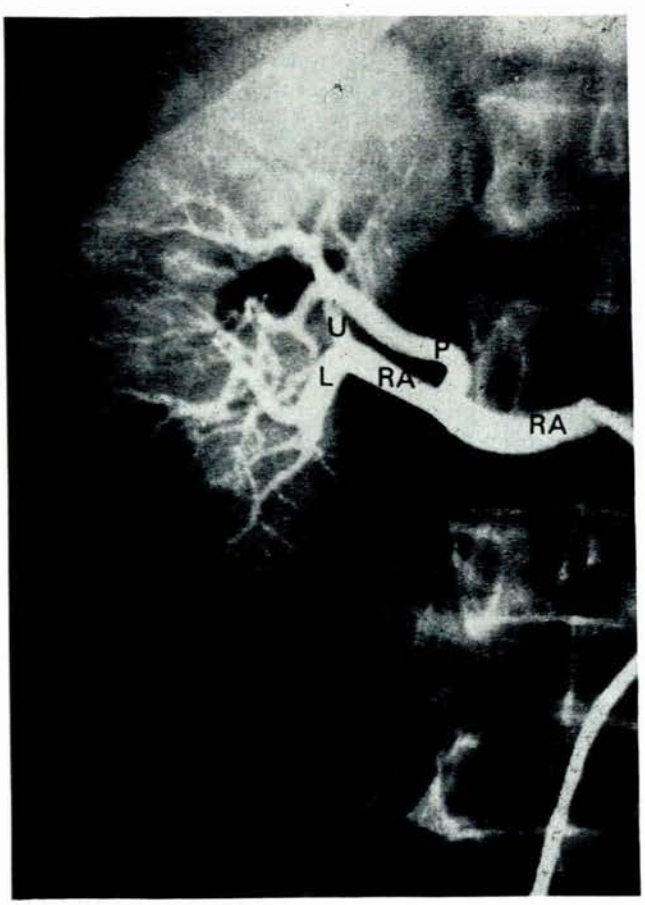


Fig. 5. Selective injection of a right renal artery. The posterior artery takes off early, and the renal artery continues to divide into the larger calibre lower artery, and the smaller calibre upper artery.

posterior artery in 66, the lower artery in 20, and the upper artery in 4. In 16 it was not possible to read the division as other than a triple origin of the three major branches. With regard to multiple aortic origin, 18 aortograms showed two renal arteries on one or other side; in 17 of these the smaller artery was the lower artery, and in 1 it was an upper artery. It is noteworthy that no examples of aortic posterior arteries were found in this series.

In 2 cases 3 aortic branches supplied the kidney. In each of these cases it was possible to analyse the 3 as being posterior, lower and upper arteries respectively (Fig. 6).

Summarizing these findings, in 52% of cases the posterior artery was the first branch of the renal artery, in 29% the lower was the first branch (or had a separate aortic origin), and in 4% the upper artery was the first branch (or had a separate aortic origin). In 13% the renal artery showed triple branching. The 2 cases with 3 aortic branches of supply have already been mentioned.

Shape of Posterior Artery

In considering this matter, we became obliged to limit the concept of a magistral posterior artery. Whereas previously a curved shape has been thought to be an essential part of this term, we found it necessary to use it to mean a stem from which subsidiary branches are given off even if it did not have a typical curved shape. Using this concept, in the 126 cases 57 had a magistral shape (45%), 64 (51%) were bifurcate, and 4 (3%) were cruciate in shape, while in one case the posterior artery consisted of 2 branches from the renal artery. It will be noted that the proportion here is rather different from that published by two of us.[1] An explanation may be that the image of the posterior artery in a radiograph is much affected by differences in the centering of the X-ray tube, and possibly also by calibre changes during life which would not be apparent in casts made on post-mortem material.

Size of the Posterior Segment

We attempted to estimate the size of the segment of the kidney which this artery supplied. We found 17 cases where it seemed to extend over the whole of the back of the kidney, including both poles. A large posterior segment extending to the upper end of the kidney was seen in 57 and a smaller segment also extending to the upper pole in 14. In 36 cases the posterior segment occupied the middle zone of the kidney without extending to either pole, and in 2 cases only it was observed to extend to the lower pole without occupying the whole back of the kidney. In summary, 88 posterior arteries (70% of the series) extended

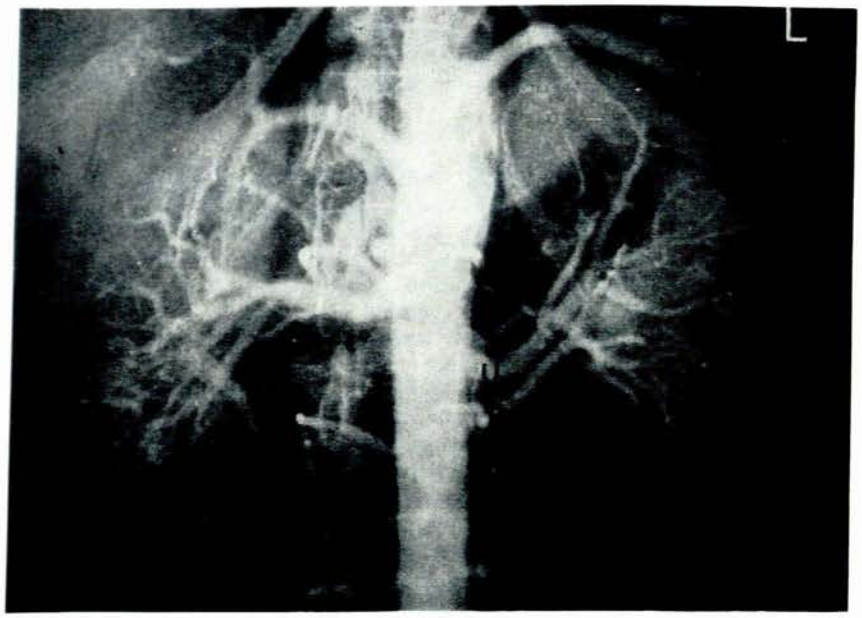


Fig. 6. Triple aortic supply of normal left kidney with selective catheterization of each aortic branch. *6a.* Panaortogram reveals triple aortic origin on the left side. Note that the lower artery has the highest origin.

Fig. 6b. Selective injection of the lower artery and the nephrogram phase. A small middle artery is present and the anterior and posterior branches are clearly visible.

to the upper pole of the kidney, and 19 (15%) reached the lower pole of the kidney. These observations agree well with our previous anatomical findings, and suggest that the ideas about posterior artery segments which we then postulated are valid in this series.

Upper Artery

The upper artery consisted of 2 separate branches in 16 of the 126 arteriograms. In these 16 the upper end of the kidney was thus supplied by more than one branch arising from the renal artery, whether before or after the origin of the first primary branch. The extent of the upper segment was estimated, and was considered of medium size, as judged from experience of casts and radiographs, in half the arteriograms. In the remainder, the segment was judged large in 42 cases, and smaller than usual in 14 cases.

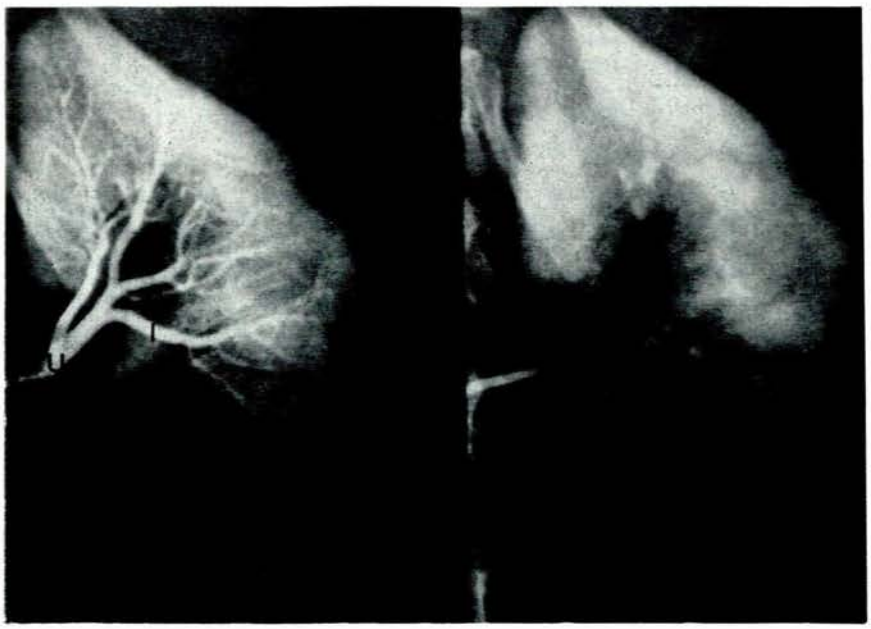


Fig. 6c. Selective injection of the upper artery and a large suprahilar branch supply the front and back of the upper part of the kidney, respectively. The nephrogram phase is reproduced.

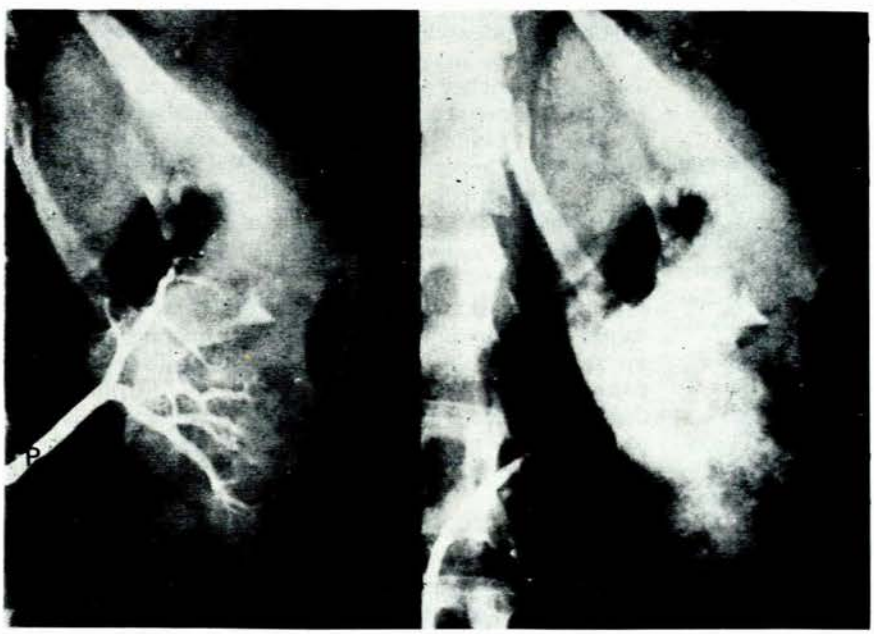


Fig. 6d. Selective injection of the posterior artery which bifurcates. Note that no branch reaches the upper part of the kidney (*cf.* distribution in Fig. 6c). Nephrogram is reproduced. The posterior artery supplies the posterior hilar lip.

Lower Artery

The lower artery was the most constant and easily recognized feature of the arterial picture, and divided into anterior and posterior branches in all but 23 cases (18%). It was a separate aortic branch in 17 cases.

Intermediate Artery

In 28 cases (22%), no intermediate artery was detected in the pattern. A type 1 intermediate artery (associated with upper artery) was seen in 73 cases (58%). In these 73 cases the artery called 'upper' ended as the intermediate in 47, bifurcated in 16, and gave off the intermediate as a branch in 10. A type 2 intermediate artery (associated with the lower artery) was present in 25 cases (20%). Again these observations agree quite well with the anatomical observations previously made, and lend weight to the certainty with which we have identified the intermediate artery in these arteriograms. In the arterial pattern the intermediate artery was seen to cross branches of the posterior artery in 65 cases, and the middle artery in 6 cases, while in 27 cases the intermediate artery crossed neither a middle artery nor the posterior artery.

Middle Artery

In the 126 arterial patterns no middle artery was observed in 53 cases. Of the 73 middle arteries observed, 65 were branches of the lower artery and 3 were branches of a type 2 intermediate artery, making a total of 68. From the upper artery only 3 middle arteries were seen branching, and 2 from a type 1 intermediate artery. Comparison with the anatomical series shows that fewer middle arteries were seen, and the deficiency was in the middle arteries arising from the upper artery. It seems to us that this can easily be explained when it is realized that the definition of a middle artery as supplying the parenchyma in front of the uppermost calyces of the lower group makes it difficult to recognize this artery when the pelvic outline is not visualized. It follows that we may very well have missed

a number of middle arteries from the upper artery in the radiological series which we would have recognized in the anatomical series.

Suprahilar Artery

This artery was seen in 36 cases (29%), and was absent in 90. The origin of the suprahilar artery was the renal artery in 21 cases, the upper artery in 7 cases, the posterior in 6 cases and the aorta in 2 cases.

It must be stated that the renal arteriograms were analysed in the light of the findings described above on the series of anatomical casts. This was deliberately done with the knowledge that the radiological series was derived from the same source as the anatomical material. At one point in the survey a possible difficulty in the identification of the lower and posterior arteries was raised. In consequence we immediately collected 17 fresh human kidneys and injected and X-rayed them with knowledge of the position of the 2 arteries mentioned. In all 17 the criteria which we had used to identify these 2 arteries were confirmed. When reasons for discarding arteriograms were surveyed it was found that inability to read a good arteriogram for anatomical reasons was found in only 4 cases, and in each of these superimposition of the anterior and posterior distributions was the responsible factor.

This study of the arteriograms reinforces previous anatomical concepts. With the exception of an unexplained absence of aortic posterior arteries in cases of dual aortic supply, the differences between the arteriograms and the anatomical cast series were trivial. In cases of triple aortic supply (Fig. 6a) separate aortic posterior arteries were seen. In particular the concept of the intermediate artery developed in the anatomical series was fully substantiated, as was the variation in the size of the posterior and upper artery segments. It must be emphasized that the arteriograms represented an unselected series, made by the use of a variety of radiological techniques. All successful arteriograms were included, and no other selection was made.

A PRACTICAL SYSTEM FOR ANGIOGRAPHIC IDENTIFICATION OF RENAL ARTERIAL BRANCHES

In the light of the anatomy revealed by the study of casts and our experience of analysing a large series of angiograms, the following plan is suggested in the belief that it will enable an observer to identify the 3 primary divisions of arterial supply to the kidney. It also becomes possible, especially when a pyelogram is present, to label intermediate and middle arteries, when either or both are present.

When analysing in detail the arterial supply of an abdominal organ, there are two methods of approach:

1. *The conventional 'prograde' method.* The components of aortic supply are traced from their aortic origin to the periphery of the organ and the pattern of division is noted.

2. *The 'retrograde' method.* The peripheral or parenchymal arterial distribution is identified first and the appropriate vessels are traced back to their aortic origins. The pattern of supply and division is thus established in a retrograde manner.

We prefer the retrograde approach because our anatomical concept dictates a variable but logical pattern of supply to 3 primary and 2 secondary renal parenchymal areas. The obvious radiological imperfections, such as superimposition of densely contrast-filled primary divisions at or near the hilus of the kidney, also favour this approach.

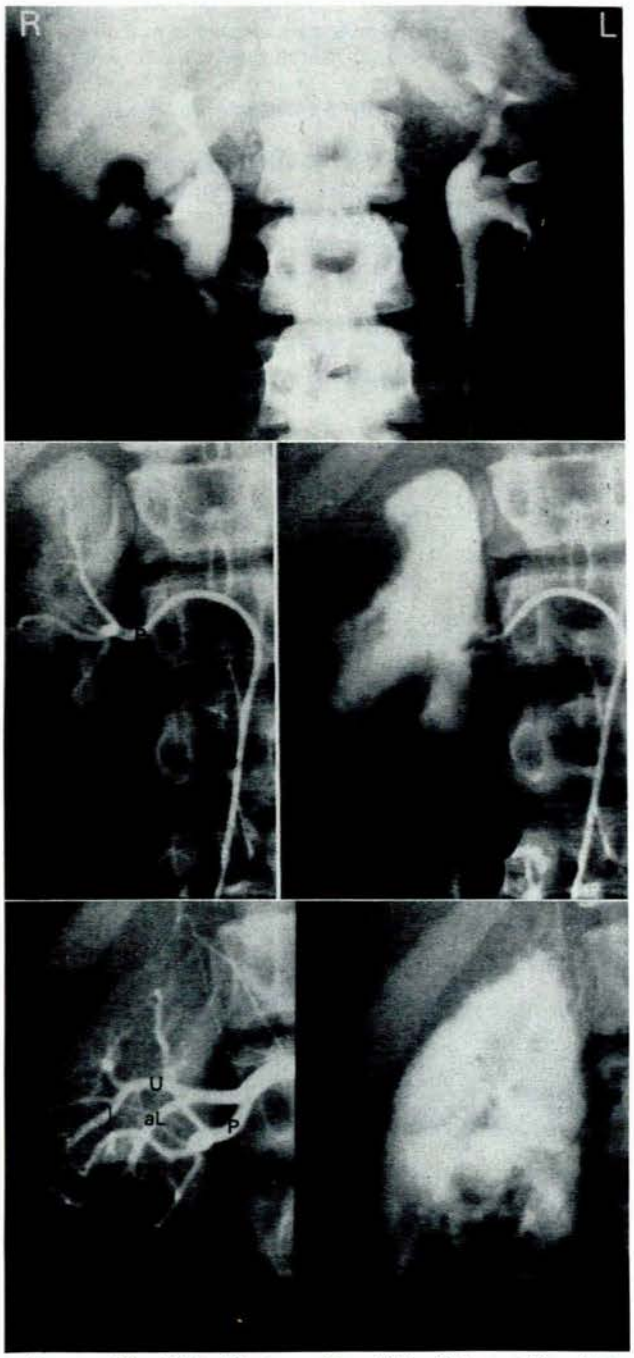
When considering anteroposterior radiographs, it is most helpful to start analysis in the lower part of the kidney as identification of the lower artery is usually easy. It descends towards the lower end of the kidney, usually in a medial position, and in the vast majority of kidneys its terminal divisions will, in fact, extend inferiorly to the peripheral limit of arterial supply. This artery so frequently bifurcates into anterior and posterior branches that its forked appearance is also a help in its identification. The other anterior branches (middle, intermediate, upper arteries) can be identified in series above the lower artery, supplying the whole of the kidney outline. As a rule the branches of these anterior arteries do not cross one another. In rare cases, however, an intermediate artery may descend far enough towards the lower end of the kidney to have branches which cross the middle artery and lower artery branches (Fig. 1). Once identified, it is often possible to observe branches of another origin crossing these anterior arteries or their branches. When present, these relationships identify a distribution in a different plane, and this is almost without exception the peripheral arrangement of the posterior artery.

Should the use of the procedure outlined lead to the identification of the lower and the posterior arteries, then it is a simple matter to follow their main stems back to their origins from the renal artery (or aorta), and so, by exclusion, to find the upper artery.

When the above procedure still leaves the observer in some doubt, then it is often possible to identify the posterior artery distribution at the upper end of the kidney. Again this is done by observing the pattern of crossing of 2 distributions in different planes. The more vertically arranged branches will normally turn out to be derived from the posterior artery (Fig. 4). Alternatively it may be possible to identify an intermediate artery, either as a branch of the upper or lower arteries, or as the termination of the upper artery. In that case the primary branch concerned will usually be the upper artery and occasionally the lower artery, but for practical purposes it will not be the posterior artery.

Confident identification of the intermediate artery necessitates superimposition of a suitable pyelogram outline on the arterial pattern. The characteristic and diagnostic position of this branch is then manifest. The distribution of the intermediate artery in the intermediate cortex is in a plane anterior to that of the posterior artery. It is therefore common to see the branches of these two crossing each other.

In the same way the presence of a middle artery, supplying parenchyma in front of the upper part of the lower calyceal system, is only made clear when a pyelogram is available. The middle artery is usually a branch of the lower artery, but is occasionally derived from the upper or intermediate arteries.



Above: *Fig. 7(a). Centre*: *Fig. 7(b). Below*: *Fig. 7(c)*

Fig. 7. Selective catheterization of a right kidney in the investigation of a suspected space-occupying lesion of the upper lateral zone of the kidney. *7a.* Intravenous urography showing a wide gap between the upper and other calyces on the right. Is there a space-occupying lesion?
Fig. 7b. Selective angiogram of the posterior division of the higher of two right renal arteries found supplying the kidney. The nephrogram phase also has a questionable filling defect in the same part of the kidney.
Fig. 7c. Selective injection of the whole of the artery illustrated in Figs. 7b and 7c by slight withdrawal of the catheter. This shows upper (U), intermediate (I) and anterior branch of lower (aL). The nephrogram shows that the defect of Figs. 7a and 7b is, in fact, not significant.

Note: Angiograms of the separate aortic posterior lower artery not included in above illustrations.

In addition to the branches mentioned, the suprahilar artery is frequently seen in arteriograms. This vessel (named 'apical' by Graves)[3] supplies anterior and posterior parenchyma above the hilus and is usually limited to the area medial to the upper calyces. When unusually large it may send branches more laterally, in front of or behind the upper calyces, supplying some of the parenchyma usually supplied by the upper or posterior arteries. The origin of the suprahilar artery is varied; it may arise from the aorta, renal artery, or any of the 3 primary branches of the renal artery. It commonly arises proximally, and may reach the medial aspect of the kidney directly without passing through the hilus.

The parenchymal distribution and areas of supply having been thus identified, the different main stems are traced back to the renal artery (or aorta), and the manner in which a particular single renal artery (or multiple arteries) divides can thus be established.

It is an interesting and sometimes useful exercise also to attempt a prograde analysis. When employing this method it is essential first to determine whether the obvious renal artery in an arteriogram is the sole supply of the kidney, as in a large minority of kidneys (15 - 30%) more than one aortic branch supplied the organ. When tracing a single renal artery from its aortic origin to its peripheral parenchymal distribution the following concepts must be applied:

Except for the rare instances where the main renal artery divides simultaneously into 3 primary components, it is the rule that the posterior, lower and upper divisions (in this order of frequency) will be the first branch. The vessel continuing beyond this point of division must for practical reasons still be considered as the main renal artery (Fig. 5). It will then as a rule divide at a more distal point into the remaining primary divisions.

An intermediate artery may rarely arise from the main stem. An upper artery, not infrequently, terminates as an intermediate. Multiple upper arteries may on occasions be present. More rarely, multiple lower arteries may be seen.

The size and extent of distribution of any particular branch obviously depend on the strength of development of the other primary and secondary arteries.

DISCUSSION

Disagreement among previous investigators has led to much confusion. An exhaustive review of the literature therefore served no useful purpose. The work of Boijsen[4] and Graves,[3] however, warrants discussion.

The monograph issued by Boijsen[4] has since that time enjoyed the reputation of being authoritative in the field of radiological exploration of renal arterial anatomy. It is necessary to point out in which respects the present study supports Boijsen, and where differences were observed.

In the first place it must be noted that Boijsen had available only 23 kidneys removed at necropsy, and that these were studied angiographically, and not dissected. Thus we can assert that as Boijsen could not take into account the anatomy of the intermediate artery, he was bound to misunderstand the distribution of many of the arteries supplying the middle zone of the kidney from a ventral source. An example can be seen in his Fig. 23, p. 51. Whereas in the frontal view the angiogram is inter-

preted in a certain way, the lateral view below clearly shows an intermediate artery passing *behind* the uppermost lower calyx, a fact not recognized in the earlier drawing.

Early in his account Boijsen dealt with the identification of the posterior artery. While much of what he says is correct, he leaves the reader with the impression that the posterior artery always has a 'characteristic course and appearance', namely a curve convex upwards and laterally. In our experience such a shape is seen in only about half the kidneys examined, and is a poor guide.

Our main differences with Graves[3] were that he also failed to establish the concept of an intermediate cortical mass and therefore could not recognize an intermediate artery. His segmental concepts of the kidney, in our opinion, are far too rigid.

The Practical Application of Detailed Analyses of the Renal Arterial Tree

This aspect will be the subject matter of a further paper. We should, however, like to stress at this stage that an intimate knowledge of the renal arterial tree is essential to the radiologist for the following reasons:

Technical angiographic aspects. Knowledge of renal arterial division will enhance the efficiency and accuracy with which renal angiograms are performed. Ready recognition of an absent or poorly filled renal arterial division will prompt the radiologist immediately to alter the position of the catheter tip, whether in the aorta or selectively placed in a renal artery, to achieve a complete study of the renal arterial tree (Figs. 7b and 7c).

Overlapping extrarenal vessels will not often confuse the initiated observer, and the necessity for selective studies will be reduced.

Radiodiagnostic interpretation. Lesions of the main renal arterial stem, aneurysms and many of the arterial abnormalities caused by renal space-occupying lesions and infections are readily recognized on renal angiograms. A more detailed knowledge, however, is required in differentiation between a pyelonephritic scar and a renal infarct; also in deciding whether a tumour is primarily intrarenal or of an extrarenal origin; and for differentiation between congenitally hypoplastic and small pyelonephritic kidneys.

Surgical value. The obvious importance of this aspect as regards segmental nephrectomy, kidney transplantation surgery, surgical procedures on congenital anomalies such as horseshoe kidneys, renal duplex, etc., need not be stressed.

Other advantages. A greater understanding and ready recognition of renal arterial patterns will not only be of value to research workers in the fields of renal pathology, physiology and haemodynamics, but will also lead to the refinement of existing radiodiagnostic criteria.

SUMMARY

The intrarenal anatomy of the renal artery and its branches is reviewed. New observations on the position or origin of the renal artery on the circumference of the aorta are made. Anatomical analysis of 126 renal arteriograms is presented and shown to confirm the revised anatomy. A practical scheme for anatomical analysis of renal angiograms, whether in a retrograde or prograde manner, is suggested. Relevant previous publications, technical advice and some practical applications of the revised approach are discussed.

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