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RESEARCH ARTICLE ANATOMY

LOWER RENAL ARTERIAL SEGMENTAL VARIATIONS AND ITS UROSURGICAL IMPORTANCE.

DR RAGHAVENDRA V. P [*1] AND DR ANJANA TELKAR.[2]

[1] Assistant Professor, Department of Anatomy, 2 Assistant Professor, Department of Microbiology J.J.M.Medical College, Davanagere 577004, Karnataka, India.

DR RAGHAVENDRA V. P
Assistant Professor, Department of Anatomy J.J.M. Medical College, Davanagere 577004, Karnataka, India

*Corresponding author

ABSTRACT

Objectives:
The advent of more conservative methods in the renal and renal vascular surgeries has necessitated a more precise knowledge of renal vascularization and its importance in partial and total renal transplantation surgeries.
Its main objectives :a) To study the Intrarenal arterial segmental patterns especially the lower segmental branch and its variations in 60 human kidneys by dissection, corrosion and radiological method, b) To help the endourologic surgeons to carry out safer surgeries on kidneys, c) To give reliable information to the anatomists for learning and teaching.

Methods:
Totally 60 adult human kidneys were studied in the present work belonging to both sexes; Out of it 40 were procured from dissection cadavers in the Department of Anatomy, J.J.M. Medical College, Davanagere and 20 fresh kidneys from Mortuary, Chigateri General Hospital, Davanagere. Before removal of the kidneys from the bodies, possibilities of additional apical renal segmental arteries from the common iliac, internal iliac, lumbar, sacral, superior mesenteric, hepatic and inferior suprarenal arteries were looked upon.
The segmental arteries of the kidneys were studied by three methods i.e. 10 each by corrosion cast and radiological method.40 by dissections,

Results:
A total of 60 kidneys were studied, anterior division is classified into 8 types out of it Type VIII showed maximum of 20% and Type II of posterior segment 51.66%. The occurrence of apical, upper, middle and lower remained the normal i.e. of 51.66%, 61.66%, 55% and 51.66% respectively.

Conclusion:
Much importance is given to the segmental artery which arises in common and divides within the renal parenchyma, as healthy renal tissue is often involved during partial nephrectomy of the affected part.

KEY WORDS

Human Kidneys; Intrarenal; endourological surgeries: Arterial segmental pattern.

INTRODUCTION

The present work on Intrarenal lower arterial segmental pattern of human kidneys and its variations has been undertaken because of its urosurgical importance in making a relatively bloodless surgical approach to the kidneys or its parenchyma and to save the normal healthy renal tissue in partial nephrectomy of disease affected lower segmental part. Therefore, advent of more conservative methods in the renal surgery has necessitated a more precise knowledge of renal vascularization and its importance in partial and total renal transplantation surgeries.

The renal vascular segmentation was originally recognized by John Hunter[1] in 1794 and wrote "The veins in the spleen and kidney anastomose in vary large trunks while the arteries do not at all" but the idea of segmental anatomy started with the discovery of bronchopulmonary segments in 1889 by William Ewart[2].

In 1952 F. T. Graves[5,6]came across two cases of nephrolithotomy which resulted in post-operative persistent hematuria which compelled him to do total nephrectomy in order to save the life of the same patient. The loss of the normal kidney that has partially affected prompted him to investigate the arterial distribution in the kidney substance. Hence in 1954, he made an outstanding contribution to the renal surgeries by describing five segmental branches of the renal artery with little anastomosis of its neighboring branches for the establishment of an effective collateral circulation in cases of segmental infarction of the kidney.

In 1955, Riches[7] said the knowledge of avascular planes is most important and therefore the renal angiography should be considered as an essential investigation prior to all the endourological surgeries and partial nephrectomy is contemplated. Even in 1950[4] Abehouse and Lerman also advocated the renal arteriography and determined the distribution of the segmental artery by noting the purplish discoloration produced by its compression.

In 1960, Robert[9] stressed the necessity of knowing the variation in the vascular segmental patterns to prevent the avoidable loss of normal healthy renal tissue which occurs in total nephrectomy while removing the infarcted renal tissue. Thus from radical total nephrectomy to conservative partial nephrectomy.

In 1963, D. Sykes[15] said that surgeons should know all the possible variations and their incidence to make through search and take spot decision at the operation table as their vascular patterns in the kidneys are not same in all the kidneys or similar in the two kidneys of the same person.

Thus, many workers especially endourological surgeons from time to time confirmed the clinical importance of the intrarenal arterial segmental patterns and its variations for adventing more conservative therapy or the surgeries.

MATERIALS AND METHODS

In the present work totally 60 number of adult human kidneys were studied belonging to both sexes, Out of which 40 were procured from dissection cadavers in the Department of Anatomy, J.J.M. Medical College, Davanagere and 20 fresh kidneys from Mortuary, Chigateri General Hospital, Davanagere.

The segmental arteries of the kidneys were studied by three methods, 40 by dissection method ,Corrosion cast and radiological method 10 specimens each.

For all the three methods, after identifying the supernumerary renal arteries from the aorta, the kidneys of each pair were separated along the

renal arteries by discarding the piece of aorta. Before removal of the kidneys from the bodies, possibilities of additional renal arteries especially to the apical region were looked upon arising from the common iliac, internal iliac, lumbar, sacral, superior mesenteric, hepatic and inferior suprarenal arteries.

1. DISSECTION METHOD:

Adult human kidneys from the dissection cadavers were washed in running tap water to remove the formalin. The capsule of each kidney was stripped off and the parenchymatous tissue was removed in piece meal with forceps under water, tracing the apical and other segmental arteries as much as possible.

2. CORROSION CAST AND RADIOLOGICAL METHOD

Fresh kidneys along with their capsule were washed in running tap water for about 30 min to 1 hour. The blood from arteries and veins were washed off by injecting warm saline till a clear fluid comes out of it. The washed kidneys were turned downwards for 2 hours to drain out the fluid completely.

The narrow end of the silicon gun was tightly kept in the stem of renal arteries and slowly silicon material was injected till complete resistance occurs. The gun was removed from the artery and the stem of the artery was tightly tagged, kept overnight for drying and immersed in low concentrated hydrochloric acid for 6 hours. After soft tissue corrosion was complete, the resulting silicon cast was washed in running tap water and kept for drying.,

For radiological method fresh solution of barium sulphate was prepared and 5ml of it is injected through the stem of renal artery and anteroposterior radiograph were taken. The same kidneys were later dissected; the arterial patterns were compared and confirmed the findings to those seen in the radiographs. The specimens were numbered and positive photographic prints of the radiograph were done.

RESULTS

CLASSIFICATION OF RENAL SEGMENTAL ARTERIES AND DIVISION OFMAIN TRUNK OF RENAL ARTERIES:

The nomenclature of the renal segments approved at the 8th International Congress of Anatomists held in Wiesbaden, Germany in 1965 is as superior (apical of Graves), anterior superior (upper of Graves), anterior inferior (middle of Graves) and posterior segments (posterior of Graves). The classification adapted here is based mainly on the classification of the various types of renal segmental arteries made by Graves. He described four types of the apical segmental arteries according to its mode of origin and three of the anterior division of the renal artery based on its mode of termination[5,6].

Kher[11] et al modified the grouping of the Graves. They grouped the other arteries also formerly omitted by Graves. They classified six types of the apical segmental arteries instead of four types described by Graves.

Verma[14] et al further modified the classification. They grouped (1) Four groups of anterior division of the renal artery instead of the three groups described by Graves (2) Three types of the posterior division not typed by the previous workers.

David Sykes[16] described the venous type of branching of the renal artery.

In the present study of different segmental arteries, the classifications adopted by Kher et al and Verma et al were also followed.

A. Eight types of Anterior division of renal artery
B. Six types of Apical segmental artery
C. Four types of Upper segmental artery
D. Five types of Middle segmental artery
E. Five types of Lower segmental artery
F. Three types of posterior segmental artery
G. Two type's accessory renal arteries were also categorized

As mainly the apical artery arises from the anterior division of renal artery an brief study on anterior division is also maid along with the apical segmental artery. The following is the classification followed in this work and the total number of specimens observed.

(A) 8 TYPES OF THE ANTERIOR DIVISION OF THE RENAL ARTERY ARE DESCRIBED

***DEPENDING UPON THE MODE OF ITS BRANCHING**:*

In type I(10%, 6spn) the anterior division terminates as the upper and middle segmental arteries after giving off the lower segmental artery. In type II (11.66%, 7spn) the anterior division terminates as the middle and lower segmental arteries after giving off the upper segmental artery. In type III (13.33%, 8spn) the anterior division gives rise to the apical segmental artery and then to three terminal branches upper, middle and lower segmental arteries. Type IV (16.66%, 10spn) the anterior division gives off three terminal branches viz., apical, upper and middle after giving off lower segmental artery much before the hilum. Type V (6.66%, 4spn) the anterior division runs downwards, in front of the pelvis of the ureter with an outward convexity from which the apical, upper, middle and lower segmental arteries arise in single or small more than one. Type VI: (15%, 15spn) Anterior division divides and terminates into normal 4 segments i.e. apical, upper, middle and lower segmental arteries much before the hilum. Type VII: (20%, 12spn) Anterior division divides and terminates either in combination with two segmental arteries in common i.e. apical with upper, middle with lower and apical with middle segmental arteries much before the hilum or within the hilum. Type VIII: (6.66%, 4spn) Anterior segmental divisions or the branches arises directly from the aorta as accessory renal artery which may replace any one or two segmental branches and supply to the definitive area without anastomosing with its neighboring artery.

***(B) 5 TYPES OF LOWER SEGMENTAL ARTERY VARIATIONS HAVE BEEN DESCRIBED*:**

Type I: in 31 specimens (51.33%) it arises from the anterior division of the renal artery along with most of the other segmental arteries.

Type II: in 5 specimens (8.33%) it arises from the posterior division of the renal artery. Type III: in 6 specimens (10%) it arises directly from the renal artery.

Type IV: in 17 specimens (28.33%) it arises from or along with middle segmental artery. Type V: very rarely in only 1specimens (1.66%) it arises from or along with upper segmental artery.

(C) POSTERIOR DIVISION

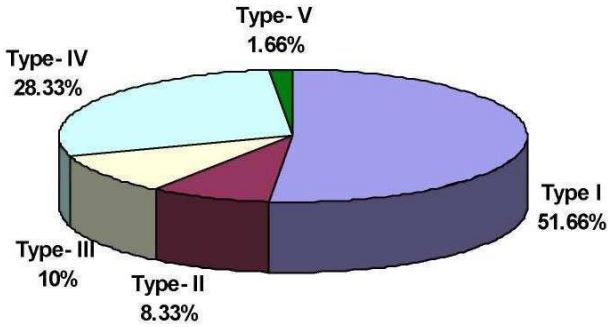
Due to the possibilities of apical artery arising from the posterior segment or divisional artery posterior division is also studied. In the present work 4 types of posterior divisions is seen but out of which only type III (16.66%, 10spn) artery giving rise to apical branch. i.e. The posterior division gives off either (a) apical or (b) middle or (c) lower segmental artery or any two of them which are all usually branches of anterior division. It supplies the posterior segment before or after giving the above said branches.

Type IV: (3.33%, 2spn) Posterior segmental or lower segmental arteries, the division arising directly from the abdominal aorta as *accessory artery.*

OBSERVATIONS

Graph 1

Showing percentage of lower segmental arterial variations



Type I: Normally in 51.66%, the lower segmental artery arises from the anterior division of the renal artery along with most of the other segmental arteries.
Type II: In 8.33% cases, it arises from the posterior division of the renal artery (fig 2). In these cases the posterior segmental artery is comparatively larger to supply the inferior pole of the kidney
Type III: In 10% of the cases, the lower segmental artery is given off directly from the renal artery much before the hilum or sometimes directly from abdominal aorta as accessory renal artery. These arteries are relatively easy for the surgeons as there stem is longer.
Type IV: Usually the lower segmental artery is seen arising from or along with middle segmental artery in 28.33% of the cases next to type I
Type V: Very rarely i.e. in 1 to 2%, it arises from or along with upper segmental artery.

DISCUSSION

The advent of more and more conservative methods in the field of endourologicalsurgeries has necessitated the precise anatomical knowledge of the renal segmentations and its vascular patterns[33]. It is also involved in knowing the renal function by noting the amount of renal perfusion by the arteries to that of amount of urine formed from the collecting system[21].

The description of Brodel`s line in 1901 revolutionized renal surgery[3]. Since that time, a variety of complex renal reconstructive procedures have evolved for renal parenchyma preservation as an alternative to simple or radical nephrectomy. As a result, the urologic surgeons and anatomist may be called upon to perform these complex renal preservation procedures in the presence of trauma, neoplasia and urolithiasis[34].

This bold approach and new technique evolved when Graves[6,7] made a definite announcement about the existence of 5 arterial segments in the kidney in the year 1952

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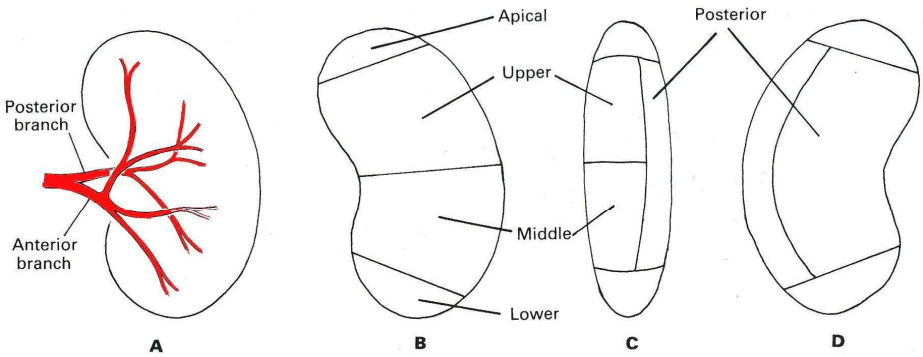

Fig. Arterial segments of the left kidney. **A** shows branches of the renal artery; **B**, **C** and **D** indicate the segments as seen from the front, the lateral side and the back respectively. The posterior division of the artery supplies the posterior segment and the anterior division supplies the other four. There may be variations in the pattern of division but the segments are constant.

Figure 1

Showing normal renal vascular segmentations

The new techniques employed in renal surgery mainly depend upon the segmental resection, namely wedge–type resections, if the disease affects lower segments. But for the mid-portion lesions, either enucleation technique or the partial nephrectomy is indicated although obviously limited to tumors, may be employed in other conditions with minimal loss of renal functions.[33]

The most commonly seen complication encountered after partial nephrectomy is bleeding. Life was threatened by post-operative complications such as severe bleeding prior to the advent of the conservative segmental resections. Later, the profound knowledge of variations of the mode of origin of the segmental arteries reduced the mortality rate. The attention to hemostasis and the use of cold ischemia have reduced the complication rate considerably.[22,23]

The lack of arterial anastomosis in the neighboring segments will affect only the affected segment and will neither produce ischemia nor interfere with blood supply of neighboring segments[22]. This lack of arterial anastomosis will render the technique of resection easier, since the field of operation will be relatively bloodless following the ligation of the segmental artery supplying the area of the operation[23].

It should be remembered that the origins of the segmental arteries are accessible. In the majority of cases, they are easily seen in the hilum and often at the points nearer the aorta. This is of practical value, since segmental resection is best carried out from the hilum towards the periphery.[24]

Accessory renal arteries to the lower aspect of the renal hilum are often found in close relation to the ureteropelvic junction or upper part of the ureter. Their presence accentuates the obstruction leading to hydronephrosis. Hence, they cannot be ignored.[20]

The present studies were compared to the studies carried out by various other workers in study of the variations of the renal vasculatures during period of 1954 to 2007 .

Table 1
THE ANTERIOR DIVISION OF THE RENAL ARTERY

Workers	F.T. Graves	Kher et al	Present study
Year	1954	1960	**2007**
Kidneys Studied	-	54	**60**
Types - I	33.3%	33.3%	**10%**
II	30%	38.8%	**11.66%**
III	16.6%	27.3%	**13.33%**
IV	-	-	**16.66%**
V	-	-	**6.66%**
VI	-	-	**15%**
VII	-	-	**20%**
VIII	-	-	**6.66%**

The table 1 shows the studies carried out by various workers to study the variations of the anterior division of the renal artery and their respective findings were compared to the present study.

F.T. Graves[5,6] and Kher et al[11] made only 3 types of anterior divisions, where as in the present study totally 8 types have been described which has not being described by the previous workers. The variation of type V has not been commented upon by Graves[5,6], but Verma et al[13,14] noticed the said variation in 12.5% of specimens in their study; but the authors have not categorized the variation. But, this has become a specific type and was observed in 6.66% of specimens in the present work

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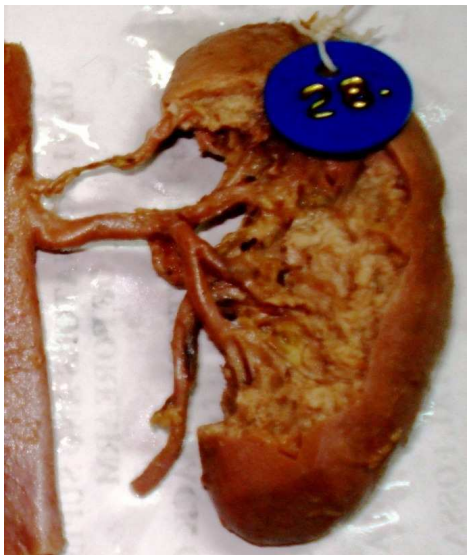

Figure 2
Showing anterior division & Lower segmental artery

Figure 3
X-ray showing anterior division of renal artery & its lower segmental branch

In the present study, the anterior division divides and terminates either in combination with two segmental arteries in common i.e. apical with upper, middle with lower and apical with middle segmental arteries much before the hilum or within the hilum and it accounts to maximum of 20% (Type VII). Such types of combinations are difficult for the surgeons especially if it occurs within the hilum or within the renal parenchyma and loss of healthy renal tissue may be there in the event of removing a solitary cyst or the infarcted tissue from the affected segment of the kidney by ligating the segmental artery.

It is followed by type IV in which 16.66% of the cases, the anterior division gives off three

terminal branches viz., apical, upper and middle after giving off lower segmental artery much before the hilum. Further, the lower segmental artery runs in front of the renal pelvis.

The normal anterior division divides and terminates into normal four segments (Type VI) i.e. apical, upper, middle and lower segmental arteries much before the hilum in only 15% of the total cases and it is similar to many text book descriptions.

In 13.33%, the anterior division gives rise to the apical segmental artery before or much before the hilum and then to three terminal branches viz upper, middle and lower segmental arteries and findings are near to F.T. Graves of 16.6% but Kher et al[12] reported 27.3%. In this type (Type III) of cases, the approach to the apical segment is quit easer unless there is no branch to the suprarenal gland from it.

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In 11.66%, (Type II) the anterior division terminates as the middle and lower segmental arteries after giving off the upper segmental artery or may along with apical segment compared to F.T. Graves of 30% and Kheret al[11] of 38.8%.

F.T. Graves and Kher et al reported 33.3% in anterior division terminating as the upper and middle segmental arteries after giving off the lower segmental artery much before the hilum (Type I) but in the present work it is seen only in 10%.

Only 6.66% (Type VIII) like type IV the anterior segmental divisions or the branches arises directly from the aorta as accessory renal artery which may replace any one or two segmental branches and supply to the definitive area without anastamosing with the neighboring artery

TABLE – 2
THE LOWER SEGMENTAL ARTERY

Workers	Servo	Kher et al	Verma et al	H. Fine et al	Present study
Year of study	1959	1960	1961	1966	**2007**
Total no. of kidneys studied	100	54	98	107	**60**
Type I	47%	40%	87%	-	**51.66%**
Type II	8%	11%	1%	-	**8.33%**
Type III	-	1%	3%	41%	**10%**
Type IV	-	1%	3%	9%	**28.33%**
Type V	45%(Dueal)	-	-	-	**1.66%**

The lower segmental artery (In table 2) was seen to arise most commonly from the anterior division of the renal artery along with most of the other segmental branches (Type I), with an incidence of 51.66%.

Type IV, where in the lower segmental artery is a direct branch from the aorta was noted in 28.33% of cases but along with the middle segmental artery. In this type IV pattern, one has to be aware of the gonadal artery arising in turn from the lower segmental artery, sometimes quite near the kidney. Ligation of the latter must therefore be made after the artery to the gonad has originated, as otherwise testicular atrophy will eventually develop (Graves[6,7]). However such variations were not seen in the present study.

In 10% of the cases (Type III), the lower segmental artery is given off directly from the renal artery much before the hilum. But others findings varies like 1% of Kher et al, 3% of Verma et al and 41% of H. Fine et al.

In Type II (8.33%) cases, it arises from the posterior division of the renal artery. In these

cases the posterior segmental artery is comparatively larger to supply the inferior pole of the kidney and similarity is seen in the findings of Servo.

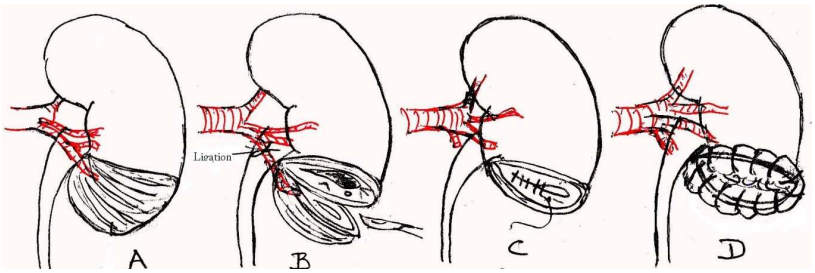

Figure 4
Showing the lower segmental partial nephrectomy

CONCLUSION

The advent of more and more conservative methods in the renal surgery has necessitated a more precise knowledge of renal vascularization and its importance in partial and total renal transplantation surgeries.

Therefore, the valuable contribution of anatomical knowledge to operative surgery, particularly in partial or segmental resection of kidneys, will help further development of different techniques for the removal of calculi or affected part of kidneys and also helps in partial renal transplantation surgeries with end to end anstamosis of the resected part of the kidney.

The presence of the arterial segments within the substance of kidney does not change, but there is a lot of variation in the course and exact point of origin from the renal artery or aorta of these segmental vessels outside the substance of the kidney.

After the advent of the renal segments, the urological complications following partial nephrectomy have considerably reduced. Nephrectomy or total removal of a kidney will no longer be performed, if a lesser procedure can offer a better prospect. Every fragment of healthy, functional renal tissue should be preserved, provided that it has an arterial supply, a venous drainage, and a urinary exit or the collecting system and expertise is available to preserve the healthy fragment.

SUMMARY

The present study on intrarenal arterial segmental pattern and its variation was undertaken in the Department of Anatomy, JJM Medical College, Davanagere. Totally 60 human kidneys were studied; 40 by dissection method, 10 by corrosion cast method and 10 by radiological method.

It was found in the present study that the human kidney has constant segmental arrangement and distribution of the renal artery within the solid substance of the kidney. On the basis of arterial distribution, the renal parenchyma is divided into five segments, which have been aptly named the apical, upper, middle, lower and posterior, each of which is supplied by its own segmental artery as stated by many text books. But a lot of variation was observed in the course and exact point from its origin to its termination of these segmental branches.

The absence of intersegmental arterial anastaomosis has been clearly demonstrated by separation of the casts of the segmental arterial tree.

The anterior division, posterior division and the

segmental arteries have been classified in detail depending upon the origin and course of the arteries which has not been classified by other workers.

Much importance is given to the segmental artery which arises in common and divides within the renal parenchyma, as healthy renal tissue is often involved during partial nephrectomy of the affected part during ligating the specified segmental artery.

After the advent of the renal segments, the urological complications following partial nephrectomy have considerably reduced. Nephrectomy or total removal of a kidney will no longer be performed, if a lesser procedure can offer a better prospect. Every fragment of healthy, functional renal tissue should be preserved, provided that it has an arterial supply, a venous drainage, and a urinary exit or the collecting system and expertise is available to preserve the healthy fragment.

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